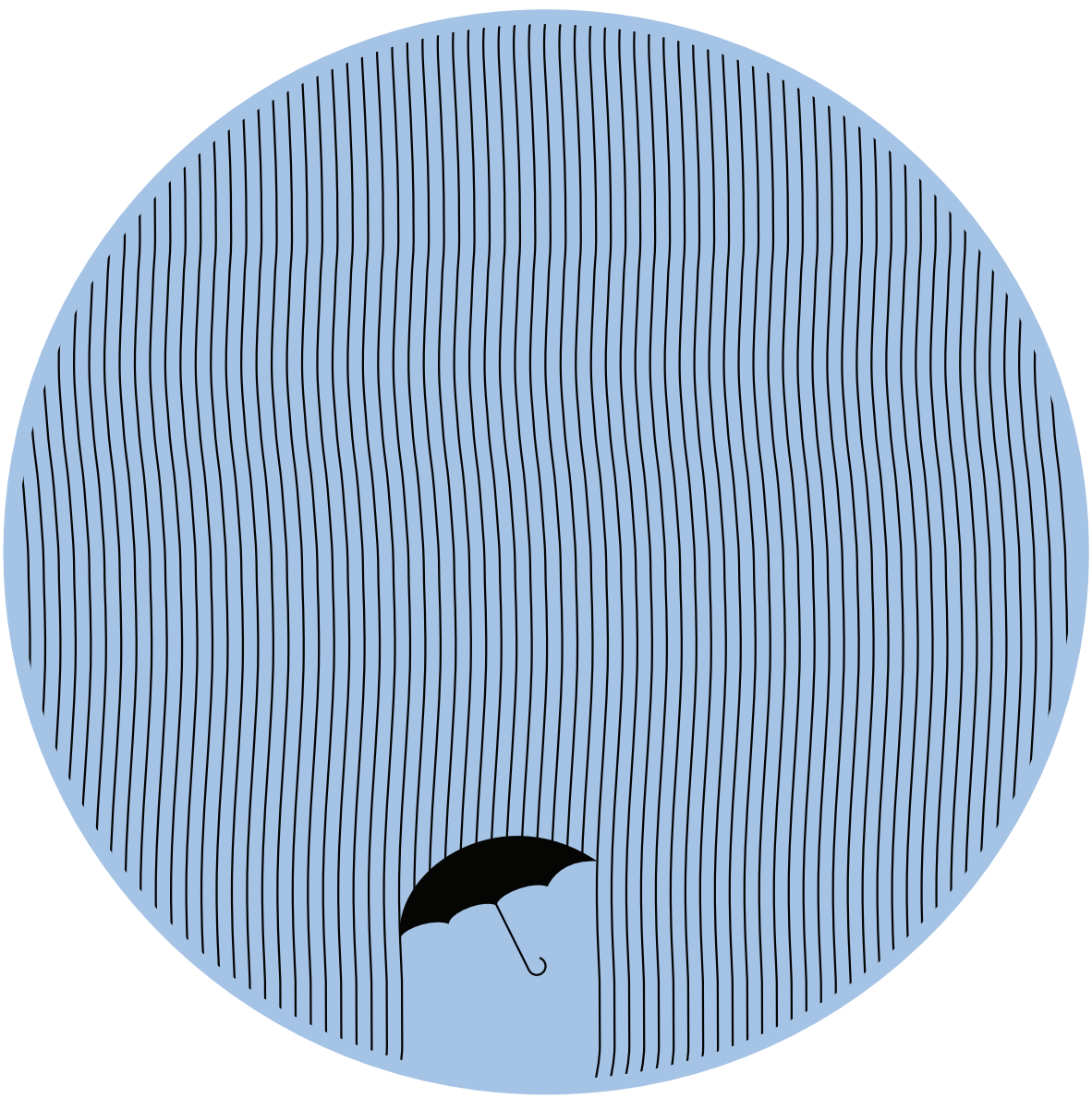
# PREVENT THE FLOOD

## Creating multi-lateral solutions for a storm water resilient Amsterdam



MASTER THESIS MARIEKE OOSTEROM

**Colophon**

**Prevent the Flood**
Creating multi-lateral solutions for a storm water resilient Amsterdam

**P5 report**
28th of June 2018

**Delft University of Technology**
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Department of Urbanism
Graduation studio: Smart Cities & Urban Metabolism

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# PREVENT THE FLOOD

## Creating multi-lateral solutions for a storm water resilient Amsterdam

# PREFACE

This thesis, called *'Prevent the flood'*, describes how my graduation project developed from its start in September 2017. The graduation project took place in the studio of Smart Cities and Urban Metabolism at Delft University of Technology, Faculty of Architecture and the Built Environment, department of Urbanism. It shows the result of literature research and research based design through several scales and times, to be able to understand the challenges of today and find and design the solutions for tomorrow.

My personal fascination for the subject 'storm water resilience' evolved as a combination of different factors. On the one hand, there is the urgency. Water nuisance after heavy rainfall is of frequent occurrence, especially in cities. Now the climate is changing, this situation will get worse rather than better. If cities do not adapt to this, the built environment will be damaged. On the other hand, there is a personal aspect in the motivation. The street in which I grew up flooded several times a year, as the sewer system could not handle the excessive amount of rain. As a child it was my biggest fear that the water would enter our house. This never happened, but every time the rain seemed to get closer and closer... The densification goal of the municipality of Amsterdam was the main reason for me to use this city as research area. The combination of the changing climate and this densification goal seems contradictory, which makes Amsterdam an interesting case to look at. This led me to the subject of my graduation project. This project focuses on the creation of site specific designs on multiple scales, which are transferable to similar locations.

This master thesis describes the research that is done during the past ten months. Research is described in theoretical and analytical frameworks, underpinning the project and supplying the required information for the design phase. With the designs, I tried to show what is possible when making different types of existing environments storm water resilient.

I would like to thank my mentors, Kristel Aalbers and Birgit Hausleitner, for their guidance and support, their critical questions and inspiring views on the research and design of this graduation project, as final project of my study at the TU Delft. Furthermore, I would like to thank my friends and family for their everlasting support and enthusiasm. Without you, graduation would have been a lot less fun!

Marieke Oosterom
June 2018, Delft

# SUMMARY

This graduation project is about the storm water resilience of Amsterdam. The effects of climate change and urban growth, like extreme weather conditions and a larger paved area, cause undesirable conditions regarding storm water resilience of (Dutch) cities. Water nuisance and sewage overflows caused by heavy rainfall occur more and more often. This is undesirable since it may cause dangerous situations related to accessibility, water quality and ecology and it disturbs daily life. Most interventions which are currently used are insufficient as they could address way more sustainable urban aspects at the same time. Therefore, the goal of this graduation project is to make Amsterdam a storm water resilient city, while simultaneously address other local and sustainable urban aspects, in order to create a future-proof city.

Reaching this goal started with an extensive analysis of the current water nuisance in the city. The water nuisance has been explained by several correlations: the correlation between water nuisance and streets with a predominant retail function, and between water nuisance and the most common spatial typology. These correlations form the basis for the chosen strategic design locations: OLVG west on building scale, Javastraat on building (block) scale, Rokin on street scale and Rivierenbuurt on neighbourhood scale. Similar locations are of frequent occurrence in the city and could be transformed in the same way.

The four design sites have been extensively analysed to find out what aspects of that location were in need of improvement, apart from the storm water resilience itself. This analysis has been done on several scales and revealed guidelines for the desirable interventions, related to environmental and socio-economic urban aspects. At Rokin, for example, the high pressure on public space resulted in underground interventions related to storm water resilience and interventions above the surface that provide the human activities of that location. Most of the design components contribute to the stormwater resilience of the city, but address other, additional benefits as well. These additional benefits include both environmental and socio-economic aspects. The designed vegetable garden on the roof of OLVG west, for example, improves the storm water resilience of that location, but creates a recreational facility too.

Implementing interventions on several scales creates a network of interventions that work together. In practise this means that when the storage or infiltration of a design component has been reached, other components should compensate. In this way, interventions on smaller scales can create a network of interventions that functions on the city scale. When the locations similar to the strategic design sites are being transformed too, this network arises. In this way, Amsterdam will become a storm water resilient, future-proof and liveable city.

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# 01

# Project Definition

This chapter is the introduction to the graduation project and it will describe how the thesis is structured. It will give an overview of the problem field, the relevance of the research, and the posed objectives. Together, this forms the basis of the graduation project.

# 1.1 Problem Field

On Monday 28th of July 2014 there was a huge cloudburst above Amsterdam. There was so much rain in a short period of time that parts of the ring road A10 were closed, flights from Schiphol airport were canceled and the streets turned into canals. Waternet and the fire department received hundreds of messages reporting flooded basements, living rooms, stations and streets (Figure 1.1 and 1.2). In some locations 40 mm of rain fell in only one hour, while most sewer systems in the Netherlands can process only 20 mm per hour (Amsterdam Rainproof, 2014). So despite the fact that the sewer system of Amsterdam was working well, there was still water nuisance. In a storm water resilient city, excessive rainfall would be stored temporarily in public and private spaces. However, the city of Amsterdam is clearly not yet well equipped for this.





**Fig. 1.1**: Water nuisance in Amsterdam on July 28 2014 (NRC, 2014)

**Fig. 1.2**: Water nuisance in Amsterdam (Kotoun, 2016)

**Causes**

According to the Royal Netherlands Meteorological Institute (KNMI) there are twice as much days with heavy rainfall today than in 1950. This amount is expected to continue to grow, as the Netherlands is getting warmer and warmer (KNMI, 2014). Human activities on earth seem to be the main cause of the current global warming effect. The natural greenhouse is changing because of industrial activities like burning fossil fuels, which cause the atmosphere to retain heat (NASA, 2017, Environmental Protection Agency, 2016). The effects include a continuing rising temperature, a longer frost-free season, changes in precipitation patterns, more droughts and heat waves, stronger hurricanes, a rising sea level and an ice-free arctic in summer (NASA, 2017). Of course the impact of these effects differs per continent, per country, and even per region, but the evidence of climate change is present, also in The Netherlands (KNMI, 2015).

At the same time, there is an increasing awareness of the impact of climate change on cities itself. This impact on cities includes effects on infrastructure, coastal cities, health, energy use, water availability and resources, tourism and cultural heritage, urban biodiversity and air pollution. Additional secondary effects may have to do with agriculture, ecosystems and the concentration of economic activity in cities (Hunt and Watkiss, 2007). Many of these effects put the water system of cities to the test. Heavy rainfall causes water nuisance and sewage overflows, sea level rise influences the amount of surface water discharge and salt water intrusion causes water shortages. These consequences of climate change ask for improvement of the city's storm water resilience.

Some of the effects of climate change on cities are being enhanced by the ongoing urban growth. In 2016, 54.5% of the world's population lived in cities and this number is increasing (United Nations,

2016). This applies to the Netherlands too, where people move away from the periphery and the population of the four big cities is growing (Centraal Bureau voor de Statistiek, 2016). The municipality of Amsterdam aims to add 70.000 houses to the housing stock of nearly 424.000 by 2040, within the existing municipal borders (Gemeente Amsterdam, 2011, Gemeente Amsterdam, 2016). This means the housing is growing by more than 16%. Such an expansion of the housing stock often means an expansion of paved areas, which negatively influences the drainage capacity, the urban heat island effect, the biodiversity and the amount of nature in the city (Van Loon et al., 2014). These aspects all affect the urban water system.

**Consequences**

The result of the increased frequency of heavy rainfall, combined with a reduced amount of permeable surface and a limited amount of storage opportunities, is that water nuisance will occur more frequently. Without spatial adjustments, this means streets, houses and stations will flood more often and the sewer system is at greater risk of overflowing into surface water. Flooded streets may lead to dangerous situations regarding accessibility, when not only residents but also emergency services cannot reach their destination. When vital and vulnerable buildings as hospitals, train stations and transformer buildings flood and subsequently fail, the damage increases rapidly. This causes dangerous situations too, for example when an aging construction fails or people find themselves trapped by water. Moreover, sewage overflows into surface water deteriorate the quality of the water, which can be a threat for ecology and public health.

**Current approaches**

The past decades, a transition took place from a focus on flushing and draining storm water immediately, towards a focus on retaining and storing storm water first, before draining it (Figure 1.3). This transition is included in the current policies and a big step in the right direction. However, many of the solutions which are proposed are still very technical (Van Eijk, 2003). The real shift from civil, technical solutions, like increasing the capacity of the sewer systems, towards water as one of the leading factors in spatial design is still happening. A few good examples of projects which are currently going on are Amsterdam Rainproof, Huisje Boompje Beter and Rooftop Revolution. They are looking for synergies in climate adaptation and they try to activate residents to participate. For governmental organisations like municipalities it is harder to change their solutions. They have to deal with dilemmas about central or decentralized solutions, conflicting interests and experimenting on different scales (Van Eijk, 2003).

Furthermore, the Netherlands is working with the multilayer safety approach, developed by the Foundation for Applied Water Research (STOWA). This approach contains three different layers (Figure 1.4). The first layer contains civil works like the Delta Works. Building strong dikes, dunes and storm surge barriers has to prevent floods. Prevention remains the primary priority of the policy. The second layer is about realizing sustainable spatial planning. A thoughtful spatial planning and design of public space can limit the amount of victims and damage in the event of flooding. The third layer is an intangible layer which is about disaster control in the event of flooding. A good preparation is essential to act effectively in the event of a flooding disaster. In this way, the amount of victims and damage can be limited (Rijksoverheid, no date).

This graduation project will contribute to the development of the second layer of safety. There is a

strong relation between spatial planning and design of public space and the water resilience of a city. Water resilience includes many aspects of water, like water nuisance, water quality, water safety and water quantity. The focus will be on preventing water nuisance from happening again in current and future situations, by improving public space. If possible, other aspects of water will be included in the improvements too.

The abovementioned description of causes, consequences and current approaches results in the following problem statement:

*Problem statement*

*The effects of climate change and urban growth, like extreme weather conditions and a larger paved area, cause undesirable conditions regarding storm water resilience of (Dutch) cities. Water nuisance and sewage overflows caused by heavy rainfall occur more and more often. This is undesirable since it may cause dangerous situations related to accessibility, water quality and ecology and it disturbs daily life. Most interventions which are currently used are insufficient as they could address way more sustainable urban aspects at the same time.*

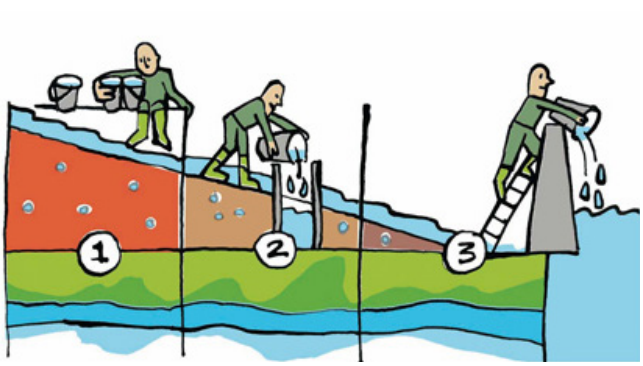



**Fig. 1.3**: The principle of retaining, storing and draining storm water (Public Space Info, n.d.)

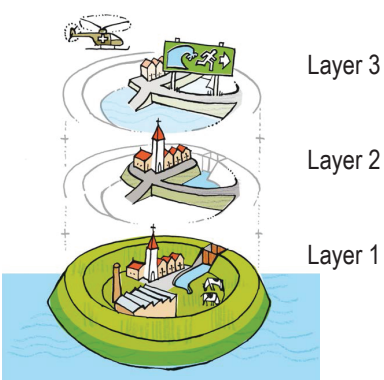



**Fig. 1.4**: Safety in three layers (The Water Channel, n.d.)

## 1.2 Objectives

Like described before, the municipality of Amsterdam aims to add 70.000 houses to the housing stock before 2040, as the number of residents is still growing and the household size is declining (Gemeente Amsterdam, 2011). As it is impossible to do something about this demographic development, it will be considered as a given fact to deal with. However, the combination of urban growth and climate change causes undesirable conditions regarding the storm water resilience of Amsterdam. Besides densification, the municipality of Amsterdam is working on other objectives too, like a coherent public transport network, attractive public space with green and water, renewable energy sources, and mixing of functions. It is therefore important to explore synergies between storm water resilience and other aspects of the city and to rethink the way current projects related to water resilience are taken care of. These urban aspects could include sustainable aspects like the urban heat island effect, biodiversity and air quality, but also more site specific aspects like traffic safety, human activities and parking. What aspects will be used as sub objectives is dependent on the design sites used.

In order to reach the main objective and the sub objectives, spatial interventions will be applied on several scales and on several locations in the city. Which locations will be transformed will be determined based on the analysis of the storm water resilience of Amsterdam. By investigating the relations between water nuisance and other systems in the city, the right interventions can be found for the right location. These spatial interventions will be based on generic, existing tools and technologies related to storm water resilience. This will contribute to the creation of a storm water resilient city, while deriving additional benefits for the sub objectives from this as much as possible.

The relation between the storm water system and the urban typology can help to do suggestions for the typology of the planned urban expansions. A garden village like Oostzaan has different characteristics and thus different ways of managing storm water than a neighbourhood like the Jordaan. Therefore, the relation between different urban typologies and their storm water resilience will be investigated during the analysis of this project. Knowing this can help to do spatial suggestions for the planned urban expansions.

This graduation project will focus on solving the water related issues from an urban perspective. This means existing technologies will be used to transform the design sites, with a focus on the spatial and environmental consequences. The technological and financial consequences are not included in the scope of this graduation project.

# 1.3 Research Questions

The consequences of climate change ask for improvement of Amsterdam's storm water resilience, especially in combination with the expected urban growth. Furthermore, the interventions which are currently used can be improved by addressing more sustainability aspects at the same time. When these are referred to as additional beneftis, the main research question is formulated as follows:

*Main research question*

*How can applying interventions on several scales reinforce the urban water system of Amsterdam, in order to create a storm water resilient city, while deriving additional, environmental and socio-economic benefits from this?*

This question attempts to tackle all the issues stated in the problem statement, arising from the current developments of climate change and urban growth. In order to find an answer to the main research question, the following sub research questions have to be answered as well. These questions can be categorized by the five phases of the project: historic systems, current systems, current challenges, future challenges and future systems. These phases are part of the larger methodology (Figure 1.5 and 1.6). The five phases are part of an iterative process and will be repeated several times.

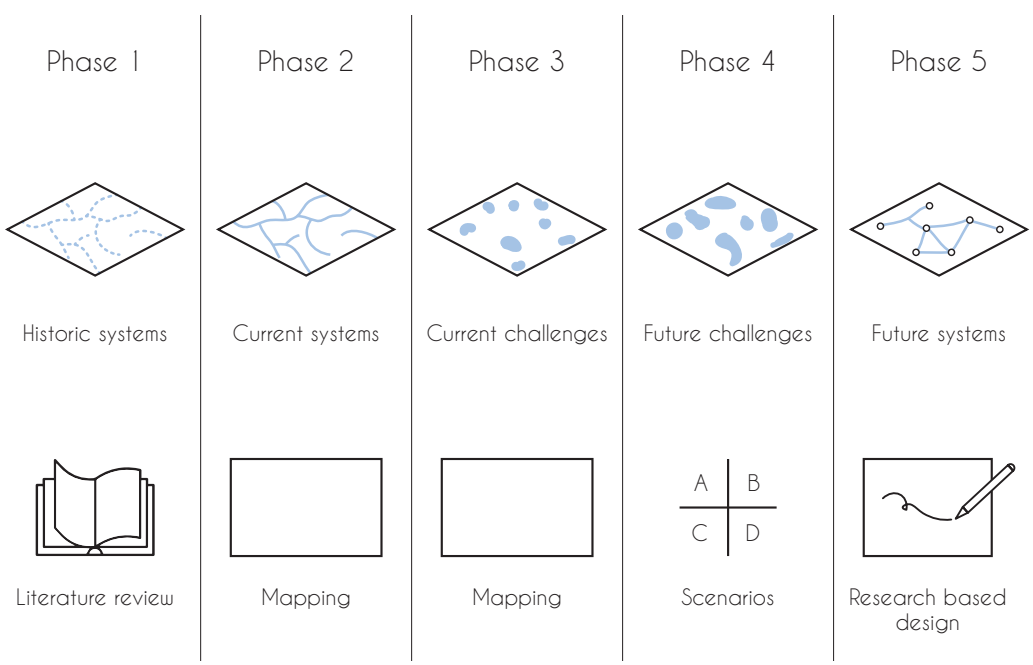



**Fig. 1.5**: Five phases of the project (Author, 2018)

*Sub research questions*

**Phase 1: Historic systems**
How did the urban development of Amsterdam evolve over time?
Method: Literature review.

How has the role of water in the city changed over the years?
Method: Literature review

**Phase 2: Current systems**
How does the storm water system of Amsterdam function?
Method: Mapping.

What are relevant systems in relation to storm water resilience and how do they function?
Method: Mapping.

**Phase 3: Current challenges**
What are the challenges in the urban design and planning of storm water resilient cities?
Method: Literature review.

Where does the storm water system of Amsterdam ask for improvement?
Method: Mapping.

**Phase 4: Future challenges**
What are the effects of climate change on the storm water system of Amsterdam?
Method: Scenarios.

**Phase 5: Future systems**
What are possible spatial interventions related to storm water resilience?
Method: Project analysis & literature review

**Phase 5a: Solutions**
What are strategic locations to implement these interventions to and what is the best way to do this?
Method: Research based design

**Phase 5b: Network**
How does the implementation of these interventions influence the storm water system on city scale?
Method: Evaluation

What will be the effect of these interventions on the sub objectives?
Method: Evaluation

# 1.4 Methodology

The process of this graduation project can be divided into three main stages: project definition, theoretical and analytical framework and design and evaluation (Figure 1.6). The first stage consists of the project definition's first steps: problem statement, objectives, research questions, methodology and relevance. This results in the main research question:

*How can applying interventions on several scales reinforce the urban water system of Amsterdam, in order to create a storm water resilient city, while deriving additional, environmental and socio-economic benefits from this?*

The methods which are used to obtain the right information and formulate this question are literature study, case study, trends study and historical research.

The first step of the theoretical framework is to have an understanding of the current challenges in urban planning and design of storm water resilient cities. This will result in an overview of challenges, which helps urban planners and designer to address the challenges in an early stage of the design process. This is done by literature study and case studies. Now the challenges are clear, insight in possible interventions related to storm water resilience is needed. This forms the second part of the theoretical framework. The possible solutions are divided by scale and their impact on several aspects. The methods used are case studies and literature study.

After getting theoretical insight in the challenges and possible solutions, the spatial characteristics of the problem must be investigated. This is done in the analytical framework. The goal of the analytical framework is to understand the weaknesses of the storm water system now and in the future. Furthermore, any relevant system related to the storm water system will be investigated. The methods used for this step are scenario thinking, mapping and observing.

The third stage of the project includes design and evaluation. The aim of this phase is to transform locations in Amsterdam which are of frequent occurance and which experience most water nuisance. By redesigning these locations, similar locations in the city can benefit from these examples and transform in a similar way. Evaluation will show the effect of the interventions on the sub objectives and on the city's larger water system. Zooming in and out is a very important part of the evaluation of the designs, in order to optimise the solutions.

Apart from going through different scales, going through different times is part of the process too. Therefore, the five phases (historical systems, current systems, current challenges, future challenges and future systems) are included in the methodology scheme as well. Following this iterative process through several scales and times will result in a complete and synergetic overview of the desired interventions.




**Fig. 1.6**: Methodology scheme (Author, 2018)

# 1.5 Relevance

**Societal relevance**

There are many projects going on in Amsterdam which are related to the storm water resilience of the city. This is, amongst others, tackled by initiatives like Amsterdam Rainproof and projects of the municipality (Amsterdam Rainproof, 2017a; Gemeente Amsterdam, 2017). Apart from this highly relevant topic, Amsterdam is facing other issues as well. The city is also working on sustainable energy generation, cleaner air and waste management, for example. It is therefore important to explore synergies between storm water resilience and other aspects of the city and to rethink the way current projects related to water resilience are taken care of. This will safe time, money and effort, and this will make Amsterdam a safer city.

Furthermore, the Dutch government is currently working on the 'omgevingswet'. This law aims to combine dozens of existing laws and hundreds of existing regulations, in order to make the legislation easier and more accessible. The various plans for spatial planning, the environment and nature will be better coordinated. This also gives the opportunity to finally include various aspects of sustainability in the legislation. Sustainable projects, like wind farms, will be promoted and there will be more space for residents to come up with their own ideas. In this way, local problems can be solved on a local level. Furthermore, municipalities, provinces and water boards will get more space too. They can adjust their environmental policy to their own needs and goals (Rijksoverheid, no date).

One of the main parts of the 'omgevingswet' is the 'omgevingsvisie'. This vision explains the outline of the long term vision for the physical environment. It contains subjects as buildings, infrastructure, water systems, water, soil, air, landscape, nature and cultural heritage. Both a description of the current situation and the preferred future quality of the living environment are included. As so many subjects are included in this vision, it will take years to make and fine-tune it. This graduation project can therefore be a source of inspiration. It shows how synergies can be found between various objectives, contributing to the climate resilience of the city. This emphasizes the relevance of this graduation project. The method can be used by municipalities to reach their several goals.

Although this graduation project specifically focuses on Amsterdam, the problems mentioned occur in various other cities as well. Therefore, the conclusions and methodology of this thesis may function as a reference and inspiration for other cities facing similar issues.

**Scientific relevance**

The main concept of this graduation project is storm water resilience in relation to climate change and urban growth, in the context of Amsterdam. There are many studies done about both these topics, since they are highly relevant and topical. However, a project about the relation between the two is relatively unexplored yet. It is expected that by looking at the historical development of the relation between urban water and urban growth, today's role of water in the city can be explained. This will help to design the right intervention for the location. Furthermore, synergies with other sustainable aspects, like the urban heat island effect, biodiversity and air quality, will be investigated in order to create a storm water resilient and future-proof city. Using a clear methodology could help municipalities and urban planners making their cities water resilient while deriving additional benefits from this as much as possible.

# 02

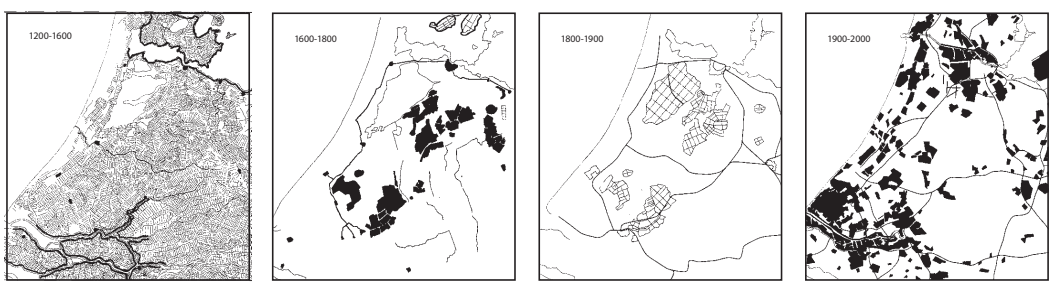
## A Brief History

This chapter will investigate the (water related) history of Amsterdam. It is important to understand how the water system of the city used to work, as decisions made in the past are still determining some of the current conditions. Furthermore, the role of water in the city changed over time, influencing the decisions taken. Knowing this will help to make the right decisions today and to create suitable designs.

# 02 A BRIEF HISTORY

**The origin of Dutch polder cities**

Even though at first it appears to be one large joined polder area, the Dutch lowlands consist of individual polders, each with their own history of development (Figure 2.1). The difference can easily be explained by their method of development. Due to the changing influences of soil, wind and water, different natural types of ground developed. Peat polders have been developed by means of exploiting the peat marshland, drained lakes by means of draining lakes, and diked areas by means of exploiting the seabed. The most important characteristic of a polder, defining the cities to be developed in this polder, is the relation between the type of soil and the exploitation. Furthermore, the development of cities is dependent on the development of technology, planning ideals and social and economic requirements (Hooimeijer et al., 2005).




1200-1600: dikes, dams, polders, cities

1600-1800: fortresses, country estates, waterways, reclamation

1800-1900: impoldering, railways, city expansions

1900-2000: motorways, industry

**Fig. 2.1**: Land reclamation throughout the centuries (Hooimeijer, Meyer & Nienhuis, 2005)

The different polder landscapes, peat polders, drained lakes and diked areas form different types of cities. One of the characteristics of the peat polder city, the oldest polder city, is the higher leveled 'dry core' on which the settlement started. Prosperity and growth led to expansion of the surrounding wet soil, derived from peat or already prepared for cultivation, but not yet prepared to be built upon (Hooimeijer et al., 2005).

The most important condition for the creation of cities in polders is the construction of dikes. These dikes can protect the areas which have become vulnerable due to settlement and subsidence against flooding. The first generation of dike rings was built in the 13$^{th}$ and 14$^{th}$ century. On the location where a dike crossed a watercourse a dam was built. This is the second characteristic of the peat polder city. Amsterdam is an example of such a peat polder city with a dam as its 'dry core'. Apart from the function as a dam, the dam ensured discharge of the river water into open water by means of a drainage sluice. Together with tidal movements, drain water was used in a practical way in order to ensure the depth of the harbour as well as city access for sea-going vessels. The dam, including the drainage sluice, which formed the city centre, illustrated the economic meaning of transport over water to the hinterland. The drainage sluice could only support smaller ships, goods from larger vessels had to be hauled or sold on the dam. The dam turned into a trading market, and the estuary outside the dikes of the peat river became a sheltered harbour. The dam town and polder became hydraulically as well as economically connected (Hooimeijer et al., 2005). This shows the first relation between water and the city.

A characteristic for all three types of polder cities is the strict control of the city plan. This need for 'strict control' is the result of the cautiousness with which an expansion of the polder city needed to be realised. First, the size of the expansion needed to be determined. One had to estimate the spatial requirements for the years to come. The second aspect was a technical plan in order to discharge and control the water and to make sure the water in the city canals would stay at a constant level. In most cases the start was initiated by building an encircling canal, which was connected through the expansion area by means of multiple parallel canals. The outer canal was primarily built for drainage, but also had a military and a transport function. By means of sluices and windmills the water level of the canal system was regulated and the excess water discharged. Then, the reclaimed land needed to be raised in order to obtain the required protection level, and it had to be consolidated and prepared for building. Mud excavated from the canals was used for raising the level, and was supplemented by ground, which often needed to be transported from far away. In the ground prepared for building long foundation piles were driven into the ground in order to stabilise the housing in the deep-set stratum of sand (Hooimeijer et al., 2005).

Besides the 'dry core' and 'strict control', 'significant involvement with the organisation and design of the polder landscape' is the third spatial characteristic of the polder city. The polders offered space for each spatial strategy and ideal city planning, but also provided the basis for several cities (Hooimeijer et al., 2005).

**Water as a source of income**

As described before, Amsterdam is an example of a peat polder city with a dam as its 'dry core' (Figure 2.2). Amsterdam is founded on the St. Antoniesdijk along the IJ. This sea dike is part of a much more extensive dike construction from Het Gooi up to the dunes of Kennemerland. It has been constructed in the 12th century to protect the region against the IJ and the Zuiderzee. Around 1220 the dam is built where the dike crosses the Amstel. This way the water level of the hinterland could be regulated and the outer water could be kept out of the city. As an economic centre the dam attracts much activity and many people. In 1300 Amsterdam is granted city privileges. The city grows via a system of canals up until the 17th century. This ring of canals, the grachtengordel, is an integral design of a street plan and a new water system. The relationship between land restructuring, surveying, and water management forms the basis of urban design in the Netherlands (Hooimeijer et al., 2005). This helps to function optimally as a trading city. The civil society decided in an early stage to organise hydraulic engineering and water management collectively, as a core business of the public institutions. Amsterdam could not exist without hydraulic infrastructure, and trading would be impossible (Tjallingii and Berendsen, 2007).




**Fig. 2.2**: Origin and development of Amsterdam (Hooimeijer, Meyer & Nienhuis, 2005)

**Water as a redundant element**

After 1850, private builders gradually enlarged Amsterdam. Many partial building plans are carried out by raising the ground and the construction of streets in accordance with the land division of the polders. In particular, this gradual expansion brings with it water technology problems, owing to the stinking pools which appear between the embankments (Hooimeijer et al., 2005).

At the same time, the relation between city and water changed drastically. Epidemic diseases like cholera caused high mortality rates, especially among the poorer population. One thought this was caused by noxiuous fumes coming from the canals (Melkert, 2004). Apart from this health related incentive to fill up canals, there also was a traffic-technical reason. The introduction of the railways, and later on of the car, reduced the importance of water as main infrastructure in and between the cities. Tow- and deck barges were being replaced by trains and trucks. Drinking water would henceforth be delivered by separate drinking water pipes; wastewater was drained via separate sewerage systems. The water in the city only seemed to be needed to control the groundwater level, but even that could largely be regulated by underground drainage systems. Water largely disappeared from the cityscape: in the course of the 19th century many canals and ports have been filled, indicated in black in Figure 2.3, and the open waterfront of Amsterdam has been transformed into a railway hub (Tjallingii and Berendsen, 2007).

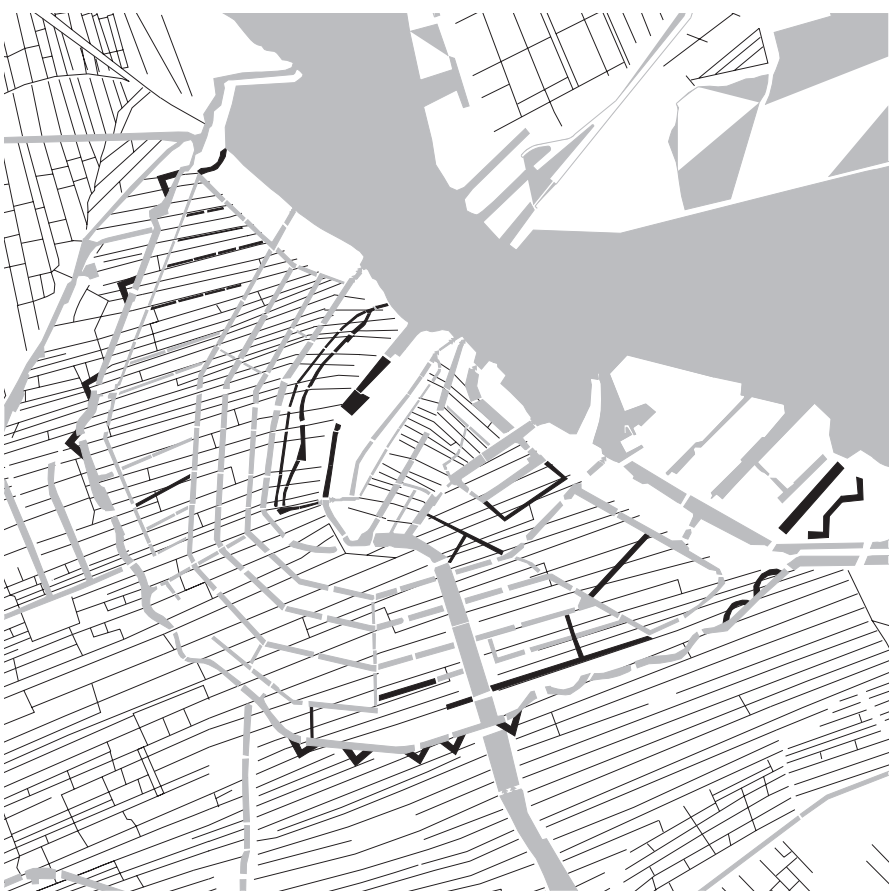


**Fig. 2.3**: Canals filled in the 19th century, indicated in black (Hooimeijer, Meyer & Nienhuis, 2005)

**Water for leisure activities**

Until 1970, a few more canals have been filled, despite the many protests (Melkert, 2004). A cultural revaluation of water in the cityscape, and the revaluation of landscape in the city in general, is a trend which is visible from the seventies onwards. This trend is an expression of resistance against the monotonous, rigid and sterile experienced urbanism from the fifties and sixties. It also shows the emergence of the need for a specific, local identity of the city, and an emphasis on the matters that make the city an attractive place to live and work (Tjallingii and Berendsen, 2007). Today the canals are Amsterdam's trademark, attracting millions of tourists per year. Besides that, new urban developments along the IJ, like the Houthavens, Buiksloterham and the Oostelijke Haveneilanden, are more popular than ever. Water is a valuable leisure related element in the city.

However, nowadays storm water poses a threat to cities too, and in the future probably even more as a result of climate change. Climate change revealed itself in the nineties by several floods and would eventually lead to a drastic change in hydraulic engineering and water management. Finding new forms of water management became of great importance to survive. The new relation between urban growth and water management is still subject to discussion: do we continue like we did for eight centuries, or do we need to find new ways to keep our feet dry?

## Urban development

For centuries, Amsterdam's spatial development was determined by its situation in the midst of a peat reclamation landscape and on the Amstel river. In this phase, the current city center was built, known as the 'grachtengordel'. In the late 19th century, railroad lines, stations and new docklands on both shores of the IJ determined Amsterdam's spatial development. New techniques related to water safety allowed the city to make use of less obvious locations. This is when the 19th century ring around the city center and the docks along the IJ were constructed. After the second World War, the upscaling of the shipping industry caused constant relocations of the docks towards the West. At the same time, the city was extended on all sides by new large residential areas, made accessible by a ring road and motorways.




Legend

peat reclamation landscape

railroad

highway

Spatial development determined by:

river & reclamation landscape

railroad lines & stations

new docks along the IJ

relocation of the docks

ringroad & motorways

**Map 2.1**: Urban development throughout the centuries (Author, 2018)

# 03

# Theoretical Framework

This chapter will investigate the contemporary challenges in urban design and planning of storm water resilient cities on several scales: building scale, street scale, neighbourhood scale and city scale. Knowing these challenges will help to apply the right interventions to the right place on the right scale.

# 03 THEORETICAL FRAMEWORK

Nowadays, urban water management is positioned high on the urban agenda in many ways, also in the Netherlands. Although the Netherlands has been praised for its robustness against coastal- and river flooding and water nuisance, water management is still of major concern. Understandable, if you realize 55% of the Netherlands is susceptible to both sea-level rise and river flooding. Of this area, 26% is located below sea-level, with -6,76 meters as the lowest point in Nieuwerkerk aan den IJssel (Planbureau voor de Leefomgeving, 2010, Rijkswaterstaat, n.d.).

Part of water management is storm water management, which means to manage the surface runoff caused by precipitation. If storm water is not managed properly, several types of flooding could occur (Stevenson, 2017):

- River flooding: River flooding, or fluvial flooding, occurs when the capacity of a river channel is exceeded as a result of intense or sustained rainfall across the catchment.
- Groundwater flooding: Groundwater flooding occurs when the groundwater table rises up to the surface during a prolonged wet period. Low lying areas, areas near aquifers and properties with cellars or basements are more likely to experience groundwater flooding.
- Surface water flooding: Surface water flooding, or pluvial flooding, occurs when the volume of rainfall is unable to drain away through the drainage systems or to soak into the land and instead flows over land. Blocked drains and sewers can increase the risk of surface water flooding as the water has nowhere to go.
- Sewage flooding: Most sewage flooding incidents are the result of overloaded sewers following heavy rainfall or blockages caused by misuse of the sewerage system.

The Netherlands are prone to all these types of flooding. This is undesirable, since it may cause dangerous situations related to accessibility, water quality and ecology, and it disturbs daily life.

With these consequences in mind, there is no lack of motivation to take care of storm water management properly. However, pluvial flooding occurs a lot in the Netherlands. Water nuisance caused by heavy rainfall occurs a few times per year, for exmple in Amsterdam (Figure 3.1). This shows cities still need to work on improving their storm water resilience. Studying projects related to storm water resilience and reflecting on them will show what challenges are currently present on several scales. The scales distinguished are building scale, street scale, neighbourhood scale and city scale. In addition, literature about challenges in designing storm water resilient solutions will be studied, to find other, general challenges which are not necessarily related to a certain scale.

The challenges found from projects and literature will be supplemented by external uncertainties, which should also be taken into account when designing urban storm water resilient solutions. These uncertainties are developments which are currently going on, but which have an uncertain future.




**Fig. 3.1**: Newspaper articles about water nuisance in the Netherlands (Het Parool, 2016)

**Challenges from existing projects**

Building scale: Intratuin Amsterdam

Goal: Watering all the plants of the garden centre with rainwater.



**Fig. 3.2**: Rainwater collection at garden centre Intratuin in Amsterdam East (Amsterdam Rainproof, 2016)

Garden centre Intratuin in Amsterdam East consumes a lot of water in order to water the plants and clean the buildings and floors. Therefore, the owner decided to make use of a rainwater utilization system already at the start of construction. Not because of cost reduction, but because of environmental considerations and because rainwater is better for the plants. The rainwater falling on the 6000 $m^2$ roof flows via gutters and indoor pipes towards a silo of 210.000 liters (Figure 3.2). The system works very simple and most processes are automated. The maintenance of the system is low; only the roofs should be cleaned every now and then. The roof catches 5 million liters of water per year. The garden centre only needs 2 million liters, but the rain does not fall evenly throughout the year. Despite the irregular rainfall, the system only ran out of water once in eighteen years (Naafs, 2016).

This project is a very good example of a sustainable, storm water resilient solution that suits the function of the building perfectly. This rainwater utilization system does not only improve the water resilience of the surrounding area, but has additional benefits for the plants too. Challenges of this kind of solutions could be the space needed for storage of such a big amount of water. When there is no space available to store water on the surface, one could decide to store the water underground. However, this involves considerably higher costs. Furthermore, there is a change that the costs of installing and maintaining such a system do not outweigh the savings on the use of tap water. This has to do with the extremely low price of tap water in the Netherlands. Therefore, motivation is a very important aspect to deal with on the building scale, especially when the building is owned by a private owner. However, apartment buildings might also experience troubles when implementing storm water resilient solutions on the building scale, like a rainwater utilization system. Such a building is owned by many people. The owners association should come up with a plan to conclude an agreement with all the residents of the building. Therefore, ownership can be seen as a challenge on the building scale too.

Street scale: De StraaD

Goal: Transform every street in The Netherlands into a climate adaptive 'straaD'.

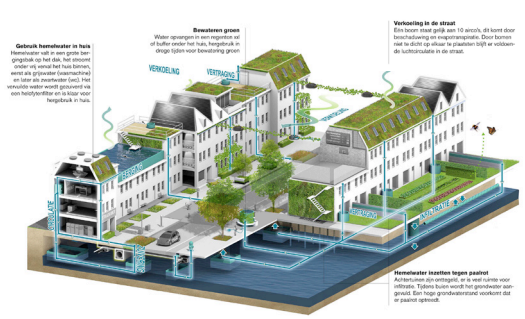



**Fig. 3.3**: Impression of how a climate adaptive street could look like (De Straad, 2016)

According to 'De StraaD', the city streets offer opportunities to improve the climate or to adapt ourselves to it better (Figure 3.3). The streets are always in development and form a powerful network. The concept relies on the

major effects a small solution can have, when it has been applied over a thousand times. The 'straaD' of the future can be summarized in four themes: the city as a sponge, efficient flows, green with added value, and social and flexible. The city as a sponge has to do with storm water resilience, and means that rainwater may no longer go to the sewer. Clean water will stay clean, and will be used for all kinds of purposes. Polluted water will be purified on site. Measures for rainwater retention and infiltration are green, permeable paving, storage in the foundation of housing and water buffers (Bosch Slabbers landschapsarchitecten et al., 2016).

According to the initiators of this project, 60% of the open space in cities is owned by residents (Bosch Slabbers landschapsarchitecten et al., 2016). Therefore, they claim it pays off when you involve residents in climate adaptive transformation. On the street scale, ownership could be one of the major challenges to overcome. Planners or the municipality may have a nice idea how a street can become climate adaptive, but when the backyards of that street are all paved, the measures make a whole less sense. This works the other way too.

This project is a good example of a combination of professionals and residents, of private and public stakeholders. These two groups both think in another time horizon, which can be a second challenge on this scale. Residents tend to focus on the near future, where professionals look much further ahead (Bosch Slabbers landschapsarchitecten et al., 2016).



**Fig. 3.4**: The transformed, storm proof Tasinge Square in Copenhagen (GHB Landskabsarkitekter, n.d.)

Neighbourhood scale: Østerbro, Copenhagen
Goal: Adapt the neighbourhood to climate change with just plants and water.

A catastrophic cloudburst in 2011, causing damage of about $1 billion, has been a wake-up call for this neighbourhood in Copenhagen. Instead of doing small scale acupuncture projects, the city decided to develop a rainwater master plan. Adding sewers was an extremely costly option, so a green-blue approach would be the more economical solution. The neighbourhood would be adapted to climate change with just plants and water. Asphalt has been replaced by a hilly, grassy carpet interspersed with walking paths. If a storm, flood or rising sea levels hits the neighbourhood again, the mini-parks will turn into water basins (Figure 3.4). Thanks to the new pipe system, the squares will even be able to collect water from surrounding buildings' roofs. Surrounding streets will be turned into 'cloudburst boulevards'. Under ordinary circumstances, they will just be ordinary streets with raised sidewalks, but during floods and mega-storms, they will become canals, draining rainwater away from the squares to the harbour. If there will never be a flood or cloudburst again, it is still value for money because the neighbourhood is more beautiful than before (Municipality of Copenhagen et al., 2016).

Because of the size of a project like this, a strong motivation of the municipality must be present in order to succeed. In case of Østerbro, this motivation was clearly there: catastrophes like in 2011 were not supposed to happen again. Besides that, the neighbourhood would become more beautiful and liveable.

Residents also play an important role in the development of the neighbourhood, since they are in progress with their own green projects too. Measures such as plant boxes, green beds and green roofs greatly contribute towards making Østerbro the first climate resilient neighbourhood of Copenhagen (Municipality of Copenhagen et al., 2016). Getting the residents on board of such a project is a challenge too, since they must feel responsible for their neighborhood before they would take action themselves.

City scale: Chicago
Goal: Reduce flooding in future storms.

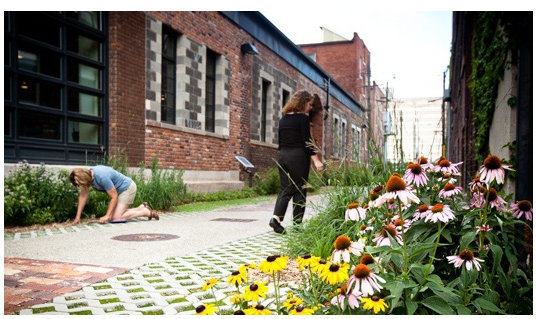


**Fig. 3.5**: One of the transformed, storm proof alleys of Chicago (Omaha by Design, 2015)

Chicago is a city of water: the city is located next to Lake Michigan, and surrounded by several rivers. Water is Chicago's most valuable natural resource, and a vital part of the city's past and future. However, today close to 60% of Chicago's land area is either paved or covered with buildings (City of Chicago, 2014). In combination with climate change, this causes events like combined sewer overflows, basement flooding and Lake Michigan reversals. The latter releases a mixture of river water, rainwater and sewage into Lake Michigan, when the rivers are at a risk of overtopping their banks. In order to prevent this from happening again, the city set up several programs: Green Roofs, Green Alleys, Green Streets, Downspout Disconnections and the Sustainable Backyard Program. Especially interesting is the Green Alleys Program. Chicago has approximately 3000 kilometres of public alleys, more than any other city in the world. Flooding is often an issue in these alleys, because most of them are not connected to the city's sewer system. In 2006, the city began the Green Alley Program to reduce basement flooding and sewer overflows by converting pavement in alleys to permeable surfaces (Figure 3.5). Since 2006, over 200 green alleys have been created.

This is an example of a city using a unique characteristic in order to become greener and more environmentally sustainable. This does not make the solution generally applicable, but the project can be an inspiration for other cities. Finding this characteristic, opportunity or concept to create a complete and coherent network of interventions, instead of doing acupunctural, individual interventions, can as well be seen as a challenge. A big project like this has a very long implementation time, challenging the city too. Therefore, coherency is important to keep the overview in such a long period of time.

Studying these projects on four scales gave insight in the following challenges:
- Building scale: space, costs, motivation, ownership
- Street scale: ownership, time horizon
- Neighbourhood scale: motivation, residents
- City scale: coherence, implementation time

**Challenges from literature**

The challenges mentioned above, can be supplemented by challenges from literature. Van Eijk (2003) describes challenges in the implementation of changes in urban water management. One of these challenges is the fragmentation of the administrative organization of water management (Van Eijk, 2003). In the Netherlands two water authorities are acknowledged: the State as authority for the main waterways and the water boards as the authorities for the regional waterways. The water boards are also responsible for wastewater treatment. Provinces and municipalities do not act as water management authorities, although they do have certain tasks in water management. For the time being, the provinces remain the competent authority for three categories of groundwater abstraction and infiltration. The municipalities have the task to provide for the collection and drainage of rainwater and groundwater (Rijkswaterstaat, 2011). This division causes diverging interests and diffuse distribution of responsibilities, according to Van Eijk (2003). During planning, this requires a clear strategy to talk with the right disciplines and organizations at the right moment in time. This challenge of fragmentation operates on a national, governmental scale, which makes it very hard to do something about it.

Another governmental challenge in designing and planning storm water resilient cities is to adapt the legal framework. At the moment, adaptive, non-structural flood measures are little used in the Netherlands. One reason for this might be the lack of supporting policies or barriers in the legal framework (Van Eijk, 2003, Van Vliet & Aerts, 2014). Policies slowly start to change from a flood probability approach to a more flood risk based approach. The laws and regulations, however, are still largely tailored to structural flood defences in the form of levees and dykes. This makes it difficult to implement adaptive measures, which decreases the support for these measures among major stakeholders (Van Vliet & Aerts, 2014). Water ambitions should be sufficiently integrated in spatial policy in order to realize them.

The occurrence of water nuisance is also very much dependent on the more general layout of the ground level. This general layout, or spatial design, includes the presence or absence of curbs, speed bumps and height differences. For example, curbs can make sure precipitation flows in the direction of the road, instead of the direction of the houses, and speed bumps function as a steering element. Municipalities could pay much more attention to these spatial elements in relation to extreme rainfall. Besides, they only have a limited amount of data available about the potential consequences of these types of events (Kluck et al., 2013).

All the different stakeholders are related to certain scales. When different developments, plans and initiatives emerging from these different scales meet, a significant field of tension and uncertainty arises. The developments proposed affect not only a range of different sectors and scales, but also involve different time horizons. Many of the small scale initiatives on the building or street scale focus on achieving short-term and medium-term goals within one to ten years' time. Large scale infrastructure on neighbourhood or city scale requires much more time for planning and construction. This means furthermore that there is a greater degree of uncertainty about the future. The challenge is to transform the risk of delays, paralysis and capital destruction into opportunities for linkages and mutual support among the different initiatives and objectives (Meyer et al., 2015).

**External uncertainties**

Apart from challenges on several scales, some external uncertainties should be considered as well when designing and planning storm water resilient cities. Climate change is one of these uncertainties. Among others, climate change involves changes in sea level, river discharges and precipitation patterns. These effects can cause major implications in urban storm water management, especially when planning long term projects (Meyer et al., 2015). Therefore, future scenarios are needed to adapt projects according to the developments.

Demographic changes should be considered in scenarios too. An aging population uses public space differently than other population groups, and shrinking cities need a different approach than a growing metropolis. Demographic changes are directly related to urban structures, and thus indirectly to urban storm water management.

Urban growth could be a consequence of demographic changes, in combination with an urbanization trend. Urban growth has major consequences for urban storm water management, since city expansion often involves expansion of paved areas. This influences the drainage capacity, the urban heat island effect, the biodiversity and the amount of nature in the city (Van Loon et al., 2014). These developments should definitely be considered, given the impact they have on urban storm water management.

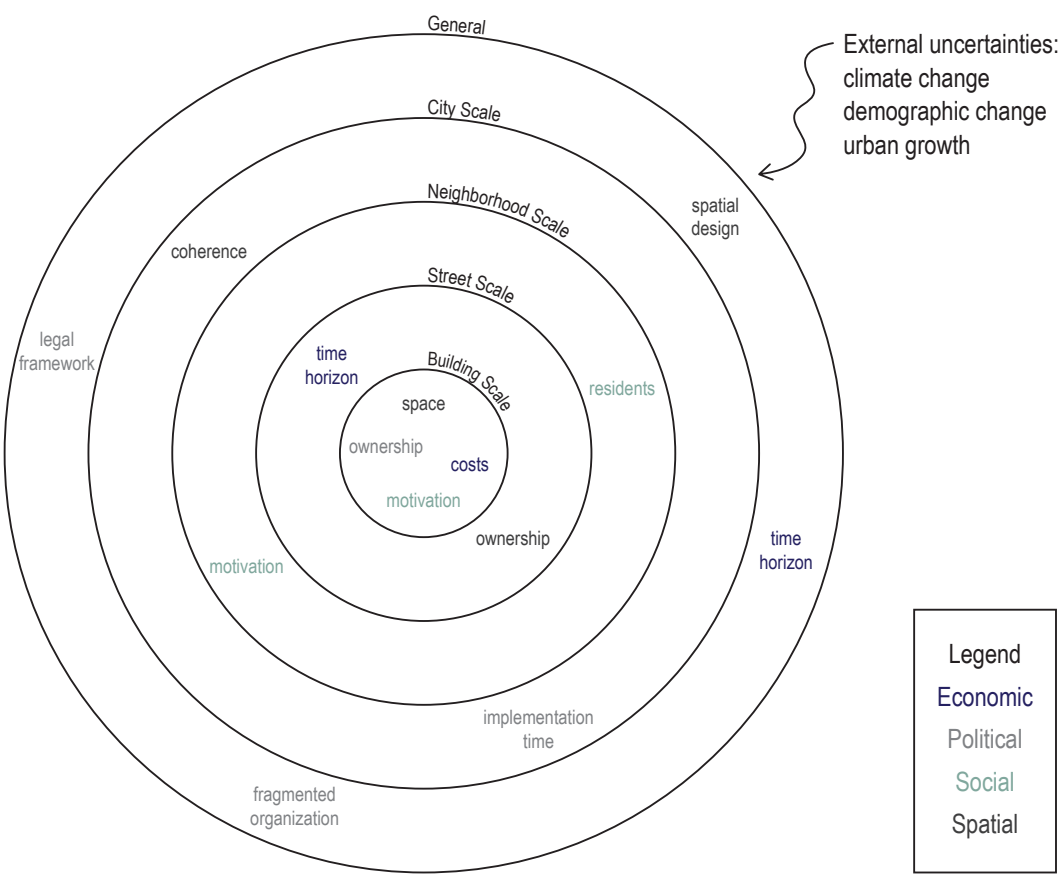



**Fig. 3.6**: Concluding diagram showing the challenges per scale and category (Author, 2017)

**Conclusion & discussion**

Studying existing projects and literature provided several challenges in designing urban storm water resilient solutions. When looking at these challenges, four categories can be distinguished: economic, political, social and spatial challenges. So apart from a division by scale, a division by category is possible as well. This is shown in the concluding diagram on the previous page, where the scales are indicated per ring, and the categories by colour (Figure 3.6). This overview helps to remind designers about economic, political, social and spatial challenges, which could occur when designing urban storm water resilient solutions on several scales. When addressing these challenges already in the design phase of the solutions, the solutions will be more complete and scale specific.

However, this overview of challenges is far from complete. Categories that could be added in the future are technological and environmental challenges. Furthermore, it would have been good to include more existing projects in this investigation, to make the challenges found more complete and trustworthy.

# 04

# Analytical Framework

This chapter shows which areas in Amsterdam are currently susceptible to water nuisance. A small collection of maps explains the main reasons why this is the case. Other layers of the city which are analysed for their relevance are collected in Appendix 1: The Maps Manual. The areas which are susceptible to water nuisance have been analysed on the street scale too. The conclusions of this analysis are included in this chapter. The sections made on the street scale are included in Appendix 2: The Section Collection.

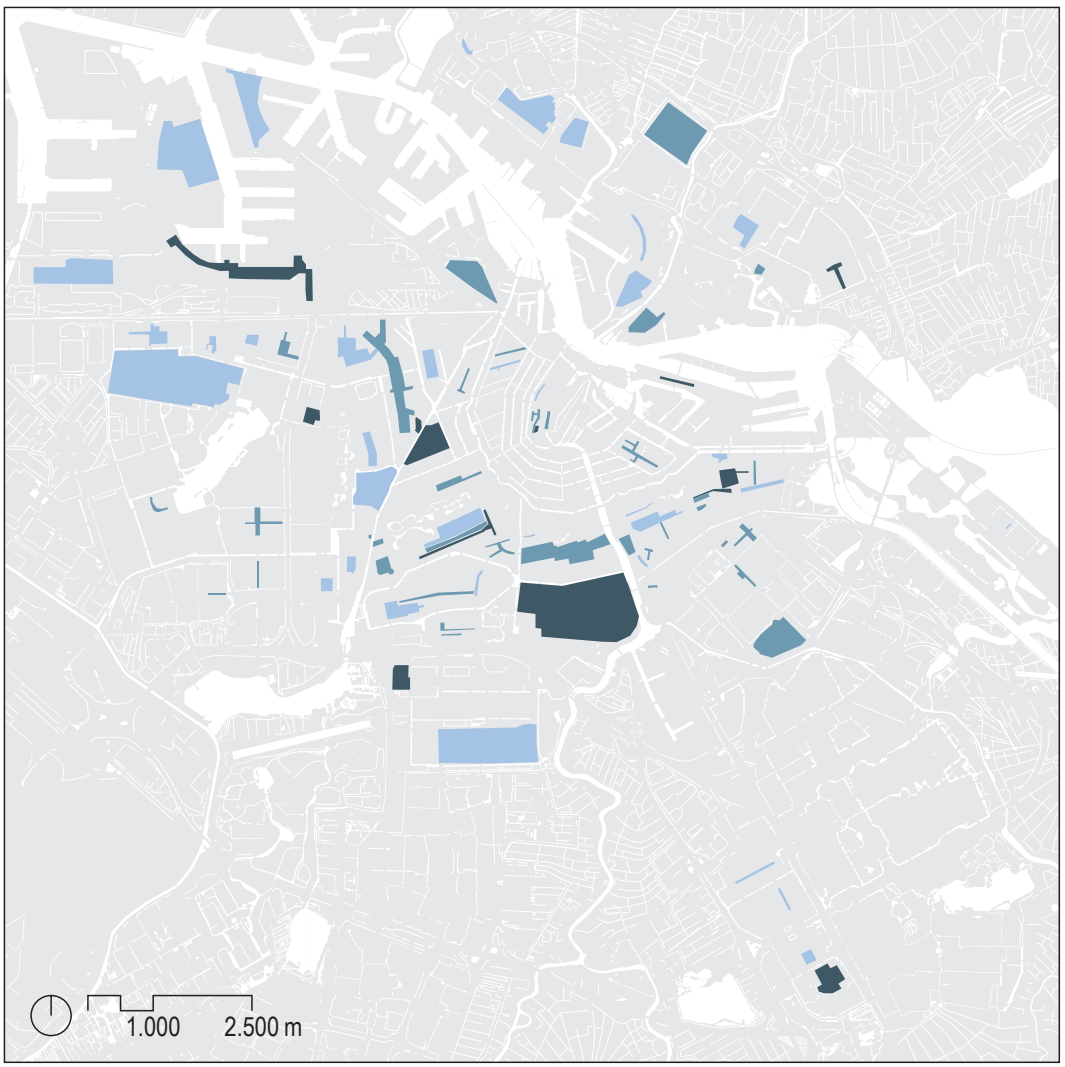
## 4.1 Water nuisance

Map 4.1 indicates the areas in Amsterdam which currently experience water nuisance during or after haevy rainfall, based on a map of Amsterdam Rainproof (2017b). These areas are divided into urgent, very urgent and extremely urgent situations. This urgency indicates the amount of potential damage on that specific location. The three gradations of water nuisance occur throughout the whole city. This suggests the overall water system is working well and bottlenecks cause water nuisance in specific locations. This can be confirmed by the fact that Amsterdam has a uniform topography without a lot of height differences. Therefore, there are no real challenges to tackle on the city scale itself. By focussing on the smaller scales, the bottlenecks can be solved and damage can be prevented.

Future water nuisance can be predicted by using climate scenarios, of which the extreme scenario forms the basis for the calculations in this research. This means the designs have been tested to an extreme rain shower of 60 millimeter in two hours. This number is based on the rain event of July 28$^{th}$ 2014. As this event has a repetition time of five to fifteen years, it is seen as an extreme event, which is partly caused by the effects of climate change. KNMI gives two important measurements about this day (KNMI,2014):

- 131,6 millimeter of rain fell over the whole day
- 12 millimeter of rain fell in five minutes

When using the logarithmic scale these measurements are part of (Savenije, 2006), this results in a rainfall intensity of **46 millimeter of rain in two hours**. The extreme climate scenario of KNMI, the $W_H$ scenario, claims a 9% increase of precipitation per degree of temperature rise, for precipitation lasting between one to three hours. With a 3,7 degree of temperature rise, predicted for 2085 (KNMI,2015), this means the amount of precipitation will rise with 33,3%, for precipitation lasting between one to three hours. Adding this increase to the 46 millimeters of rainfall of July 28$^{th}$ 2014, results in 61,3 millimeter of rain in two hours. Therefore, **60 millimeter of rain in two hours** is used as test value, which equals 60 liters of water per square meter.




Legend

- extremely urgent: chance of severe damage to real estate (a lot of water), critical infrastructure, hospitals and museums and disruption of accessibility (>30 cm water on main roads).
- very urgent: chance of damage to real estate and severe traffic disruption.
- urgent: chance of damage to real estate.

**Map 4.1**: Areas which are currently sensitive to water nuisance (Author, 2018)

## 4.2 Green & water

A large amount of rainwater can be stored in the soil, but only when it has access to it. Buildings and paved areas prevent rainwater from infiltrating in the soil. Map 4.2 shows the green and water structures of Amsterdam. The ‘grachtengordel’ contains a large amount of surface water, but barely any green. Still, this area does not experience a lot of water nuisance, apart from a few smaller locations. This is due to the dimensions of the building blocks, which have been determined by the amount of rainwater drainage required. The 19th century ring around the ‘grachtengordel’ contains small amounts of green and surface water.This partly explains why this area experiences more water nuisance than other areas. Closer to the outskirts of the city there is more green present, but these areas are still not water nuisance free.




Legend

- urban green
- green landscape
- water

**Map 4.2**: Green and blue areas (Author, 2018)

## 4.3 Polders

The Netherlands consists of over 3500 polders, in which the water level is controlled by using pumping stations. In order to discharge the water from the polder areas to the open water, such as the sea, a system of boezem water is being used. A boezem is a closed, elevated system of waterways where polders discharge their water to. When the water level of the boezem gets too high, water is being discharged to open water. At the same time, water is being pumped from the boezem to the polders when they are in need of water. The boezem functions as a buffer (Bobbink, 2016).

Amsterdam consists of boezem land and polders (Map 4.3). Boezem land is land on the level of the boezem water. In Amsterdam boezem land is located at around -0,4 meters NAP. The polders within the city are located at around -2,7 meters NAP. It is interesting to see that the polders within the city do not necessarily experience more water nuisance than the higher boezem land, even though the polders are located much lower. This shows the polder-boezem system is working well.

However, in future situations, this might be different. As a consequence of climate change, the sea level will rise. But when the difference between the sea level and the ground water level increases, more seepage will occur in the coastal areas. Shallow ground water will cause polders to have less storage and infiltration capacity, so water should be discharged to the boezem system earlier. In turn, the boezem will be full sooner, having to discharge water to open water. So even though the polder-boezem system of Amsterdam is working well at this moment, climate change may have negative consequences.

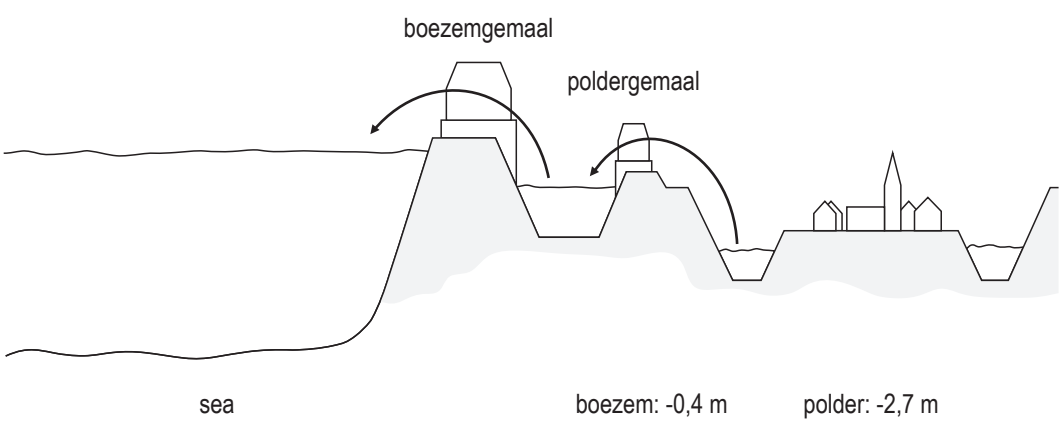
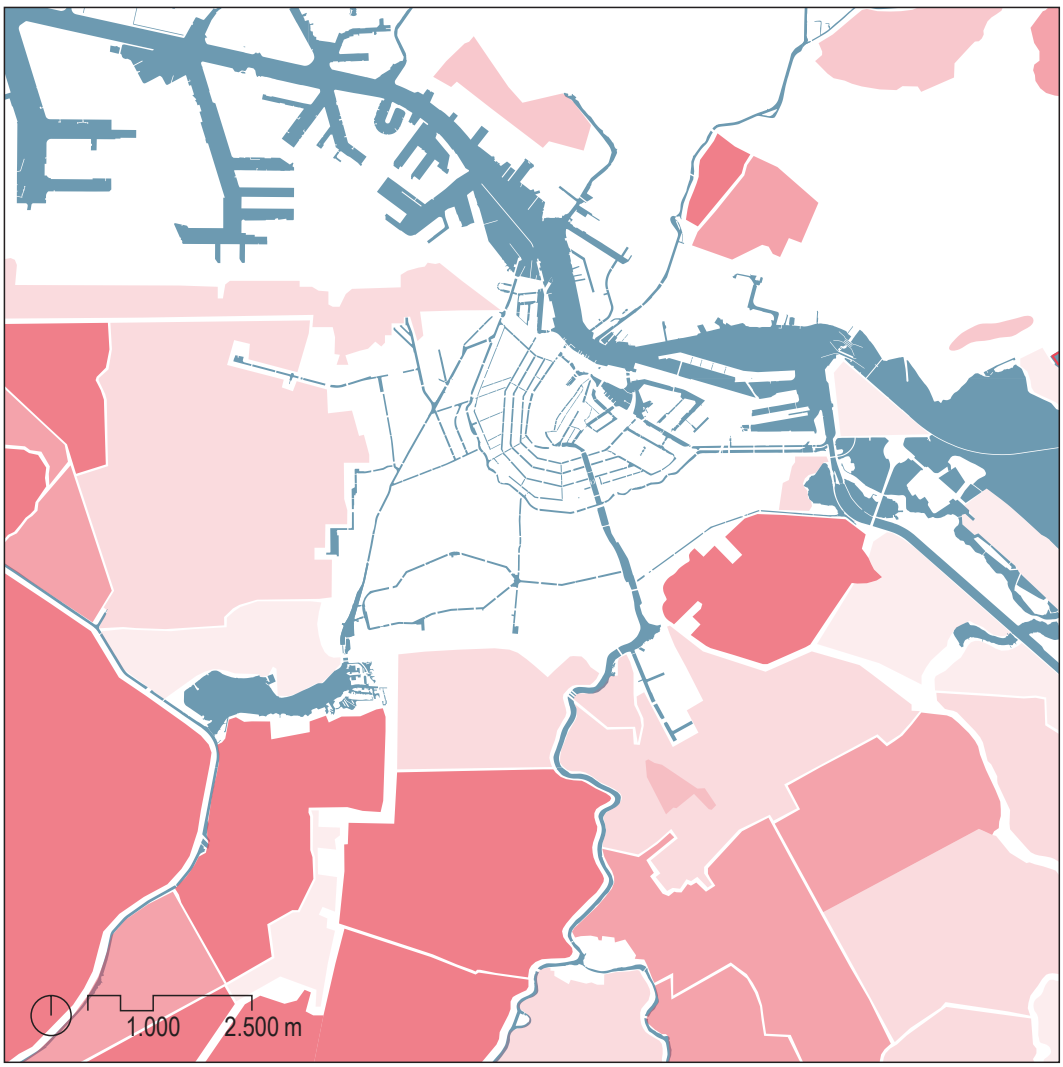



**Fig. 4.1**: Polder and boezem system (Author, 2018)




Legend

boezemwater

(Desirable) water level of polders:

-5 m >

between -4 and -5 m

between -3 and -4 m

between -2 and -3 m

between 0 and -2 m

**Map 4.3**: Polder areas (Author, 2018)

# 4.4 Non-residential functions

In Amsterdam, the non-residential functions are scattered around the whole city, with a high concentration of offices, retail and horeca in the city centre (Map 4.4). It is remarkable that most streets which experience water nuisance are shopping streets. These shopping streets are often very intensively used by several traffic flows, like pedestrians, cyclists, cars and trams. When each traffic flow uses its own paved lane, there is barely any space left for rainwater storage or infiltration. The only possibility to infiltrate rainwater is often just a few tree boxes, like in the Ceintuurbaan which is shown in the section below (Figure 4.2). This means all the rainwater from the roofs and the streets is drained via the sewer system. The sewer system often can not process heavy rains, resulting in a flooded street.

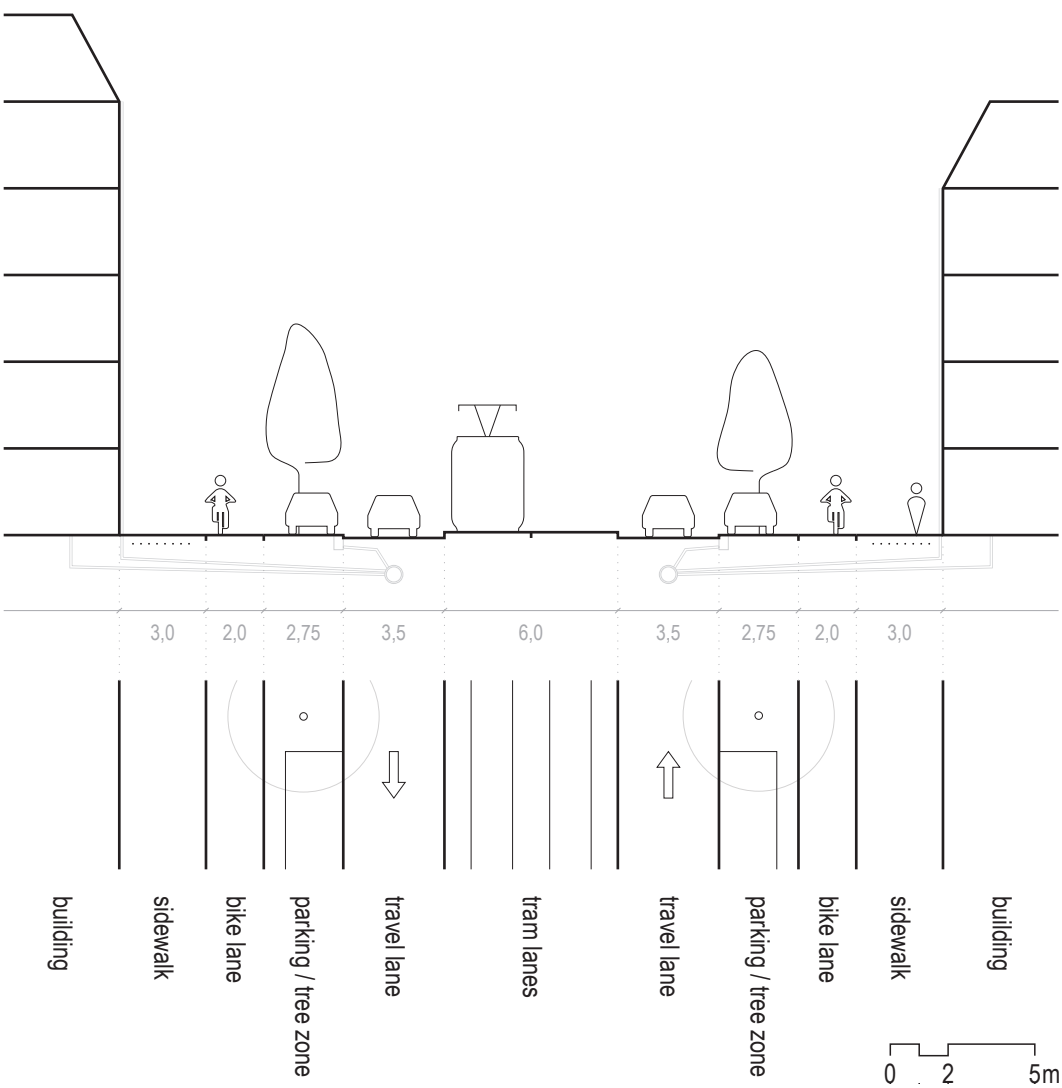
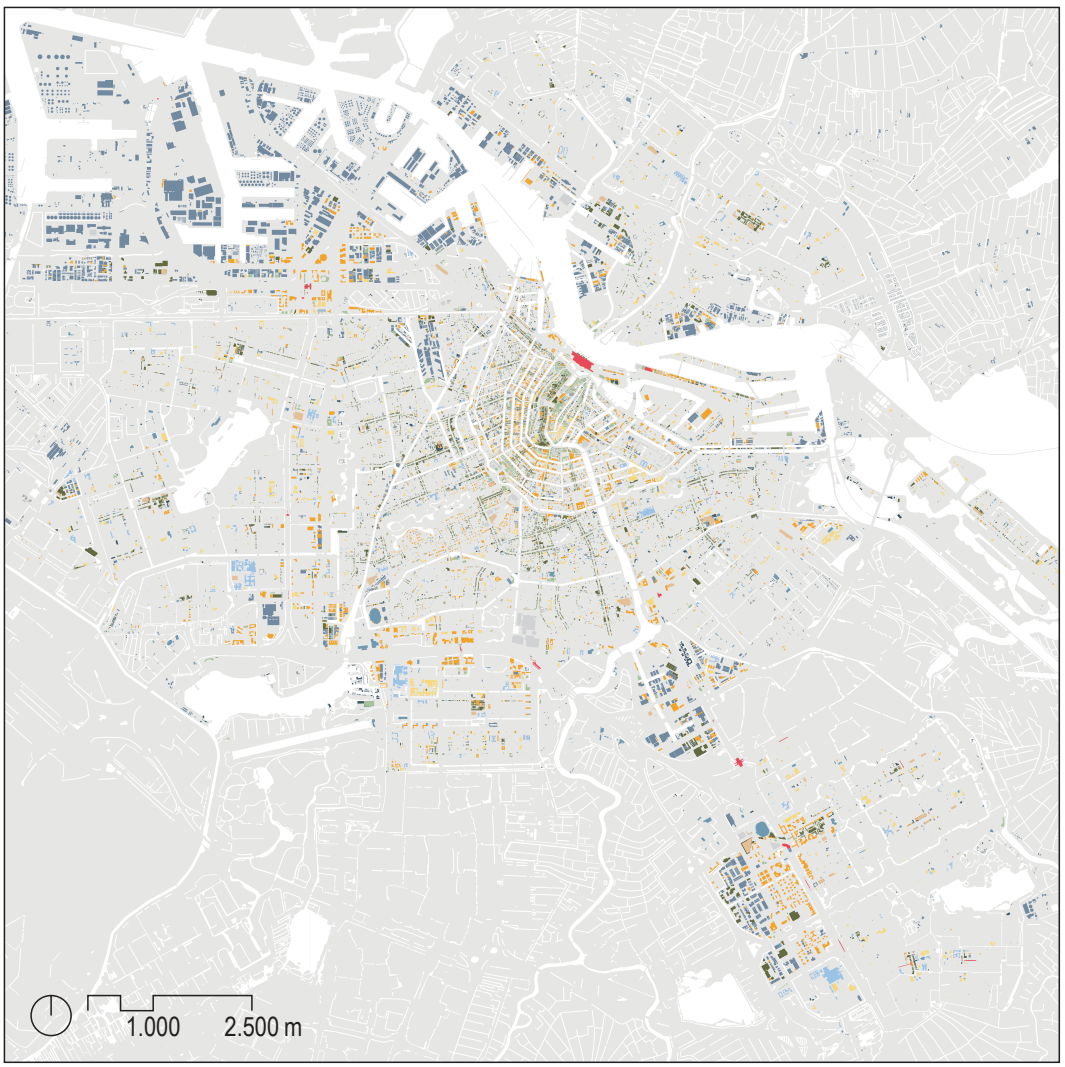



**Fig. 4.2**: Section of the shopping street Ceintuurbaan (Author, 2018)



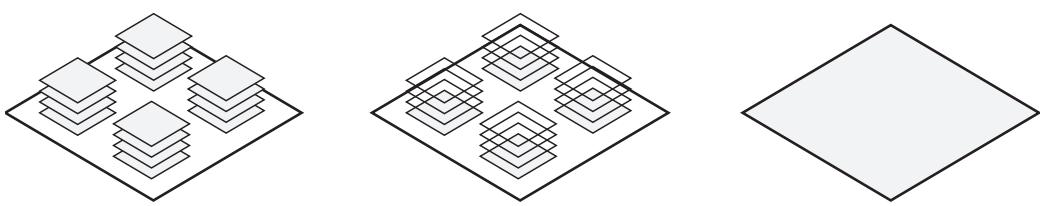

Legend

- activities & meeting
- businesses
- education
- entertainment & tourism
- healthcare
- horeca
- offices
- parking
- public transport
- religion
- retail
- sports

**Map 4.4**: Non-residential functions (Author, 2018)

# 4.5 Spatial typologies

Amsterdam is founded in the 13th century and has expanded ever since (Gemeente Amsterdam, 2011). Every city expansion is characterised by different developments, views and technical possibilities, resulting in different types of neighbourhoods. Building densities can give an indication about the amount of paved surface and thus about the rainwater discharge in an area. However, building densities are mostly expressed in amount of houses per hectare or amount of residents per square meter. This does not include the physical, spatial density and only applies to housing. In order to include more spatial characteristics, Floor Space Index (FSI) and Ground Space Index (GSI) can be used. These values indicate intensity (FSI) and compactness (GSI) and are based on the footprint, floor area and the area of aggregation (Figure 4.3) (Berghauser Pont & Haupt, 2005). By calculating the FSI and GSI for the building blocks of Amsterdam, spatial typologies can be recognised based on the combination of these two factors. In the end, the city is divided into six spatial typologies, as can be seen on Map 4.5. These typologies describe the relation between the size of the building block and the space around it.



FSI = F / A

F = gross floor area
A = area of aggregation

GSI = B / A

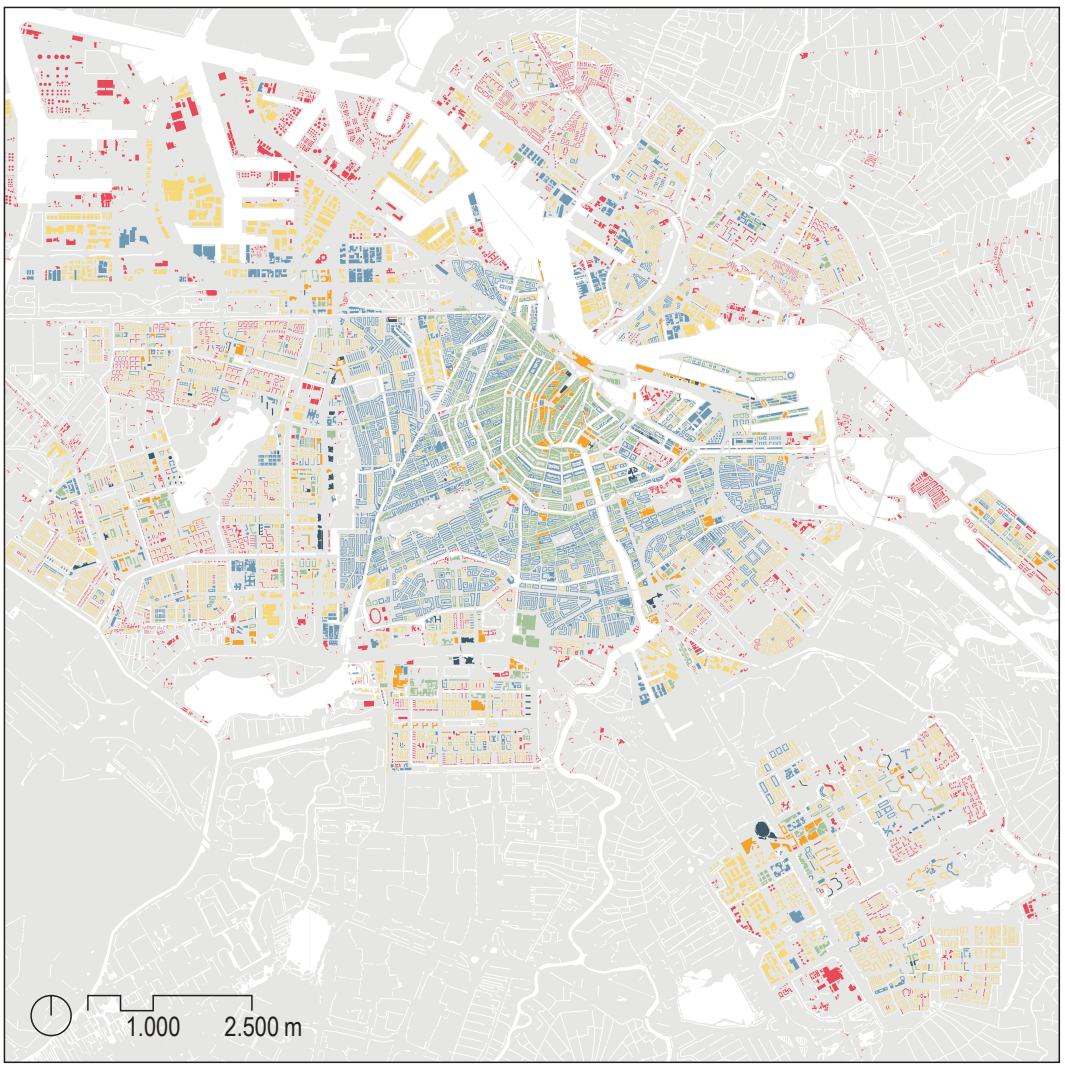
B = footprint
A = area of aggregation

Area of aggregation

**Fig. 4.3**: Way to calculate FSI and GSI (Author, 2018)

The water nuisance in Amsterdam seems to be related to spatial typology 'mid rise, high compactness, low density'. Most buildings of this typology are closed building blocks, built in the late 19th century or the early 20th century. They are mainly located in the ring around the inner city. This spatial typology has the highest GSI value of the typologies calculated, which indicates a high compactness. The FSI of the typology is relatively low, indicating a low building intensity and multi-layered buildings. Physically this means most buildings have a height of around 5 storeys.

Even though most urban designs within this spatial typology contained a design for public place, most original street profiles have been lost through time. Especially the advent of parking lots caused large changes. Often, green strips had to make space for this. As the amount of green in the original plans was already limited to the accentuating of the urban structure, not a lot of green spaces are left (Rijksdienst voor het Cultureel Erfgoed, 2012). This may be one of the reasons why this spatial typology experiences most water nuisance. Even though the building compactness is high and the density low, there is not enough infiltration or storage capacity available.




Legend

- low rise, medium compactness, medium density
- low rise, low compactness, low density
- mid rise, high compactness, low density
- mid rise, medium compactness, medium density
- high rise, medium compactness, high density
- high rise, medium compactness, medium density

**Map 4.5**: Spatial typologies (Author, 2018)

# 05

## Design Proposal

This chapter elaborates on the designs made for four locations in Amsterdam. It shows the context of the site, analysis of water nuisance, analysis of human behaviour, design proposal and a qualitative as well as a quantitative evaluation. The chapter closes with a reflection on the applicability of the design proposals on similar locations.

# 5.1 Site selection

Based on the analysis done on city scale, four design sites are selected on three different scales. These sites will be analysed to get insight in local water related issues and spatial and environmental qualities and shortages. This information will then be used to redesign the location, while making use of existing tools and interventions. The outcome will show how similar areas in the city can adapt themselves to become storm water resilient.

**Building scale: OLVG west**
OLVG west is an hospital located in the west part of Amsterdam. It has been selected as a design site on the building scale, as it is a very big building with an important function which should definitely not fail. Still, this building suffers from water nuisance during heavy rainfall. Because this building covers such a large area, all the rain falling on the roofs should be taken care of. Since more big buildings in the city experience water nuisance, like the Foodhallen, AMC and VU, this is an interesting design site to explore.

**Building (block) scale: Javastraat**
A building block in the Javastraat has been selected because it mainly has a residential function. The building block is located in a bigger area which experiences water nuisance during heavy rainfall. It is partly owned by a housing association, which might ask for different solutions to solve this nuisance. At this design site, it would be interesting to look at the opportunity of residents participating in the process of becoming storm water resilient. Participation could be very important, as most residents own valuable outdoor space which they can use to apply interventions to.

**Street scale: Rokin**
On the street scale a part of Rokin will be analysed and redesigned because of the main function of the street, which is retail. Streets with a retail function are often intensively used, especially in the city centre. Furthermore, these streets are often completely paved and a lot of shopfronts have glass facades to the ground. This is partly why a lot of shopping streets in Amsterdam experience water nuisance during heavy rainfall. By exploring the posibilities to make this type of street storm water resilient, a lot of other streets in the city can benefit from this.

**Neighbourhood scale: Rivierenbuurt**
The Rivierenbuurt is selected as design site on the neighbourhood scale, as this large area has a big chance of severe damage to real estate, critical infrastructure, hospitals and museums and disruption of accessibility. Apart from this urgency to make the area storm water resilient, most buildings in the Rivierenbuurt are part of a common typology. This typology occurs a lot in Amsterdam and often coincides with areas that experience water nuisance. Therefore, it is interesting to explore how to improve the storm water resilience of this typology, in order to apply the same interventions in similar areas. On this scale all the interventions from smaller scales come and work together.




Legend

- Neighbourhood scale: Rivierenbuurt
- Street scale: Rokin
- Building scale: Javastraat
- Building scale: OLVG west

**Map 5.1**: Chosen design sites (Author, 2018)

# 5.2 OLVG west

## 5.2.1 Context

In 2015 the Sint Lucas Andreas hospital was renamed to Onze Lieve Vrouwe Gasthuis (OLVG), location west. The hosptial is located in Amsterdam New West, but knows a location in Amsterdam East too. OLVG west is designated as one of the big development sites of Amsterdam. This means the municipality is looking into possibilities to attract social and commercial functions.

During the site visits several observations are done. The observations related to the storm water resilience of the location are photographed, collected and shown below. Then, the design for the location will be elaborated.

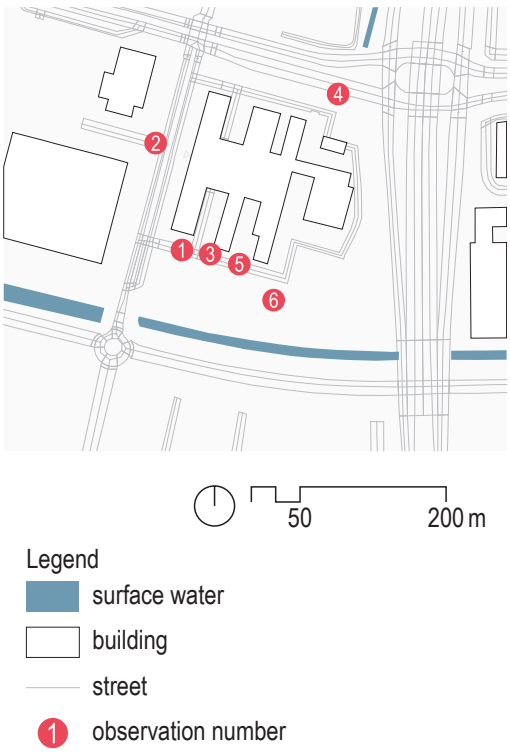



**Fig. 5.1**: Map of the OLVG west indicating the observations (Author, 2018)



**Fig. 5.2**: Parking below the building (Author, 2018)




**Fig. 5.3**: Surrounding streets (Author, 2018)

### 1. Parking below building

Below the OLVG west are parking lots located, about half below the ground level. These parking lots are available to both visitors and employees and are very close to the entrances of the building. The surroundings of the building seem to be dominated by cars and parking.

### 2. Surrounding streets

The streets around the OLVG west are wide and intensively used. Most of them have multiple lanes for several types of transport. These broad streets make the building and its grounds feel like an island. There are not many pedestrian crossings to reach the building safely.



**Fig. 5.4**: Descending streets (Author, 2018)




**Fig. 5.5**: Enormous flat roof area (Author, 2018)

### 3. Descending streets

The streets that provide access to the parking lots below the building are descending. This means rainwater will automatically flow there too, while you actually want to lead rainwater away from the building, especially when considering the important function of the building.

### 4. Enormous flat roof area

The building has an enormous flat roof area of over 12.000 $m^2$. Currently, this roof does not seem to be fully utilised. Furthermore, it seems like the building has been adjusted several times after its construction. It contains many different building parts which are of different heights.



**Fig. 5.6**: View from the back of the building (Author, 2018)



**Fig. 5.7**: Car parking (Author, 2018)

### 5. View from the back of the building

The back of the building does not seem to be very carefully organised. The grounds of the OLVG west are completely paved and there is barely any green. It is desirable to have greener and more natural surroundings when staying in the hospital. Especially since green surroundings are proven to be beneficial for human health.

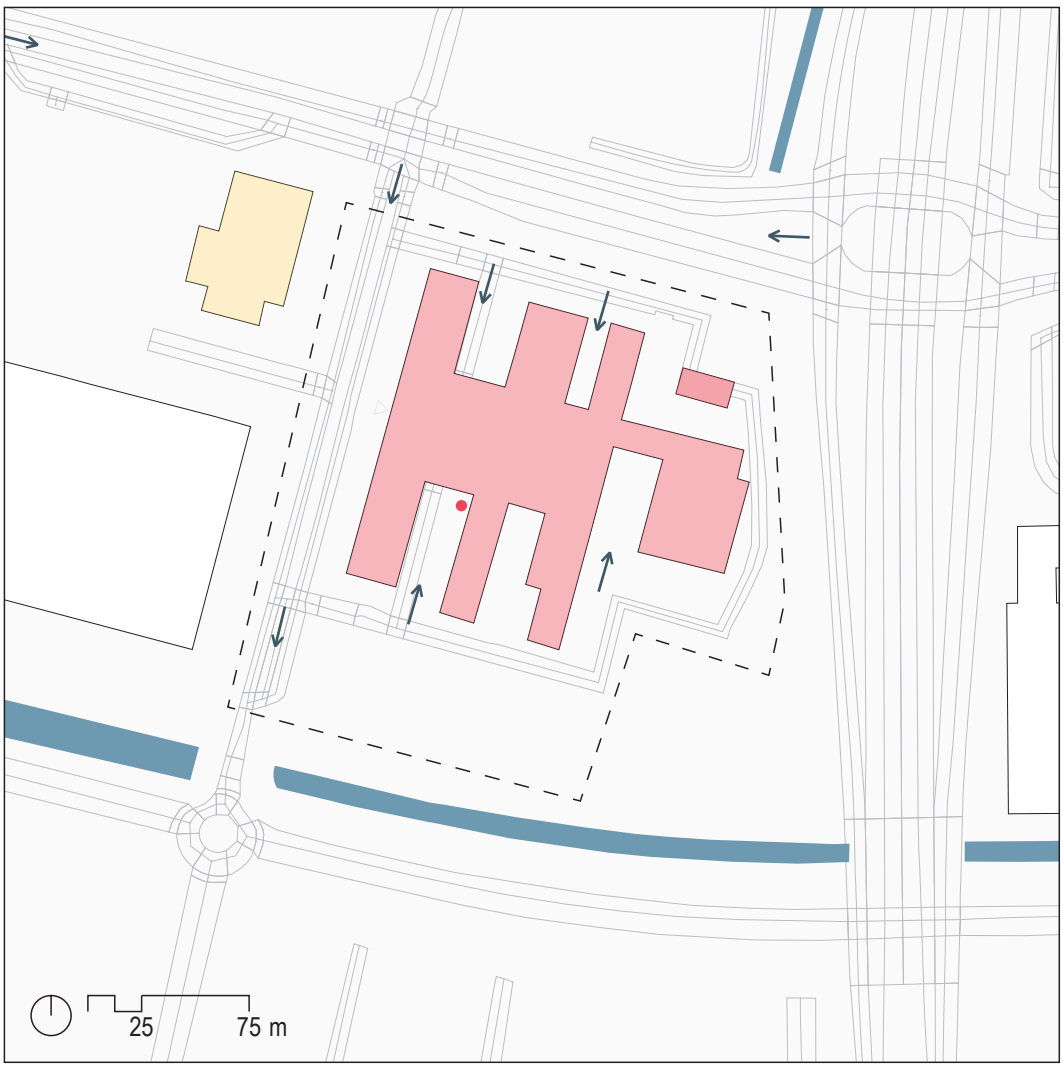
### 6. Car parking

The grounds of the OLVG west include several parking lots. They take a lot of space, as they are all located at the ground floor. This huge paved area creates a challenging situation when it comes to rainwater drainage. Furthermore, it forms a source of heat, as asphalt absorbs heat.

### 5.2.2 Water nuisance

The observations can be substantiated by factual information about water nuisance around OLVG west and the surrounding streets. Map 5.2 shows the risk of damage to buildings and infrastructure due to extreme precipitation, based on the Rainproof factsheet of Slotervaart, obtained via Amsterdam Rainproof (2016d). This risk is based on a rain shower simulation of 100 millimeter of rain within one hour and the functions of buildings and public space. This means the risk of damage that is shown is based on a very extreme rain shower. In addition, the complaints of water nuisance reported to Waternet on July 28th, 2014 are added to the map. The map shows the hospital building itself is most prone to damage caused by water nuisance. The water nuisance could obstruct people in need of help when they try to reach the building. The ringroad A10, which is located next to the building, experiences water nuisance too, especially below overpasses. However, this is not the case right next to the hospital. The streets located on the terrain of the hospital descend towards the building, as there are parking lots located below the building. These parking lots form a bathtub, which makes all the rainwater from the surrounding area flow towards the building. As the whole terrain is paved, this is a very large amount of water. Rainwater flowing towards the building is not a preferable situation, especially when the building has such an important function. This shows the design site is not yet storm water resilient.

This location has been selected because of the size and important function of the building. Besides that, the building itself offers a lot of opportunities when transforming the design site to become storm water resilient. The enormous roof and the different heights of it offer conditions that are very well usable for cascading of rainwater. Furthermore, the municipality of Amsterdam is making plans to develop the terrain of the hospital and add housing and retail facilities. The combination of these conditions resulted in the decision to just make a design for the building itself. In this way the proposal is realistic and it could even be a good temporary solution in case the hospital and its surroundings undergo a renovation during the developments.




**Map 5.2**: Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation (Author, 2018)

Legend

- surface water
- building
- border water nuisance
- street
- water nuisance reported to Waternet on July 28th, 2014

Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation:

- increased risk
- strongly increased risk
- extremely increased risk

### 5.2.3 Design proposal

The large flat roof area of the OLVG west collects a very large amount of rainwater every time it rains, which has to be processed by the sewer system. Preventing this amount of water from going to the sewer system would already make a large difference when it comes to water nuisance in the area. This can be done by adding functions to the roof, in the form of a water roof, blue-green roof, gardens and vegetable gardens. Studies have shown that green vistas, natural sunlight and access to natural surroundings all work together to improve the patient's psychological and physical wellbeing, and even reduce the length of stay and the need for pain medication (Land8, 2017). Furthermore, this combination of functions is suitable for cascading rainwater:

1. The highest roof will be established as a rainwater roof. When a heavy rain shower is predicted, the rainwater on the roof can be drained towards the lower roofs or the sewer system to make space for the upcoming rain. The roof has a cooling function too.
2. The roof below will be a walkable blue-green roof, of which a part will be accessible and established as a roof garden. People staying in the hospital can go here to get fresh air, exercise and meet family and friends. Rainwater will be collected and stored in a container under the plants. Via small pipes filled with wool the plants will always have as much water as they need. If this container is full, or water is needed in the vegetable garden, the rainwater surplus can flow to a lower roof via an overflow pipe.
3. The roofs below will be established as a vegetable garden. These gardens can be established with separate planters of different sizes, which can be rented by people. As vegetables need a lot of water, the water from the higher roofs can be used to water the plants. The vegetable gardens will be accessible for people staying and working in the hospital, but also for residents from the surrounding neighbourhoods.



roof garden
(Townshend, no date)



vegetable roof garden
(ZinCo, 2018)



greenhouse roof
(Rooftop Revolution, 2017)



roof garden
(Optigroen, 2018)



rain barrel
(Stowers, 2015)

**Fig. 5.8**: Possible functions for the roof

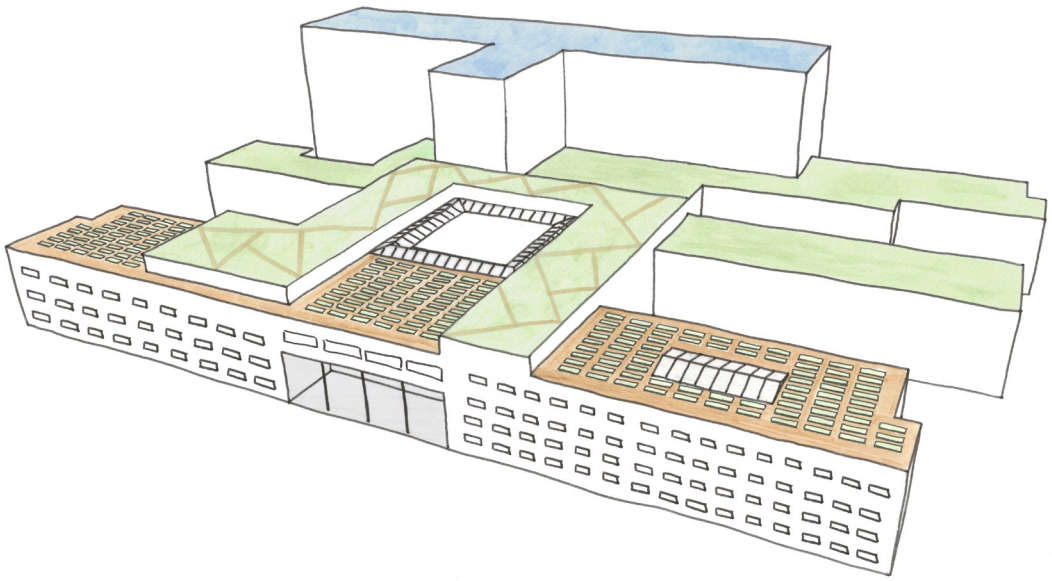


**Fig. 5.9**: Possible layout of the roofs of OLVG west (Author, 2018)

Transforming the roofs of the OLVG west in this way offers a lot of advantages for the hospital and its visitors. First of all, blue and greef roofs cool the building down, which is very important for a building like a hospital. Furthermore, the OLVG west could use a pleasant outdoor space, as the hospital is clearly lacking this at the moment. A roof landscape can compensate the large paved car parking and the view on the ringroad A10. With a vegetable garden, the building can enhance its public function in the neighbourhood. If residents from the surrounding neighbourhood are able to rent or use a small garden, they will interact with visitors and social cohesion will be enhanced. The roof will be the place where people staying in the hospital can feel like they are away for a moment.

The analysis of the water nuisance around the building showed that the parking lots below the building are prone to water nuisance, as the streets descend towards these parking lots. These height differences can be used to collect the water in a tank or a pond below the building. This water could be pumped to the roof and be used to water the gardens. This might be necessary is periods of draught, as vegetables need a lot of water. Because of this buffer capacity, the periods without rain can be bridged without making use of tap water.

When the terrain of the hospital will be developed, storm water resilience should be considered in an early stage of the design process. The area shows to be prone to water nuisance at the moment and contains a critical function so it deserves close attention. In that way, water nuisance will be prevented from happening in the future, even though rain showers get heavier due to climate change.

### 5.2.4 Qualitative evaluation of the design

The interventions applied will contribute to the creation of a storm water resilient area, while creating additional benefits for other sustainable or socio-economic aspects too. This is depicted in Figure 5.10, by the lines between the design components on the one side, and the additional benefits on the other. The thicker the line, the greater the impact on that aspect. The design components are ordered from most water related to least water related, and include components of the three other design sites too. This applies to the additional benefits as well. The relations between the design components and the additonal benefits are based on the book *Green-blue grids*, by Hiltrud Pötz and Pierre Bleuzé (2016), in which the same kind of method has been used.

This qualitative evaluation scheme shows that a limited amount of interventions does not necessarily imply a limited amount of additional benefits. The applied interventions have a positive impact on the following environmental and socio-economic benefits: the indoor and outdoor climate, air treatment, urban agriculture, biodiversity, health and mood and of course storm water resilience. So even though the design proposal limits itself to the the building, it still offers a lot of advantages.

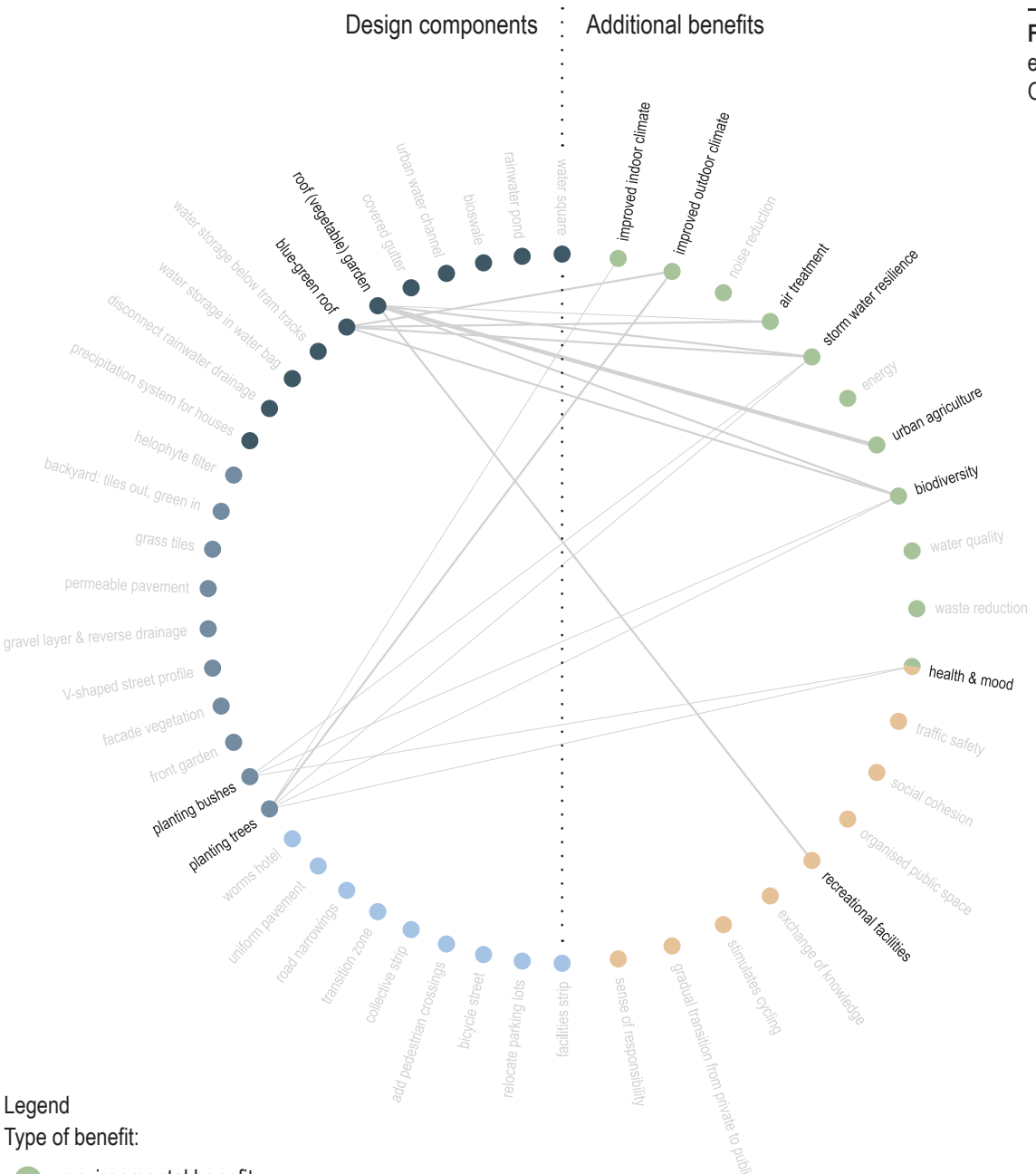



**Fig. 5.10**: Qualitative evaluation scheme of OLVG west (Author, 2018)

### 5.2.5 Quantitative evaluation of the design

A quantitative evaluation has been done too, indicated by the scheme below. This evaluation shows to what extent the current design can prevent future water nuisance. Future water nuisance is predicted by the KNMI climate scenarios, of which the extreme scenario forms the basis for these calculations. This means the designs have been tested to an extreme rain shower of 60 millimeter in two hours, which equals 60 liters of water per square meter (section 4.1 elaborates on the origin of this number).

Roof 1 contains a water roof without any runoff. If roof 2 contains a (blue-)green roof, the runoff will be limited to 20% of the amount of rainwater. Roof 3 contains the vegetable gardens that have a runoff of 50%. The rainwater surplus of both of these roofs can partly be stored in rainwater tanks on roof 2 and 3. This water can be used to water the plants and the vegetables. A rainwater storage below the building, like a rainwater tank or a pond, is required to store the rest of the rainwater surplus. In this way, the surplus can be used during dry periods and rainwater falling on the roof of the building does not go to the sewer system. The rainwater tank or pond below the building can be supplemented with rainwater surplus from the terrain of the hospital, as this area already slopes down towards the building.

rainwater on roof 1:
207.000 L
runoff 0%

rainwater on roof 2:
261.000 L
runoff 20% = 52.200 L
surplus roof 2: 22.200

rainwater on roof 3:
157.500 L
runoff 50% = 78.750 L
surplus roof 3: 48.750 L

left to store:
70.950 L

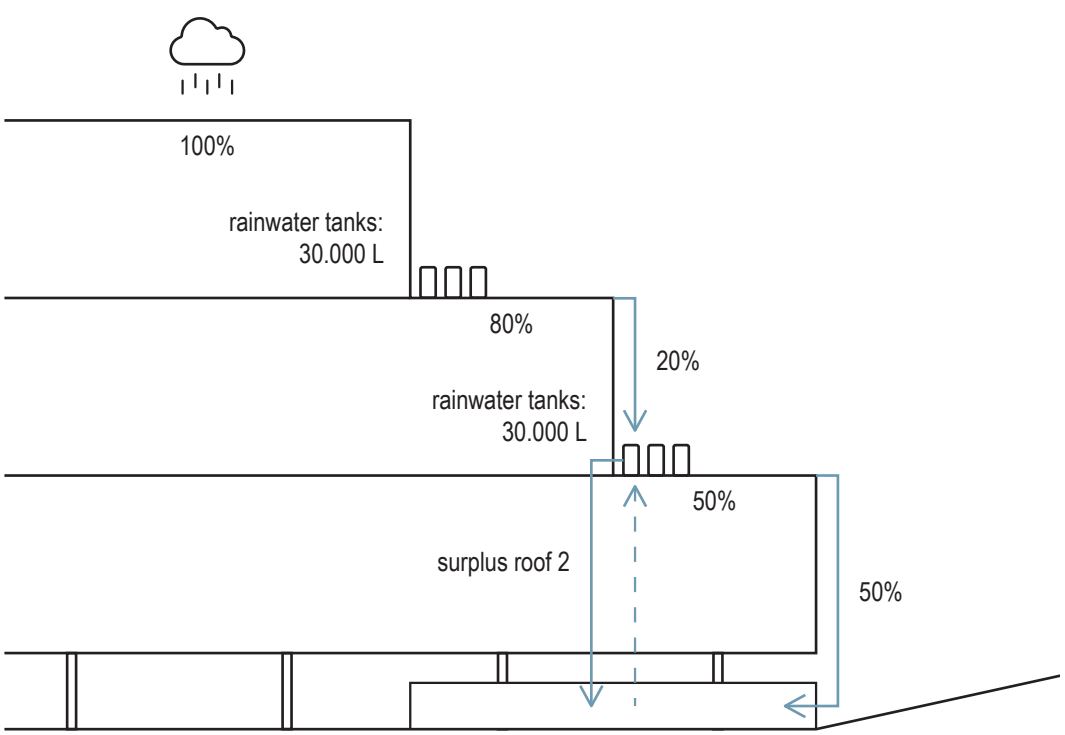



**Fig. 5.11**: Quantitative evaluation scheme of OLVG west (Author, 2018)

# 5.3 Javastraat

### 5.3.1 Context

The buildingblock at Javastraat 4-86 is located in the Indian neighbourhood in Amsterdam East. The block is enclosed by the Javastraat, Balistraat, Celebesstraat and Sumatrastraat. Most of the buildings in the building block are around five storeys high. A large part of the building block is owned by housing association De Alliantie.

This design site will be transformed to show what interventions can be applied to both the street and building scale. First, some observations for this site will be discussed.

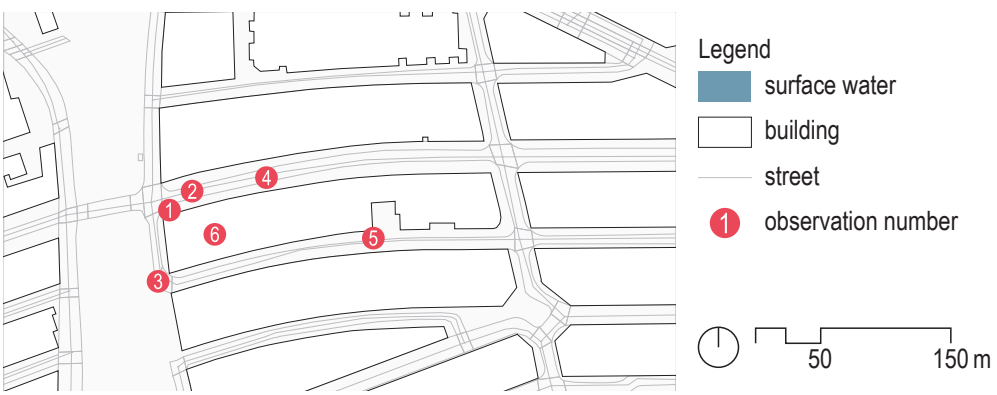



**Fig. 5.12**: Map of the Java- straat indicating the observations (Author, 2018)



**Fig. 5.13**: Ownership (Author, 2018)

**1. Ownership**

Most houses of the building block are built in the same style as the houses along the canals in the 'grachtengordel'. However, there are a few exceptions, like on the picture above. These exceptions are most probably owned by a housing association.



**Fig. 5.14**: Car parking (Author, 2018)

**2. Car parking**

In the Javastraat a lot of space is reserved for car parking. Moreover, these parking lots are wider than an average parking lot. These parking lots highly contribute to the big amount of non permeable pavement of the street and the neighbourhood.



**Fig. 5.15**: Blind walls (Author, 2018)



**Fig. 5.16**: Shopfronts (Steden in transitie, 2015)

### 3. Blind walls

Some parts of the building block contain (almost) blind walls at the ground floor, because of the function behind them. The picture above shows the blind walls of a supermarket which may cause unsafe feelings at night.

### 4. Shopfronts

Most buildings of the building block along the Javastraat have a shop at the ground floor. These shops vary from phone stores to grocery stores and from laundry services to restaurants. Shopfronts have a very direct connection with public space, whereas houses have a more gradual transition from private to public space.

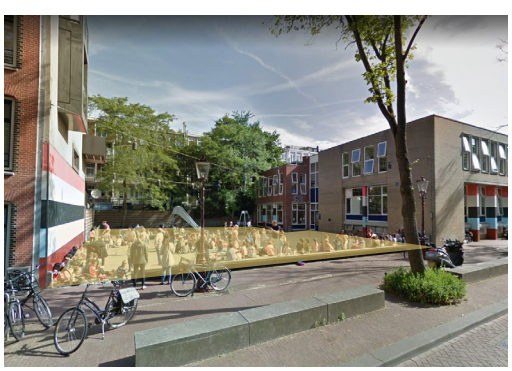


**Fig. 5.17**: School square (Google Maps, 2018a)



**Fig. 5.18**: Closed building block (Google Maps, 2018b)

### 5. School square

The ‘gap’ in the building block is used as a school square for the adjacent elementary school and school care. The school square is completely paved and about 20 by 20 meters in size. In front of the square the sidewalk is a little wider than in the rest of the street.

### 6. Closed building block

The building block which will be investigated is a closed building block with several inner courtyards. Some building owners decided to develop their courtyard to extend their house. The courtyards which are still there could be used for sustainable, storm water resilient interventions.

### 5.3.2 Water nuisance

The observations done can be substantiated by factual information about water nuisance in the Javastraat and the surrounding streets. Map 5.3 shows the risk of damage to buildings and infrastructure due to extreme precipitation, based on the Rainproof factsheet of Oostelijk Havengebied en Indische Buurt, obtained via Amsterdam Rainproof (2016c). This risk is based on a rain shower simulation of 100 millimeter of rain within one hour and the functions of buildings and public space. This means the risk of damage that is shown is based on a very extreme rain shower. In addition, the complaints of water nuisance reported to Waternet on July 28th, 2014 are added to the map. The map shows a few of the main routes are poorly accessible for emergency services. This applies to the Javastraat as well. Furthermore, a large part of the building block concerned is at risk of damage due to 20 centimeters of water against the facade and/or in the courtyard. This shows the building block in the Javastraat is not yet storm water resilient.

The area around the building block concerned offers a lot of possibilities. The subsurface is still available for water related interventions and the street profile offers room for improvement. The building block itself offers opportunities as well, as it contains a courtyard and a lot of flat roofs. Several water related interventions are selected to reduce the current water nuisance in and around the Javastraat. The interventions operating on the street scale include a water square, bioswale, helophyte filter and a V-shaped street profile.




Legend

- Javastraat 4-86
- building
- border water nuisance
- street
- above ground flow direction
- water nuisance reported to Waternet on July 28th, 2014

Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation:

- increased risk
- strongly increased risk
- extremely increased risk

**Map 5.3**: Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation (Author, 2018)

### 5.3.3 Socio-economic profile

In order to get an idea about the users and inhabitants of the Javastraat and Balistraat, the main demographic information has been studied (Figure 5.19). This information may be useful when improving the spatial design. It is remarkable that the group of children is relatively large, which means traffic safety and playgrounds are important aspects to pay attention to. Another remarkable number has to do with home ownership: more than half the number of residents rents his house from a housing association. If agreements can be made with the housing association, implementing interventions on the building scale could be easily facilitated. Another large part of the houses is owned by private home owners. In this case, residents should be encouraged to invest in storm water resilient interventions themselves. Income per household is an important indicator for this too. For the Javastraat the amount of low or high incomes as a percentage of household is not very striking, so this does not necessarily have positive or negative effects.

Another important socio-economic characteristic of the Javastraat has to do with the strong social cohesion in the street. According to a news article of newspaper NRC, the Javastraat is showing how different nationalities, cultures, concepts and generations should live together. Old and new shops alternate each other. Entrepreneurs of the street speak of solidarity and respectful interaction (Van de Beld, 2017). This social cohesion is a characteristic of the street which should be preserved and enhanced. One of the ways to do this is by providing residents with collective space to meet, socialise and do activities together.

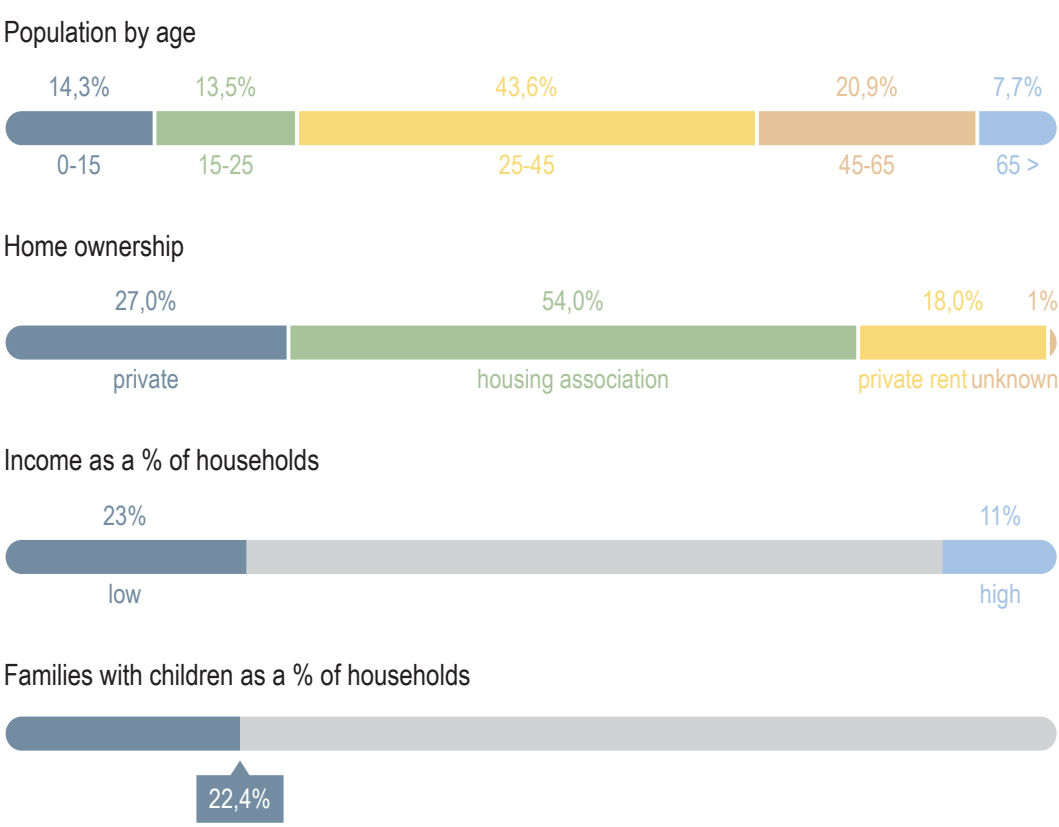



**Fig. 5.19**: Main demographic information of the Indische Buurt West, the neighbourhood around the Javastraat (Author, 2018)

### 5.3.4 Human activities

Understanding the level of privacy that each space requires is an important element in meeting multi-purpose design goals. The human activities around the building block are partly determined by the shops in the Javastraat. These shops keep the street lively, both during the day and in the evening. At the moment, there is a lot of traffic flowing through the street, splitting the street into two sides. Therefore, slowing down the traffic and creating a connection between the two sidewalks is desirable. Furthermore, there are not a lot of places to stay in the Javastraat. There are some shops which offer seating, but seats in public space are barely present. Furthermore, the amount of green in the street is very limited. Creating a pedestrian friendly street is an additional goal for the Javastraat, with a gradual transition from private to public space.

The Balistraat has a completely different level of privacy compared to the Javastraat, as it is a residential street. However, the street contains one important function which adds up to the human activities too, namely an elementery school and school care. Like described before, there is a school square located next to the school. This square is around 20 by 20 meters in size and it offers opportunities regarding storm water resilience and education. A watersquare could be added to the square, both to increase the storage capacity of the street, and to show the children how much water you can collect when it is raining. Water from the roof of the school can be lead towards the water square by a waterfall from the roof. Water from the adjacent street can be drained towards the square too via a covered gutter. The square will not be too deep, given safety considerations. A bioswale can be added to the school square as well, to increase the infiltration capacity and add more green to the square. A possible layout is shown below in Figure 5.20.

Other educational opportunities can be found in elements like a small garden with fruit plants and herbs and a worms hotel. Teaching children how to grow plants and herbs at a young age makes them more aware of the possibilities when living in a city. This applies to the worms hotel too. This is a small unit made of sustainable materials which contains a lot of worms (Figure 5.21). They can process vegetables, fruit and garden waste to compost in a very short period of time. A worms hotel can process green waste of 20 households and is suitable for a residential street like the Balistraat. Adding these kind of elements to a street enhances the social cohesion and makes a street more lively and active.

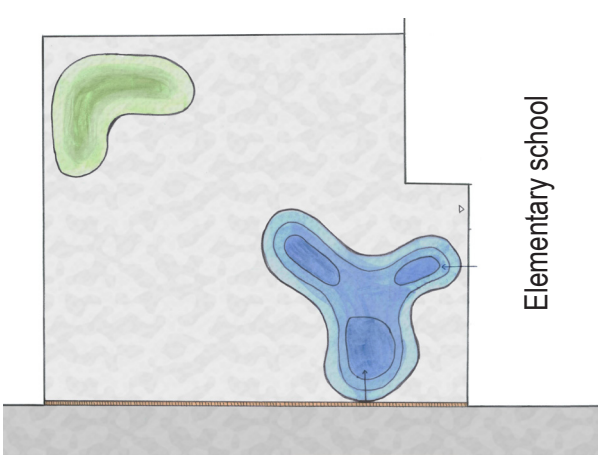



**Figure 5.20**: Possible layout of the school square (Author, 2018)

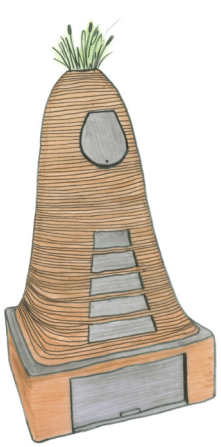


**Figure 5.21**: Worm hotel (Author, 2018).

### 5.3.5 Design proposal

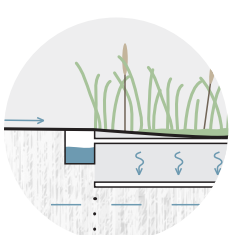
Map 5.4 shows the design proposal for the building block and its adjacent streets: the Javastraat and Balistraat. The interventions applied are based on the current water nuisance, socio-economic profile and the human activities around the building block. The level of privacy in the streets is also very important, as a different level of privacy requires different interventions.

First, the three parts of the design are described: the Javastraat, Balistraat and the building block itself. The applied interventions are underlined and supplemented with details below. These details are coming from the sections on pages 76-79 (Figure 5.25 and 5.26) that show the redesigned building block and its adjacent streets.

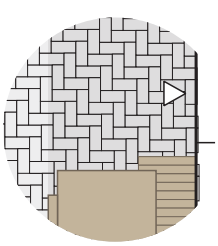
**Javastraat**

In the Javastraat the parking lane on the northern side of the street will be transformed into a green strip. A part of these parking lots will be relocated to the Celebesstraat along the train tracks. The other part will be removed completely, based on the assumption that car usage will decrease in the coming years. This assumption is based on the shift of main mode of transport within the city: from car to bicycle and public transport (Gemeente Amsterdam, 2010). Without these parking lots there is more space available for infiltration of rainwater. However, as the Javastraat is intensively used by cars, rainwater from the street can not infiltrate into the soil directly, because it is contaminated. Therefore helophyte filters will be applied. This is a sand filter that is planted with reeds. The actual treatment of the water is done by bacteria living in the roots. The reeds serve to aerate the roots and to capture nitrates and phosphorus. A drain is placed at the bottom of the sand filter to capture the treated wastewater and infiltrate it into the soil, which is called reversed drainage. In order to do this, the drain must be located above the ground water level, which is -0,6 meters in this location. If not all the rainwater can be infiltrated, the pipe will work as a regular drain. In this case the water will be drained towards infiltration or storage capacity in the surrounding neighbourhood like the Nieuwevaart.

Furthermore, a transition zone will be added to both sides of the street, which can be organised by residents and shop owners themselves. This also applies to the collective strip which will be added to the northern, sunny sidewalk. Residents can add furniture and organise a barbecue together, for example, in order to enhance the social coheseion. Collective functions like bicycle racks and waste containers will be collected in the southern parking lane of the street, in between the parked cars. In order to create a safer street road narrowings and pedestrian crossings will be added to the Javastraat. This will cause cars to slow down and be more careful. Uniform pavement will be applied to create organised public space.



helophyte filter



transition zone



collective strip

**Fig. 5.22**: Details of the design proposal for the Javastraat (Author, 2018)




Legend

- building
- green
- street
- bicycle street
- bicycle path
- transition zone
- sidewalk
- bioswale
- helophyte filter
- section
- waste containers
- bicycle racks
- tree

**Map 5.4**: Design proposal for the building block, Javastraat and Balistraat (Author, 2018)

**Balistraat**

The Balistraat, which is currently already one-way traffic, will be transformed into a bicycle street. In a bicycle street cars are allowed, but only as a guest. In the Balistraat this could help to create a safe environment for the children which are living and going to school here. It also promotes cycling and discourages car usage. Parking is still possible, but only at one side of the street instead of two. As the Balistraat is not very intensively used by motorised traffic, the rainwater falling on the street can flow immediately to the new bioswales. The rainwater can infiltrate into the soil directly as it is not seriously contaminated by rubber and other street dirt. A drainpipe is placed below the bioswale to prevent the bioswale from overflowing during heavy rainfall. This drainpipe connects the bioswales with the nearest surface water: the Lozingskanaal. The water is lead to the bioswales above the ground by the V-shaped street profile and curbs on the right locations. The bioswales replace a part of the diagonal parking lots, which are relocated along the train tracks in the Celebesstraat. The parking lots that will remain, the ones on the south side of the street, will be paved with grass tiles to increase the infiltration capacity. As the parking lots in the Balistraat are mostly empty during the day, the grass still has the ability to grow properly.

Apart from bioswales, plants and flowers will be added to the green strip too. Residents can also use their front garden or this green strip to grown herbs and fruit plants. Like explained before, adding fruit plants or a worms hotel close to the school shows children possibilities. The bioswales will be alternated with these plants to create a changing streetscape, also during the different seasons. Overall, the street will look more green and less car oriented, especially in combination with the interventions on the scale of the building block.

Underground waste containers are collected in the strip of parking lots on the south side of the street. Bicycle racks are collected on the north side of the street, along the new strip of green. Close to the school and its square more bicycle racks will be placed, as the current situation looks very messy and disorganised.

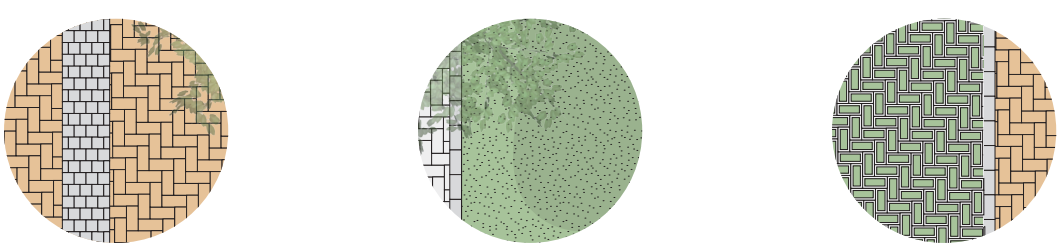



**Fig. 5.23**: Details of the design proposal for the Balistraat (Author, 2018)

**Building block**

On the scale of the building block, interventions could be implemented both inside and outside. Flat roofs can be transformed into blue-green roofs, which can store a lot of water and which have a cooling function too. On a blue-green roof rainwater is collected in a tank below the plants. Via small pipes filled with wool, the plans can suck up as much water as they need. In comparison to a traditional green roof, a blue-green roof evaporates the rainwater much more evenly. The remaining runoff of the roof can be collected in a rain barrel in the backyard or an underground watertank. This water can be used to water the garden, flush the toilet and run the washing machine. In this way, the rain pipes can be disconnected from the sewer system.

Adding a small front garden and facade vegetation helps to enlarge the infiltration capacity of the street. Besides that, it creates an extra opportunity to drain the remaining runoff from the roof too. Additional benefits are the cooling effect of facade vegetation on the indoor climate and the positive effect on the biodiversity in the street. Removing tiles from the backyard and adding grass and plants instead increases the infiltration capacity of the area too. The small, private backyards could all be combined into one garden, in order to create a communal garden and enhance social cohesion. There are some successful examples of building blocks that did the same, like Emma's Hof in The Hague. Residents of this closed building block bought the vacant building in the inner courtyard together, demolished it and designed an urban garden. Various activities are organised in the garden, such as workshops, exhibitions and drinks for locals. The garden is maintained by volunteers, who are also local residents.

There are enough interventions available on the building scale to let residents and/or building owners decide which interventions they would like to apply to their building. Creating a system of points could help to encourage residents to help solving the water nuisance, when they are required to obtain a minimum amount of points. This could also be applied by housing associations too. In this way, residents still have a certain amount of freedom in choosing interventions.

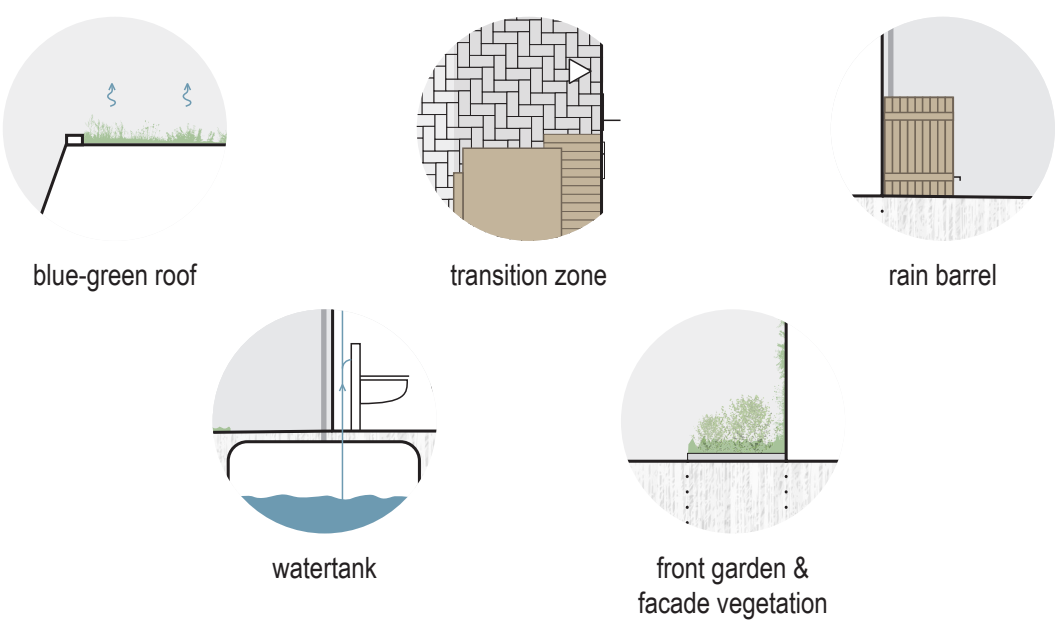



**Fig. 5.24**: Details of the design proposal for the building block (Author, 2018)

**Fig. 5.25**: Section Balistraat. See overleaf for right side of the section (Author, 2018)



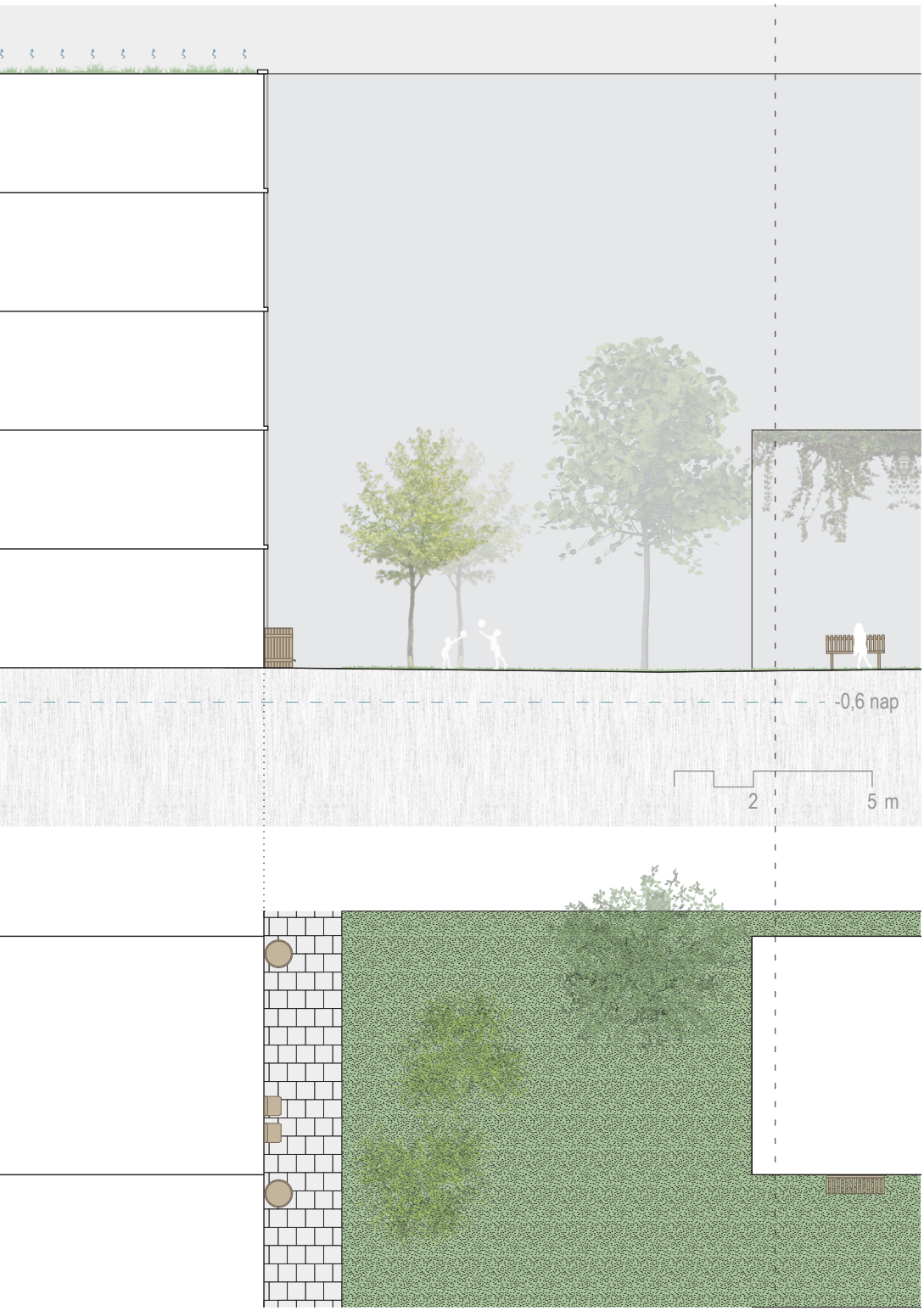
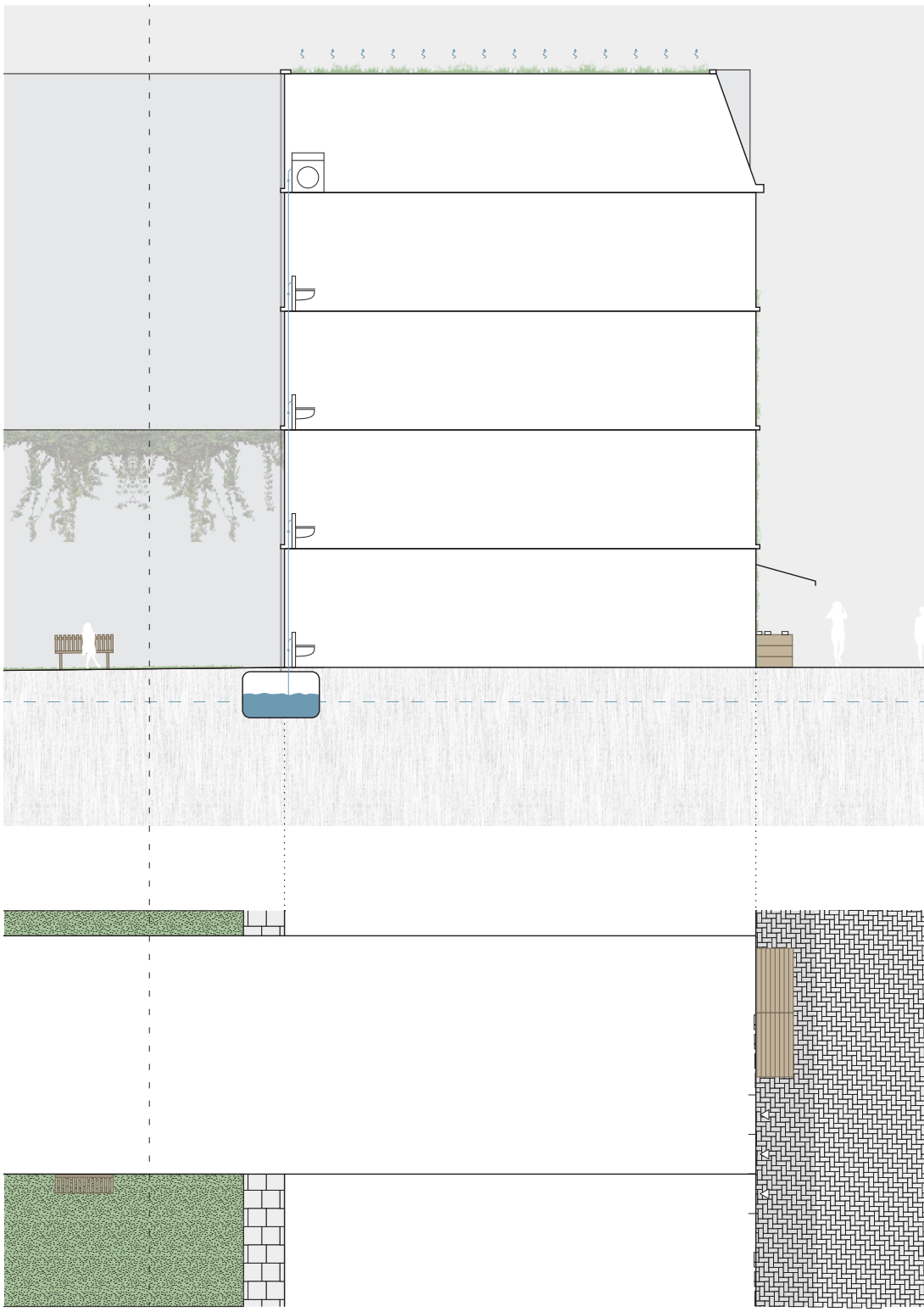
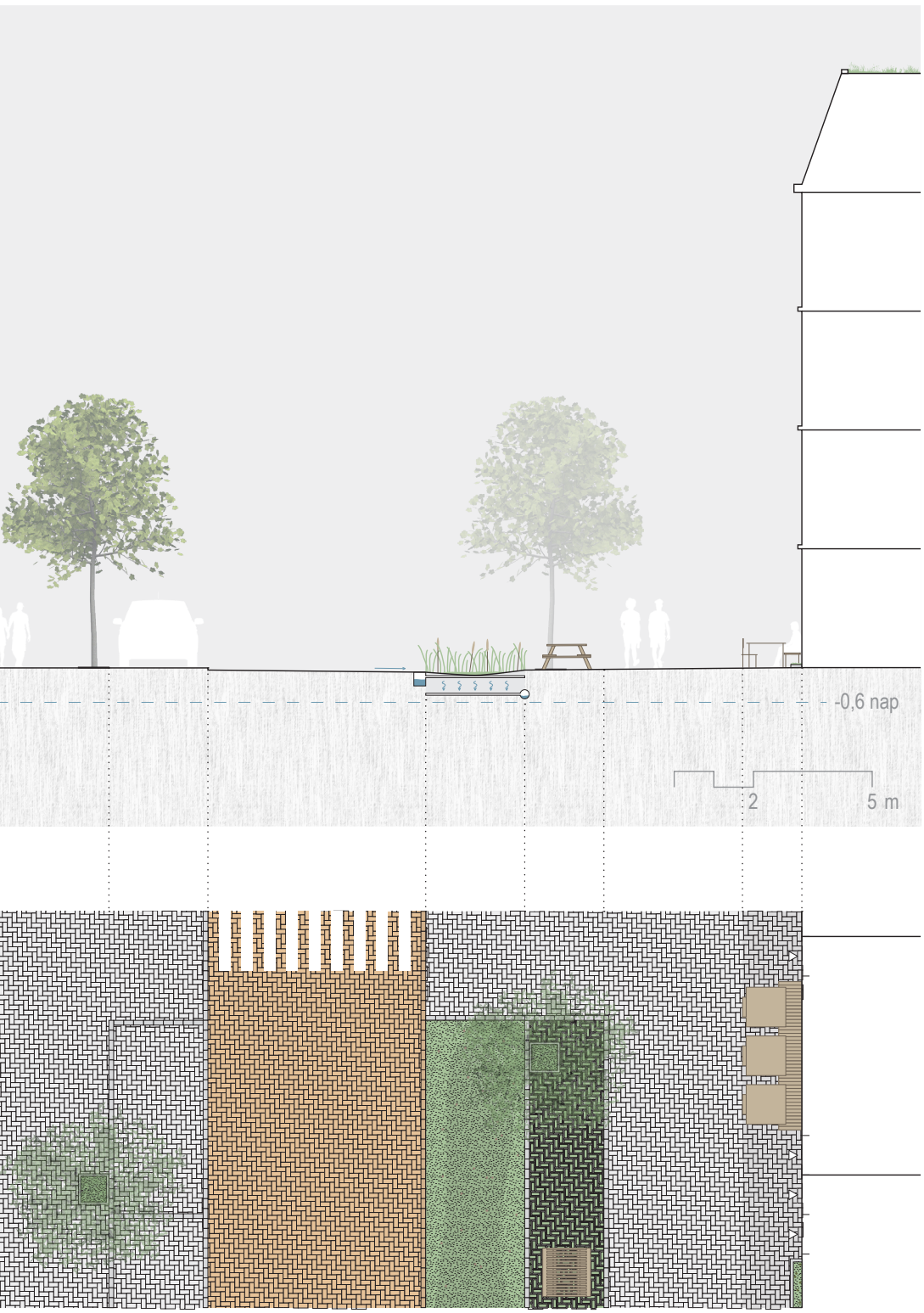

-0,6 nap
2
5 m

**Fig. 5.26**: Section Javastraat. See overleaf for left side of the section (Author, 2018)

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5 m

### 5.3.6 Qualitative evaluation of the design

The interventions applied will contribute to the creation of a storm water resilient street and building block, while creating additional benefits for other sustainable or socio-economic aspects too. This is depicted in Figure 5.27 for the interventions on the scale of the building block. The lines between the design components on the one side, and the additional benefits on the other indicate a positive relation. The thicker the line, the greater the impact on that aspect. The design components are ordered from most water related to least water related, and include components of the three other design sites too. This applies to the additional benefits as well. The relations between the design components and the additonal benefits are based on the book *Green-blue grids*, by Hiltrud Pötz and Pierre Bleuzé (2016), in which the same kind of method has been used.

This qualitative evaluation scheme shows that residents can have a high impact on the storm water resilience and liveability of their street. The interventions that residents can implement themselves have a lot of additional benefits, both environmental and socio-economic. The water related interventions mainly have environmental benefits, like improved indoor and outdoor climate, noise reduction, air treatment and biodiversity. The other interventions take place in the outdoor space owned by residents and have a positive impact on socio-economic benefits as well. These benefits include health and mood, recreational facilities and a gradual transition from private to public space.

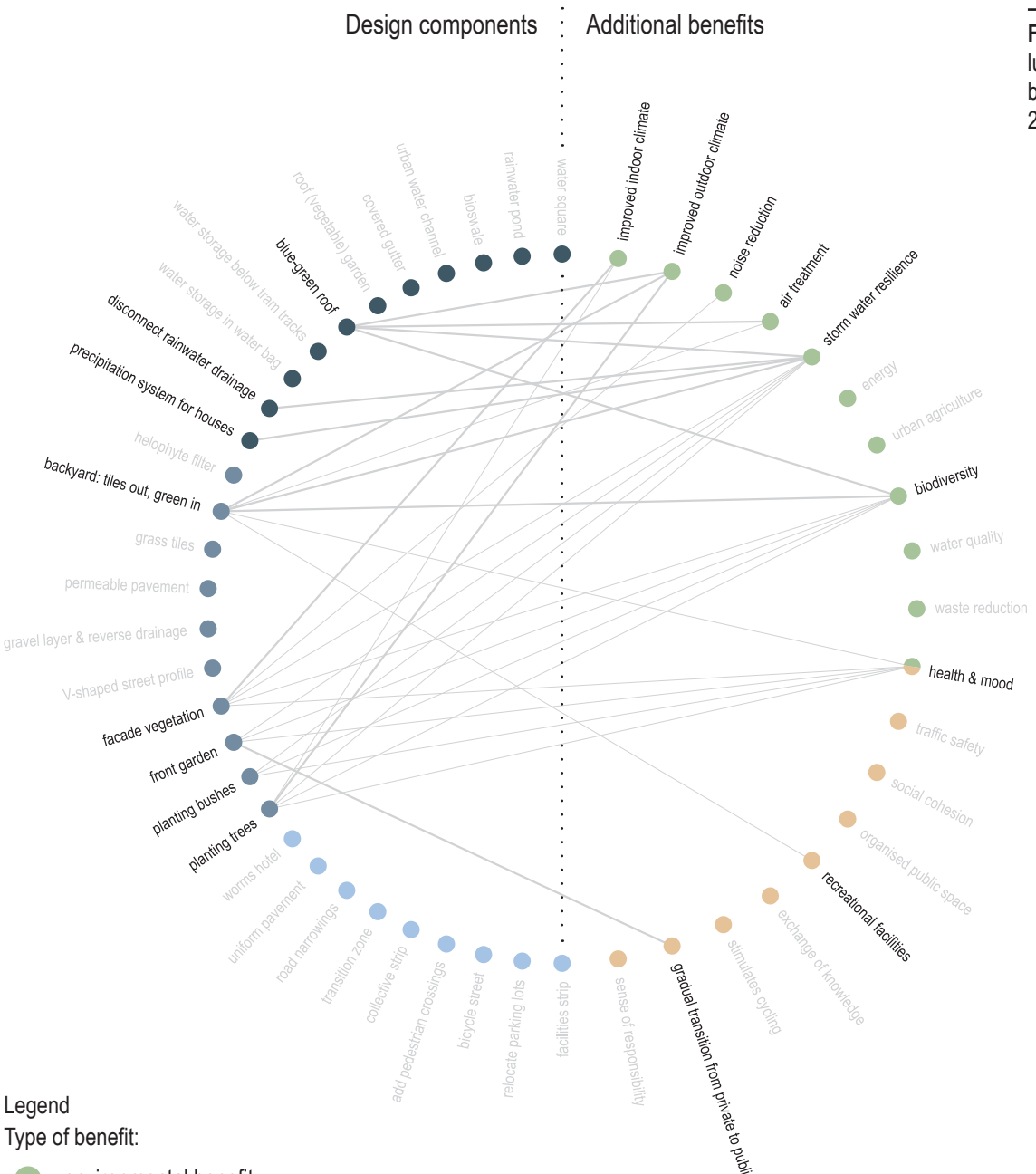



**Fig. 5.27**: Qualitative evaluation scheme of the building block (Author, 2018)

### 5.3.7 Quantitative evaluation of the design

A quantitative evaluation has been done too, but about the water related interventions only. This evaluation shows to what extent the current design of public space can prevent future water nuisance in the Balistraat. Interventions on the building scale are not included in this scheme, as it is difficult to influence residents. However, the (high) impact of blue-green roofs is indicated to show the importance of this intervention. This evaluation includes the Balistraat to show that a residential street can be storm water resilient on itself, even though space seems to be limited at the moment. Future water nuisance is predicted by the KNMI climate scenarios, of which the extreme scenario forms the basis for these calculations. This means the designs have been tested to an extreme rain shower of 60 millimeter in two hours, which equals 60 liters of water per square meter (section 4.1 elaborates on the origin of this number).

The flowchart on the right shows what happens when heavy rainfall takes place in the Balistraat. The blue icons refer to the isometric figure of the Rivierenbuut on page 111, which shows the links between the several scales and interventions. The flowchart shows that when nothing happens to the buildings in the street, an overcapacity can still be created. This also means that when all or even half of the roofs in the street are blue-green roofs, the street can be a very large buffer for the surrounding neighbourhood. The grass tiles at the parking lots, the water square on the school square and the bioswales replacing the other parking lots offer a very large infiltration and storage capacity. This also means that replacing a part of the parking lots by bioswales can be posponed or scheduled in a later stage of the transformation. In this way, residents can still park their car in the street in case the trend of declining car usage stagnates. The water square and the bioswales are connected to the nearest surface water in order to discharge rainwater to when the water level has dropped again.

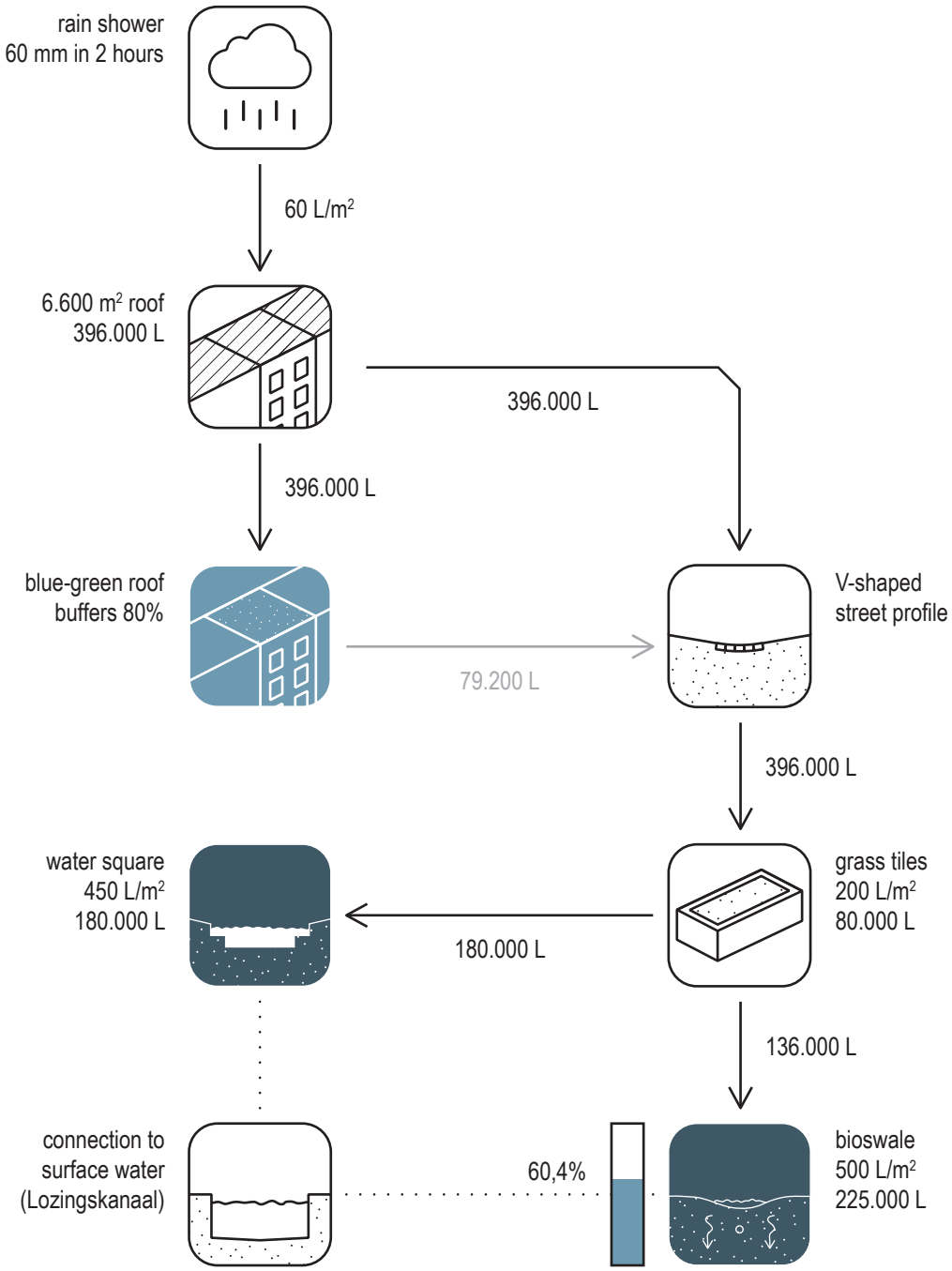



**Fig. 5.28**: Quantitative evaluation of the Balistraat (Author, 2018)

# 5.4 Rokin

## 5.4.1 Context

Rokin is a street between the Dam Square and Muntplein in the city centre of Amsterdam. The street is part of the former course of the Amstel river and owes his name to the quay which was located along the river. In July 2018 subway station 'Rokin' will open as part of the North/South line, providing a subway connection between the north and south of the city. Furthermore, Rokin underwent major changes in the past two years to transform from a thoroughfare to a chic boulevard.

During the site visits several observations are done. The observations related to storm water resilience are photographed, collected and shown below.




**Fig. 5.29**: Map of Rokin indicating the observations (Author, 2018)



**Fig. 5.30**: Bathtub function (Author, 2018)



**Fig. 5.31**: Terraces (Author, 2018)

### 1. Rainwater collection

Rokin seems to collect a lot of rainwater, as the street descends from the Dam square towards the middle. This affects the surface drainage of rainwater. As the street is very intensively used by pedestrians, this may cause an annoying and even dangerous situation during heavy rainfall.

### 2. Terraces

A part of the very broad sidewalk is used for terraces of the several restaurants and cafes along the Rokin. They take around four to five meters in width and the owners of the terraces are bound to strict rules, defined by the municipality. For example, fences or partitions between the terraces are not allowed.





**Fig. 5.32**: Shopfronts (Author, 2018)

**Fig. 5.33**: Traffic strip (Author, 2018)

### 3. Functions

Most buildings along the Rokin contain shopfronts at the ground floor. These shops differ from a department store and clothing stores, to souvenir shops and restaurants. Some of the facades have glass shop fronts until the ground, which could lead to water nuisance during heavy rainfall. The floors above the stores mainly have a residential function.

### 4. Traffic strip

The west side of the Rokin contains a very wide strip of relatively fast traffic. This is where the trams, cars and bicyles pass by. This strip could be experienced as a barrier between the two sides of Rokin, especially since there are not that many pedestrian crossings available. All these different strips make the street look very chaotic.





**Fig. 5.34**: Underground functions (Author, 2018)

**Fig. 5.35**: Bicycle parking (Author, 2018)

### 5. Underground functions

Below the Rokin, a new subway line, a bicycle parking and a car parking will soon be opened. Therefore, there are many connections between the Rokin at the surface and the facilities below: two entrances to the subway station, two entrances to the bicycle parking and two entrances to the car parking.

### 6. Chaotic sidewalk

At the moment, there are a lot of bicyles and other obstacles parked on the sidewalk of the Rokin. Everything is scattered around and this takes a lot of space. However, when the new underground bicycle parking is opened, the amount of bicycles on the sidewalk will most probably decrease, as most bikes will be owned by residents of the street.

### 5.4.2 Water nuisance

The observations done can be substantiated by factual information about water nuisance at Rokin. As Rokin is located at the former course of the Amstel river, the area will always be disadvantaged when it comes to water nuisance. Rokin descends from the Dam Square, causing the rainwater to flow to the lowest area of the street, as indicated on Map 5.5. This map shows the risk of damage to buildings and infrastructure due to extreme precipitation, based on the Rainproof factsheet of Centrum West, obtained via Amsterdam Rainproof (2016a). As there are many old buildings located along the Rokin, the possibility of damage to buildings is relatively high compared to the possibility of damage to infrastructure. This could mean the street profile is currently shaped wrongly, as the rainwater is flowing towards the buildings instead of away from them. Furthermore, there is barely any infiltration capacity available, as the street is completely paved and there are only a few tree boxes. So even though there is surface water available to drain the rainwater surplus to, due to the height differences and the limited infiltration capacity of the street, all rainwater is drained towards the (combined) sewer system. During heavy rainfall, the sewer system can not process the amount of rain and the street floods. The sewer system will overflow towards the surface water, which will seriously deteriorate the water quality.

At Rokin, the spatial conditions are limiting the possibilities. Especially the underground parking garages and the subway station and tunnels pose a challenge to the improvement of the storm water resilience of Rokin. These underground functions make it very hard for rainwater to infiltrate into the soil. Therefore, the solutions must be found in storage and drainage interventions. Furthermore, the space available for interventions is very limited at Rokin. The pressure on public space in this part of the city is really high. Every bit of space has to be used and preferably for multiple functions.

Opportunities are offered by the tram tracks, as they could be used to store and drain rainwater below. By using smart technologies, the storage can be emptied prior to a rain shower. The natural slope of the street, descending from the Dam Square towards the Amstel river, could be used to drain the rainwater towards the surface water. The water storage exists of strong crates, which offer a storage of around 450 liters per square meter. The crates are connected to gutters, which collect the rainwater (Figure 5.36). These gutters could be connected to water bags too. Rainwater will be collected in these water bags first, before it flows to the storage below the tram tracks. The water bags are located below planters and trees, and contain small pipes filled with rockwool which protrude above the water. The sucking effect of the rockwool ensures the plants and trees always have water. During dry periods, the water bag can be filled manually.

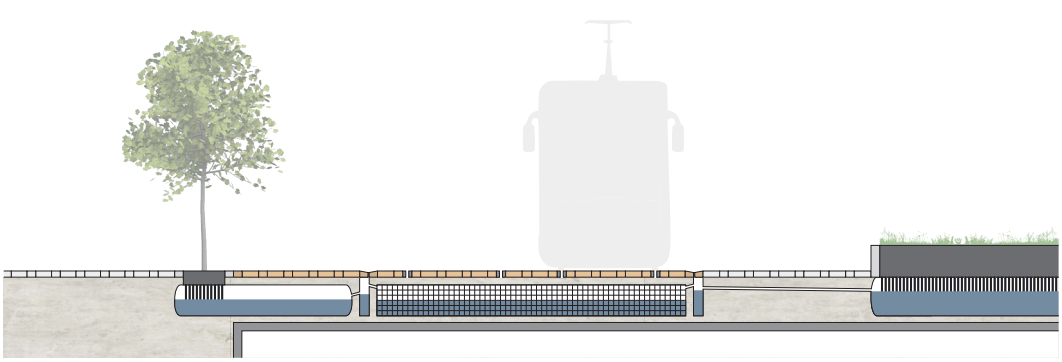
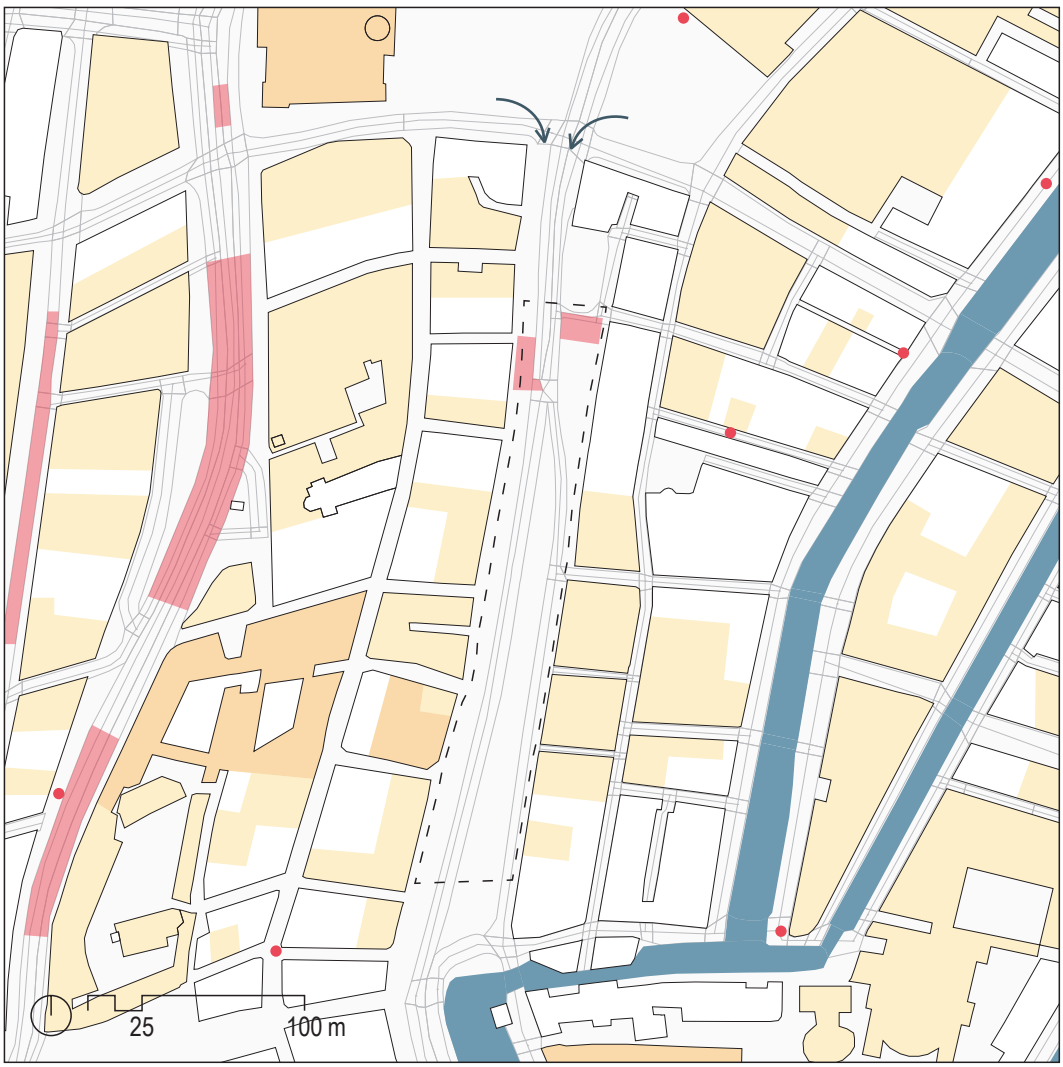


**Fig. 5.36**: Technical detail of water storage below tram tracks and in water bags below planters and trees (Author, 2018)




Legend

- surface water
- building
- border water nuisance
- street
- above ground flow direction
- water nuisance reported to Waternet on July 28th, 2014

Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation:

- increased risk
- strongly increased risk
- extremely increased risk

**Map 5.5**: Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation (Author, 2018)

### 5.4.3 Socio-economic profile

Rokin is part of the 'Rode Loper', a project by wich the municipality wants to upgrade their historic entrance to the city. A common theme within this project is the pressure on public space: the Rode Loper includes the busiest streets of Amsterdam. In order to get an idea about the users and inhabitants of Rokin, the main demographic information has been studied (Figure 5.37). This information may be useful when improving the spatial design. It is remarkable that the group of children is very small, which means traffic safety and playgrounds are less of a concern. The age category of 25 to 45 years old is by far the largest group. In general, this age group would be progressive and open to ideas. However, around two-third of the residents rent their house from a private landlord. This means ownership is a challenge to overcome when proposing interventions for private outdoor space. Income per household is an important indicator for this too, regarding the private home owners. For Rokin the amount of low or high incomes as a percentage of households is not very striking, so this does not necessarily have positive or negative effects.

Another remarkable number has to do with the average living space of the houses in the area. With 77 $m^2$ the average living space per household is relatively low, compared to houses within a ten kilometer radius of this neighbourhood. This could raise the pressure on public space, as people look for extension of their living room outside, especially when the weather is good. Therefore, it is very likely that a significant part of the users of this public space is resident of Rokin or the neighbourhood around it, which is called Burgwallen Nieuwe Zijde.

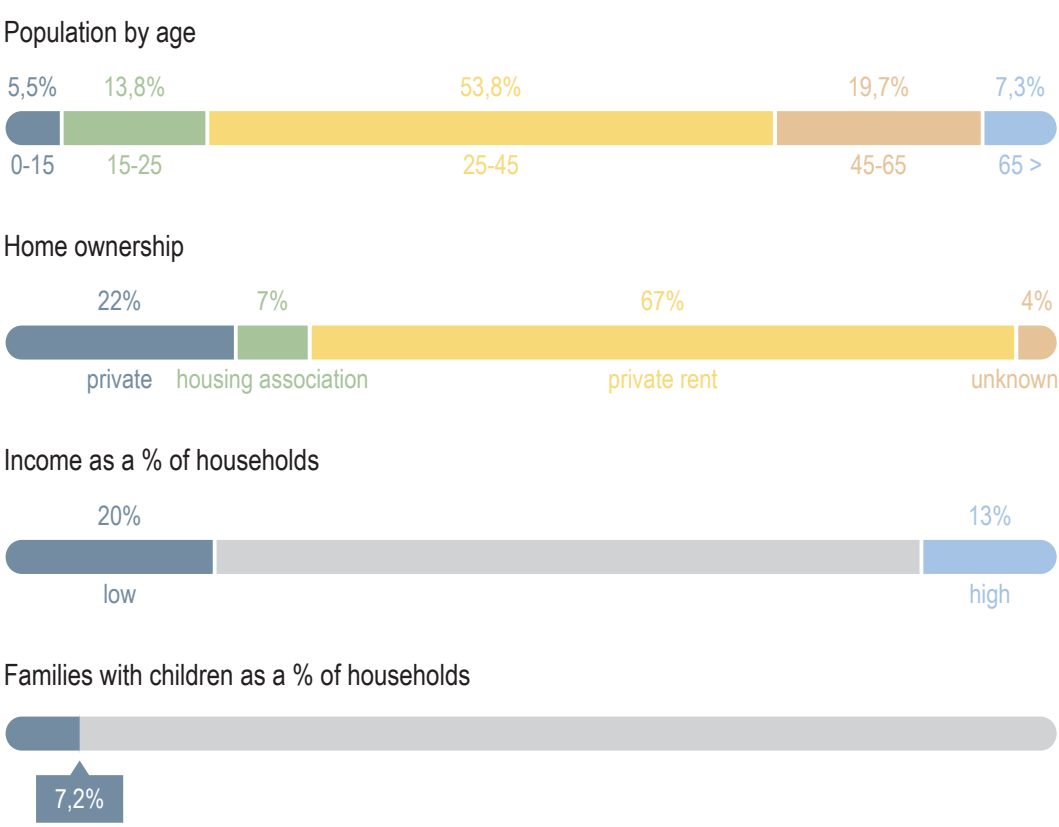



**Fig. 5.37**: Main demographic information of Burgwallen Nieuwe Zijde, the neighbourhood around Rokin (Author, 2018)

### 5.4.4 Human activities

At the moment Rokin contains many different non-residential functions at the ground floor, for example several types of retail, like clothing stores, souvenir shops and tour operators, but also restaurants and cafes and even an enormous department store. These different types of non-residential functions prefer different types of interaction between indoor and outdoor space. Clothing stores attach less value to a connection with the street than a restaurant with outdoor terrace does.

These interactions are not only dependent on the type of function, but also on the (seasonal) weather conditions. Terraces will not be such intensively used in winter as in summer, limiting the connection between indoor and outdoor space. This makes the terrace area suitable for other functions in winter. Especially in crowded public space like Rokin multi-purpose space design is very important to be able to offer both space and functions to people. When this space is experiencing water nuisance too, like Rokin does, it is even more important to make use of the available space efficiently.

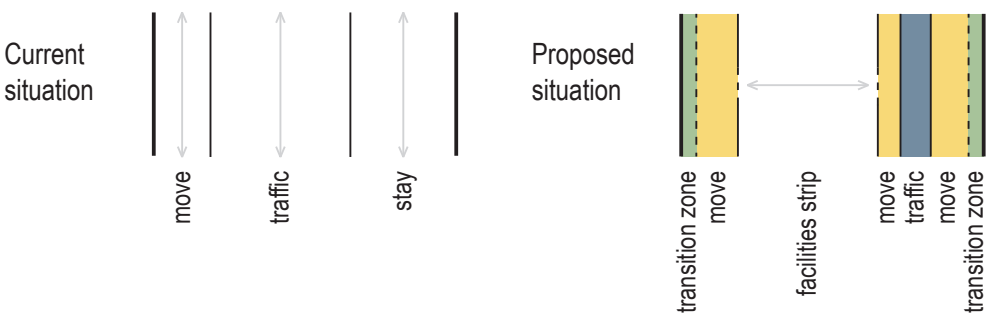



**Fig. 5.38**: Current and proposed future layout of Rokin (Author, 2018)

The combination of the aim for multi-purpose space design and the observed barrier and chaos in the street asks for more nuance in the street profile. In order to connect the two sides of the street and overcome the traffic barrier, more pedestrian crossings will be added. By using a uniform pavement with less height differences between the different strips of traffic, the public space will look more organised. The space will not be completely shared, but the lines between the different strips of traffic will be softer. Furthermore, the 'stay side' of Rokin will be divided into different strips of functions to structure the chaos on the sidewalk (Figure 5.38). The 'stay strip' will contain several functions, like terraces, planter boxes, benches and a few bicycle parking spots. In this way, the 'move strips' will stay clear. This facilities strip will have different functions in winter and summer, to serve the aim for a multi-purpose space design. Possible functions are indicated in Figure 5.39. In summer, restaurants and cafes can have their terraces in the facilities strip. However, in winter, the terraces will be limited to the transition zone of the street. The space in the facilities strip can then be used for other purposes. A very interesting solution could be to use this space for a temporary art exhibition. The exhibition could, for example, show art of local artists, or it could have a specific or even a seasonal theme. Such a changing function of the street is an attractive characteristic that could easily be added. Another option would be to use the space in the facilities strip for a seasonal market with, for example, local and biological products. A market can provide a great, human experience for the city at eye level. It has been the ultimate way for people to meet and conduct business (Groenendaal, 2016). A combination of these two proposed functions would be possible too.

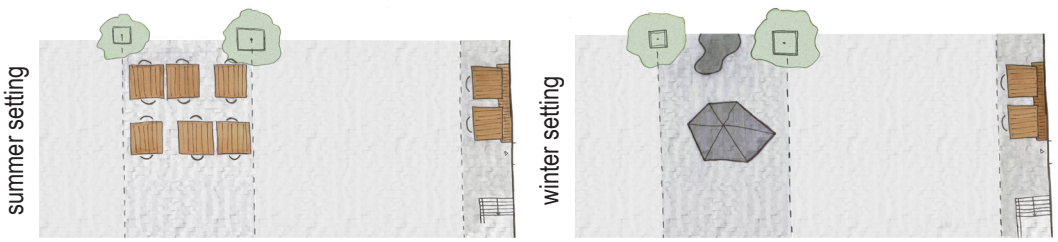



**Fig. 5.39**: Possible options for setting up the facilities strip in both summer and winter (Author, 2018)

Furthermore, a transition zone will be added to the street profile, on both sides of the street. In some places in the street such a transition zone is already present. It creates a gradual transition area between inside and outside space, and often between private and public space. Such a transition zone can be set up in the way the user of the building prefers. Moreover, it creates more contact between neighbours and it makes people feel responsible for their zone and the space around it (Van der Ham & Van Ulden, 2016). In this way, social cohesion in the street could be enhanced. Figure 5.40 indicates different possibilities for the set up of the transition zone for different types of non-residential functions. A cafe would probably prefer to have a small terrace outside, where a clothing store would rather have a front garden. Adding such a transition zone also contributes to the overview in the street, as obstacles like planter boxes and waste bins could be placed in here too.




**Fig. 5.40**: Possible options for setting up the transition zone for different functions at the western side of the street (Author, 2018)

**Fig. 5.41**: Idea for planters in facilities strip (Author, 2018)

Apart from these flexible or seasonal functions in the facilities strip and the transition zone, the street would benefit from fixed functions too. Fixed functions can be used to turn 'space' into 'place', by creating inviting places to stay. To contribute to a vibrant streetscape it is important to have these places to stay and enjoy public space (Knuijt, 2016). In the case of Rokin, the space could use more places to sit which are not related to a certain restaurant of cafe. Furthermore, the experience of the street is very urban and paved. By adding several types of green, this experience could be improved.

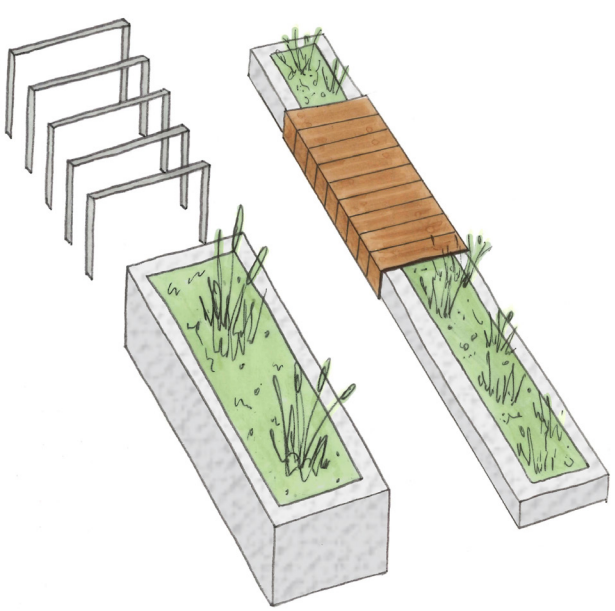





**Fig. 5.42**: Fixed functions added to summer and winter situation (Author, 2018)

Adding green can be combined with the aim to create places to stay in the form of planters. Elongated planters can give direction, offer seating possibilities and create a pleasant atmosphere. Moreover, green has a positive impact on the biodiversity in the city. Planters like in Figure 5.41 will be placed in the facilities strip on the eastern sidewalk, at places where the adjacent functions do not require a terrace on the street, like an office or a hotel. For these functions it is even beneficial to have a place to stay in front of their entrance. The planters can be alternated with the terraces in summer and temporary art exhibition or market in winter (Figure 5.42). Furthermore, elements like bicycle stands could be added to the rhythm of planters. In order to enhance feelings of responsibility, residents of the street can adopt one or more planters or tree box to grow herbs and flowers. As long as they take care of their plants, they can make use of this small part of public space.

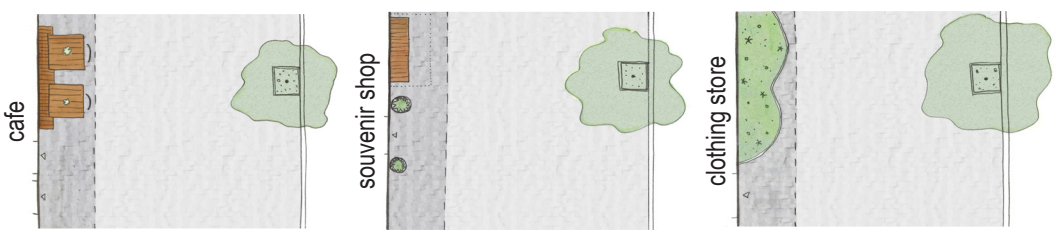



**Fig. 5.43**: Green added to possible options for transition zones (Author, 2018)

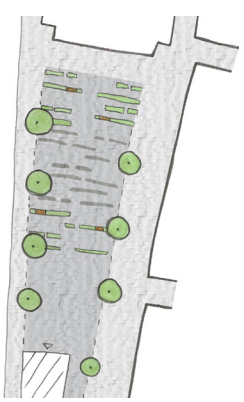


**Fig. 5.44**: Possible layout of the square at Rokin (Author, 2018)

Green will be added to the western sidewalk of Rokin too, but then by planting trees (Figure 5.43). This side of the street does not contain any green yet. Because of the parking garage and subway station below, the trees can not be too big, but at least they contribute to a cooler indoor and outdoor climate, biodiversity and the health and mood of people. London planetrees are suitable as they have low requirements regarding their location. The tree box around the tree can be part of the adoption plan. Apart from the vertical strips of functions, Rokin contains a square too. This square is located at the north side of the street, close to one of the entrances of the subway station. The surface area is around 1.000 square meters, so it could have a special function. The square can have a fountain which is supplied by rainwater. The rainwater can be stored below the square in a water bag and when it has been raining the fountain can be turned on. By making visible what can be done with rainwater, residents and visitors will be more aware of the impact of heavy rainfall. In dry periods the square can be used for other activities, like a small local market. It might even be a good idea to let residents of Rokin organise events at this location. The fountain can be supplemented by fixed seating elements, in order to create a place to stay.

### 5.4.5 Design proposal

Map 5.6 shows the design proposal for Rokin with all its design components included. To summarise, the design includes the following interventions:

- Water storage in crates
- Water storage in water bags
- Aboveground (covered) gutter
- Planting trees
- Planting bushes / planters
- Small front garden
- Self-organise transition zone
- Facilities collected in facilities strip
- Adding pedestrian crossings
- Applying uniform pavement

Most of the interventions which are applied above the surface, like adding planters, more pedestrian crossings and a facilities strip, are designed in a specific place by analysing the current non-residential functions and the movement patterns of people. These two aspects, the non-residential functions and the movement patterns, are very important at this location, as Rokin is experiencing water nuisance partly due to its function as a shopping street. Therefore, the approach is mainly focussed at human activities.

Figure 5.45 below is a collage of the eastern part of the street, indicating newly placed elements above the surface, like planters, demarcation of the facilities strip and the transition zone and extra seating elements. Figure 5.46 on the next page shows a section of the redesigned Rokin. This section indicates new functions too, but also technical details about the connections between the several water related interventions.

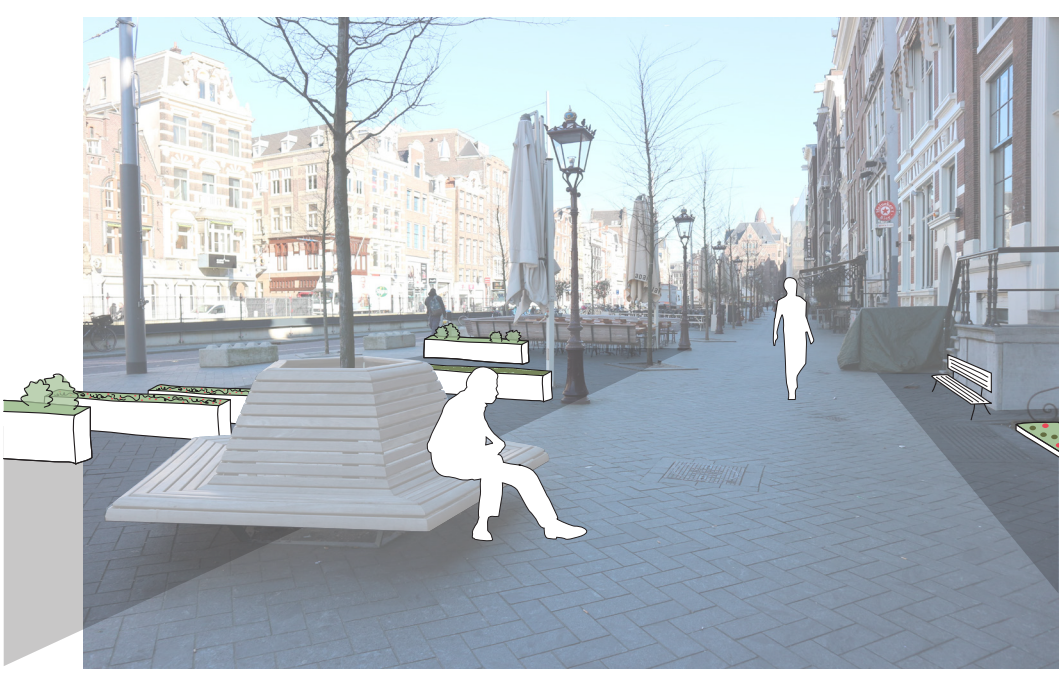
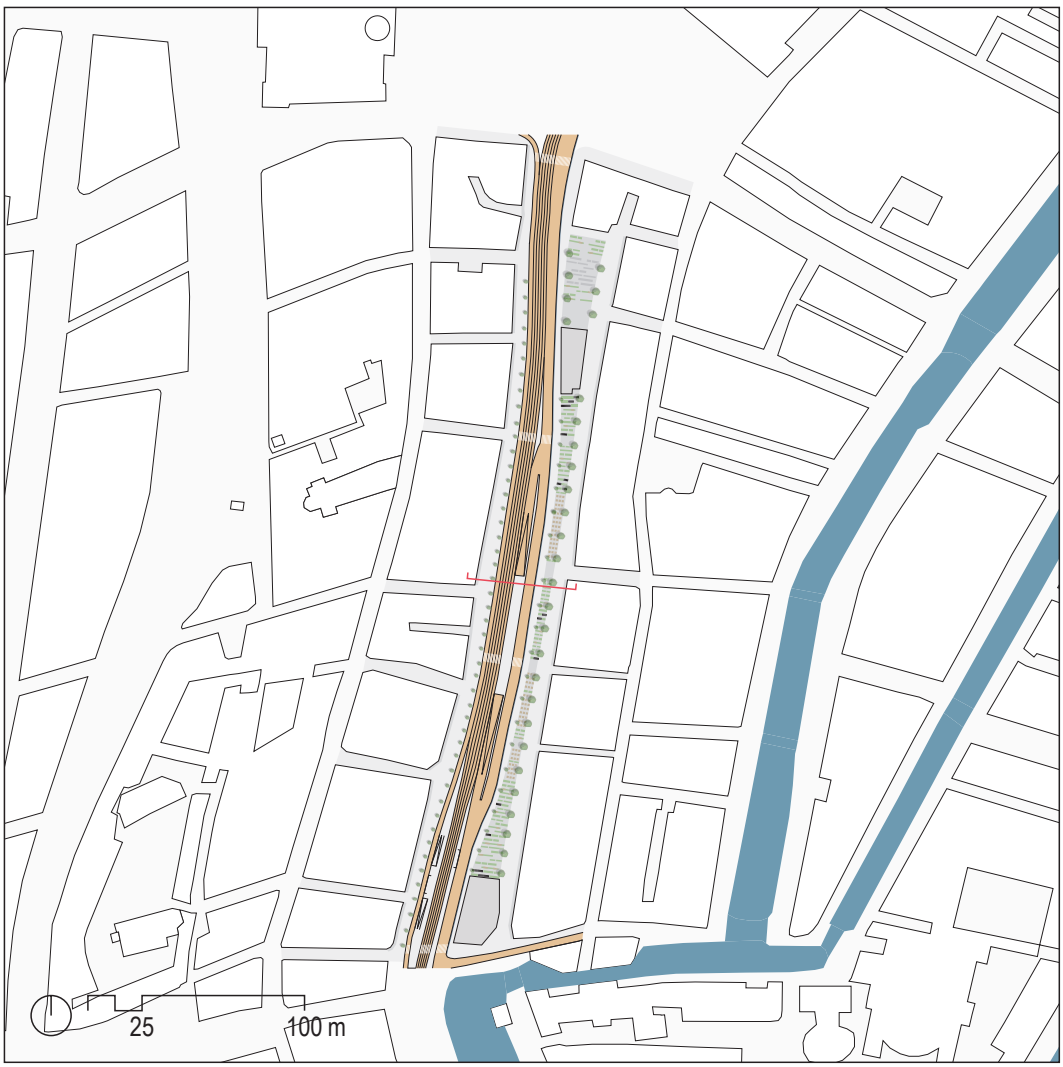


**Fig. 5.45**: Collage of eastern part of the street (Author, 2018)

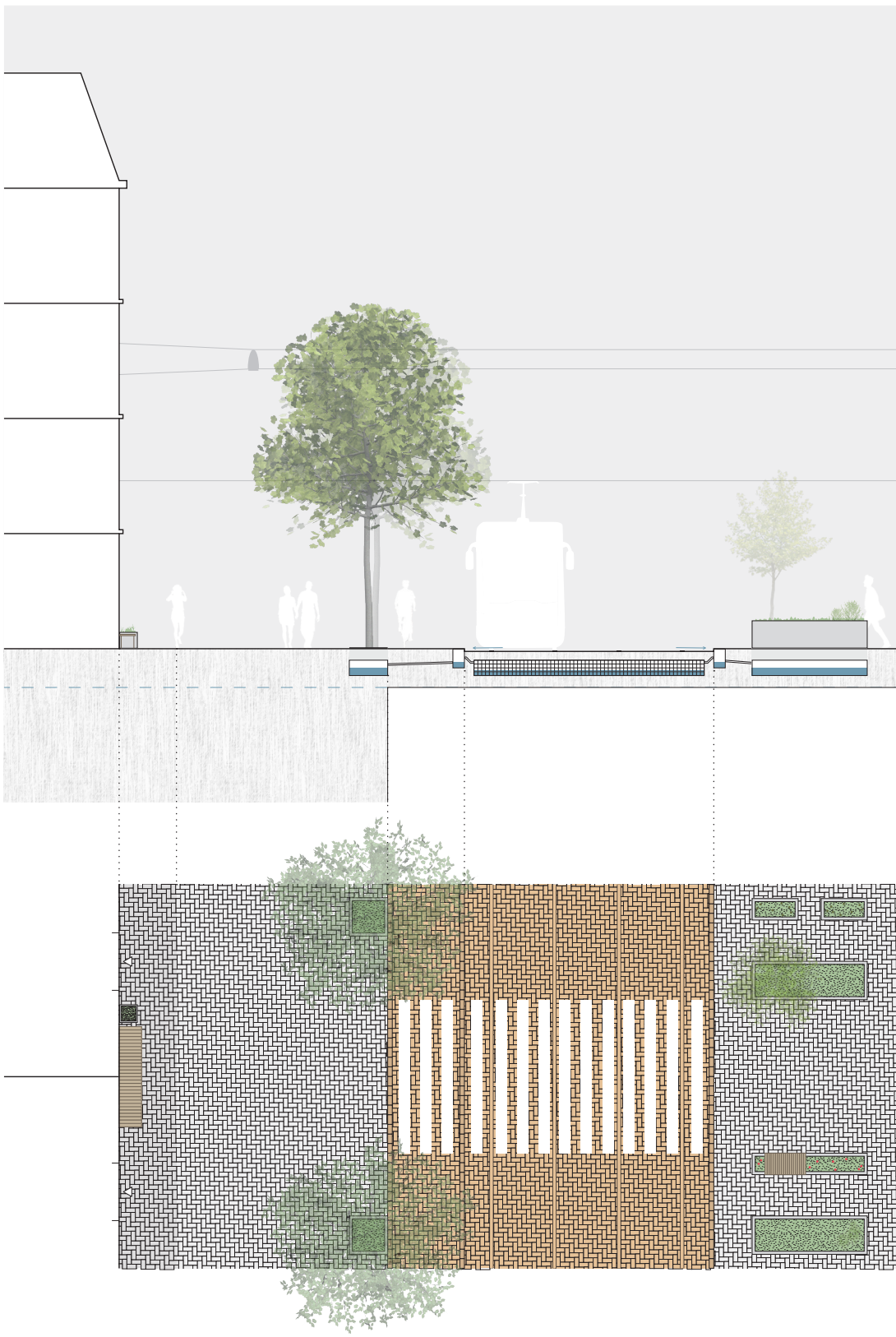



Legend

- surface water
- building
- sidewalk
- hybrid zone & facilities strip
- traffic lane
- entrance subway station
- section
- planters with bench & bicycle stands
- foutain elements
- tree

**Map 5.6**: Design proposal for Rokin (Author, 2018)

**Fig. 5.46**: Section Rokin (Author, 2018)




-0,7 nap
2
5 m

### 5.4.6 Qualitative evaluation of the design

The interventions applied contribute to the creation of a storm water resilient street, while creating additional benefits for other sustainable or socio-economic aspects too. This is depicted in Figure 5.47, by the lines between the design components on the one side, and the additional benefits on the other. The thicker the line, the greater the impact on that aspect. The design components are ordered from most water related to least water related, and include components of the three other design locations too. This applies to the additional benefits too. This applies to the additional benefits as well. The relations between the design components and the additonal benefits are based on the book *Green-blue grids*, by Hiltrud Pötz and Pierre Bleuzé (2016), in which the same kind of method has been used.

This qualitative evaluation scheme shows that the water related design components do not have any additional benefits, next to improving the storm water resilience, where the not water related design components address more aspects at the same time. This can be explained by the fact that the pressure on public space of Rokin is really high. Therefore the water related interventions are all located under the surface and they can not address any other sustainable or socio-economic aspects simultaneously. The less water related design components are all located above the surface, and are therefore able to address both sustainable and socio-economic aspects.

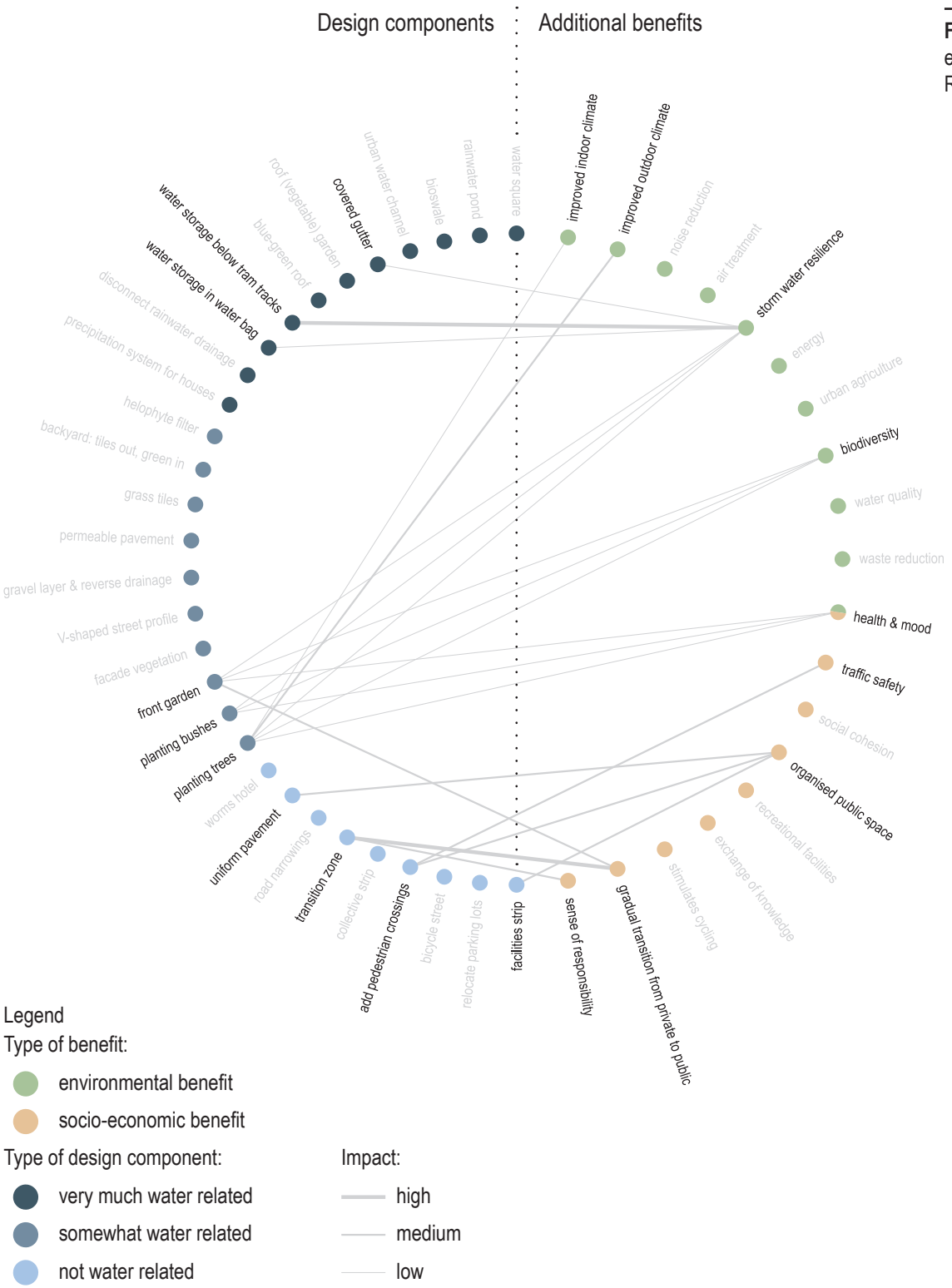



**Fig. 5.47**: Qualitative evaluation scheme of Rokin (Author, 2018)

### 5.4.7 Quantitative evaluation of the design

A quantitative evaluation has been done too, but about the water related interventions only. This evaluation shows to what extent the current design can prevent future water nuisance. Future water nuisance is predicted by the KNMI climate scenarios, of which the extreme scenario forms the basis for these calculations. This means the designs have been tested to an extreme rain shower of 60 millimeter in two hours, which equals 60 liters of water per square meter (section 4.1 elaborates on the origin of this number).

Figure 5.48 shows how the total storage capacity, provided by the interventions applied to Rokin, is calculated. The roof area is not taken into account in these calculations, as interventions on the building scale are not included in this design location. This means the total amount of water to store is based on the surface area in between the buildings along Rokin. It turned out there is an overcapacity of storage when applying both water storage in crates and water storage in water bags. This overcapacity could be used to store rainwater from the surrounding streets and buildings too, especially since the storage capacity is twice as big as needed. As these interventions do not have any additional benefits, storing water from the surrounding area is needed to make the design proposal economically feasible.

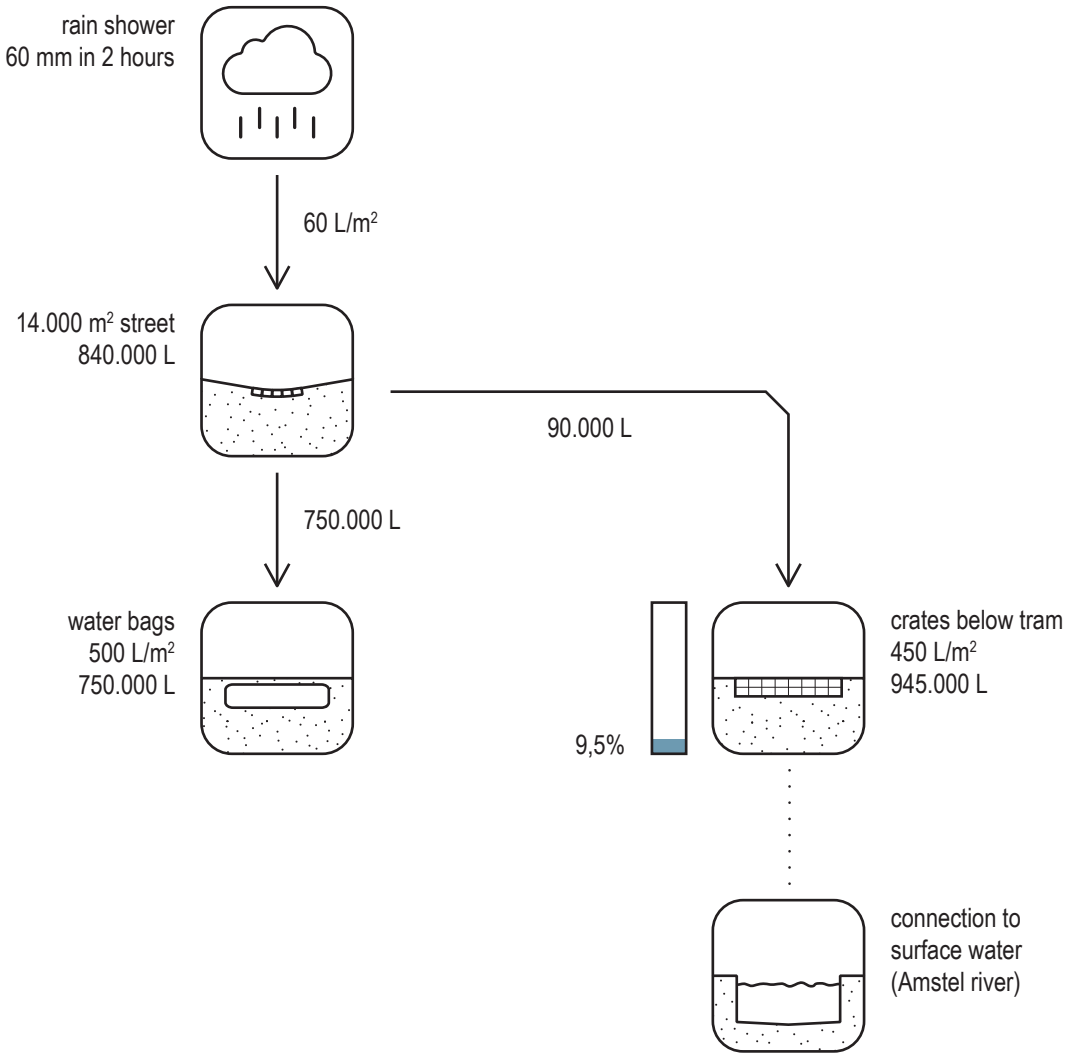



**Fig. 5.48**: Quantitative evaluation of Rokin (Author, 2018)

# 5.5 Rivierenbuurt

### 5.5.1 Context

The Rivierenbuurt is a neighbourhood in Amsterdam South, located between the Amstel river and the ringroad A10. The neighbourhood consists of the Schelde-, IJsel- and Rijnbuurt, and is part of the protected cityscape Plan Zuid. This plan, designed by Berlage, consists of monumental traffic axes and smaller, winding residential streets. The architecture of the residential buildings has been used to shape the urban spaces.

During the site visits several observations are done. The observations related to storm water resilience are photographed, collected and shown below.

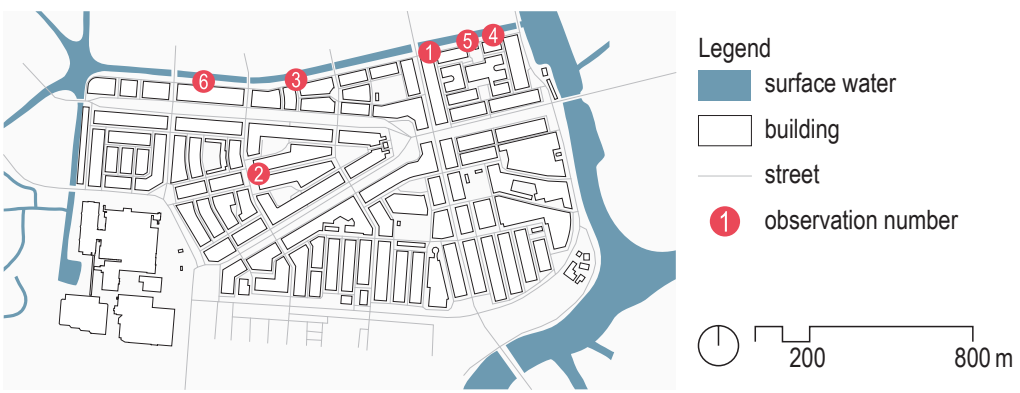



**Fig. 5.49**: Map of the Rivierenbuurt indicating the observations (Author, 2018)



**Fig. 5.50**: Descending streets (Author, 2018)



**Fig. 5.51**: Parking lots (Author, 2018)

**1. Descending streets**

The Rivierenbuurt is connected with other neighbourhoods via several bridges. The streets parallel to the water which connect to these bridges descent towards the neighbourhood. This causes rainwater to flow into the neighbourhood, instead of towards the surface water.

**2. Parking lots**

Most streets in the Rivierenbuurt offer a lot of space for car parking. These parking lots contribute highly to the big amount of non permeable pavement of the neighbourhood. This leaves little space for storage or infiltration of rainwater, for example in the form of a green strip, surface water, front gardens or more trees.



**Fig. 5.52**: Usage riverbank (Author, 2018)



**Fig. 5.53**: Obstacles riverbank (Author, 2018)

### 3. Usage riverbank

The bank of the Amstelkanaal, north of the Rivierenbuurt, is currently used as anything but a riverbank. It functions as a garbage dump, jetty for sinking boats and bicyle parking space. However, such a messy riverbank has potential to become multi functional and beautiful public space.

### 4. Obstacles riverbank

The Rivierenbuurt is surrounded by surface water. This offers an opportunity to drain rainwater directly towards the surface water. However, the current design of the public space does not allow this, as there are a lot of obstacles. These obstacles include curbs and a wrong descent, for example.



**Fig. 5.54**: Unique open spaces (Author, 2018)



**Fig. 5.55**: Drainage on the streets (Author, 2018)

### 5. Unique open spaces

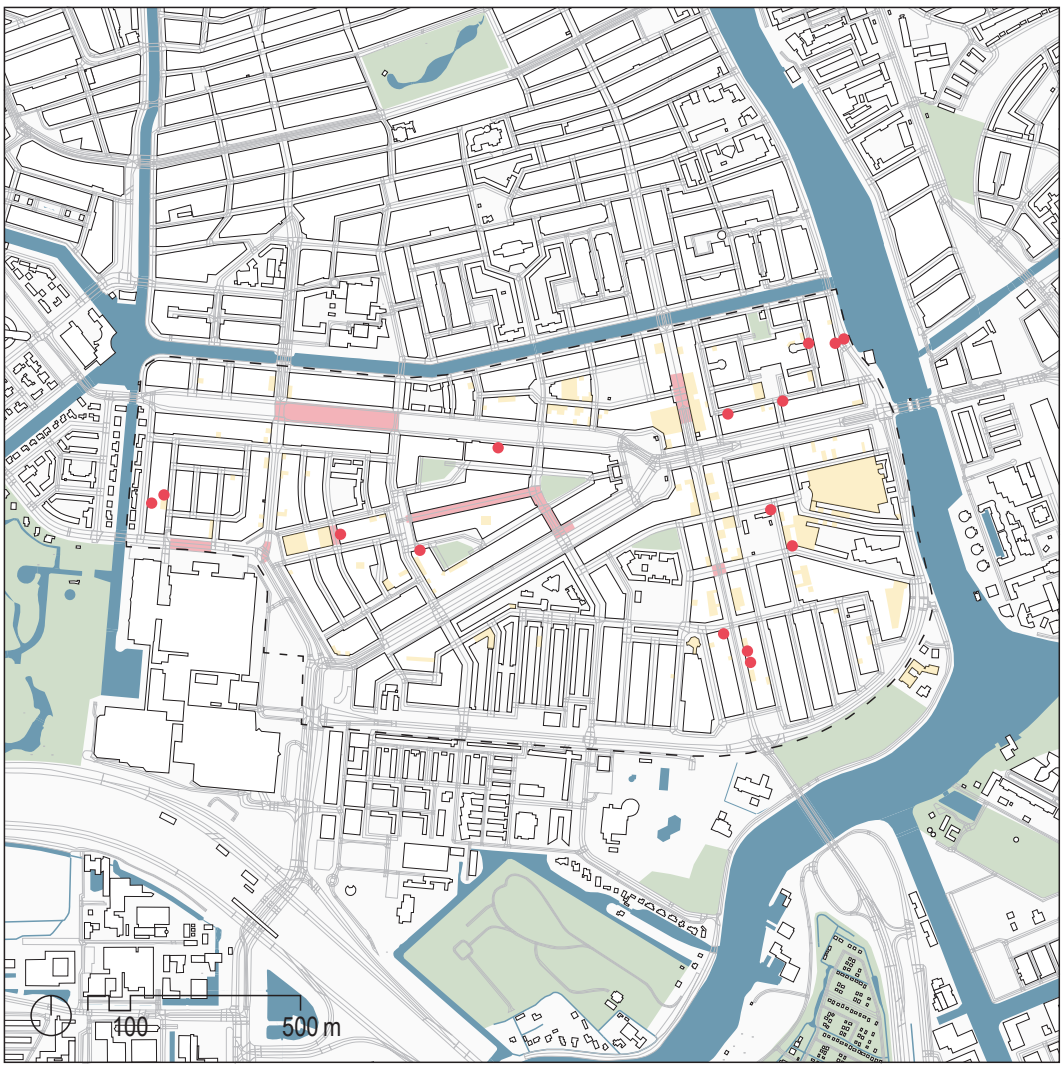
The Rivierenbuurt contains unique open spaces which could play an important role in storing and infiltrating rainwater. These spaces are scattered around the neighbourhood and often surrounded by building bocks. Most of the open spaces are arranged as a playground.

### 6. Drainage on the streets

Most streets in the Rivierenbuurt are constructed in such a way that they drain rainwater to both sides of the road. However, in some situations this way of draining is not the smartest way, seen from a storm water management point of view. It would be better to use V-shaped street profiles, to collect rainwater in the middle of the road.

### 5.5.2 Water nuisance

The observations done can be substantiated by factual information about water nuisance in the Rivierenbuurt. Map 5.7 shows the risk of damage to buildings and infrastructure due to extreme precipitation, based on the Rainproof factsheet of De Pijp - Rivierenbuurt, obtained via Amsterdam Rainproof (2016b). This risk is based on a rain shower simulation of 100 millimeter of rain within one hour and the functions of buildings and public space. This means the risk of damage that is shown is based on a very extreme rain shower. In addition, the complaints of water nuisance reported to Waternet on July 28th, 2014 are added to the map. The map shows a few of the main routes are poorly accessible for emergency services. This applies to the Churchill-laan, Rijnstraat, Wielingenstraat and the Scheldestraat, which are indicated in red. Furthermore, a few streets can experience nuisance from contaminated water, caused by bottlenecks in the combined sewer system. This poses a serious health risk. When it comes to vital functions, one police station could have trouble when taking action. Besides that, a lot of buildings are at risk of damage due to 20 centimeters of water against their facade and/or in the courtyard. Even though the Rivierenbuurt is almost enclosed by surface water, the neighbourhood is not storm water resilient.




Legend

- surface water
- green
- building
- border water nuisance
- street
- water nuisance reported to Waternet on July 28th, 2014

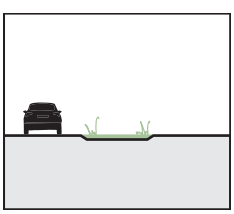
Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation:

- increased risk
- strongly increased risk
- extremely increased risk

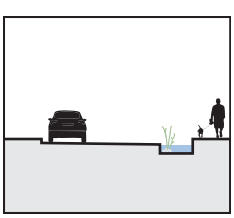
**Map 5.7**: Risk of water nuisance & damage to buildings & infrastructure during extreme precipitation (Author, 2018)

### 5.5.3 Design proposal

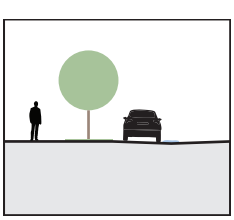
In order to improve the storm water resilience of an entire neighbourhood, interventions should be applied on all scales. Water related interventions are always interconnected and can not operate individually, as every intervention has its limit. If this limit is reached, a backup capacity should be available. By connecting the interventions on several scales, a storm water resilient network can be created. In case of the Rivierenbuurt, the hierarchy in the street network of the neighbourhood will be used to link the different scales to each other. This unique characteristic is designed by Berlage when he created Plan Zuid for Amsterdam. In this plan, primary, secondary and residential streets are clearly recognisable, also in the Rivierenbuurt. Squares played an important role in the design too, which are being formed by the architecture around them. These different types of public space form the basis for the network of storm water resilient interventions and will be transformed into storm water roads, retention roads, green roads and retention areas (Map 5.8). The next four pages show collages of how these four types of public space could look like (Figure 5.57-5.64).



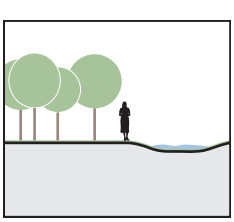
The primary roads of the neighbourhood will be turned into retention roads. In these streets a retention volume should be established to handle storm water on site before reaching even more vulnerable points. In general, primary roads offer most space, so therefore these roads are most suitable to add a retention volume to. In the Rivierenbuurt these roads are mainly located in east - west direction.



Secondary roads will be turned into storm water roads. Stormwater roads channel and direct rainwater to surface water and retention areas. These streets can be formed with a V-shaped profile and raised curbs to ensure water will flow in the middle of the road, away from the buildings. Channels and bioswales can be established along road edges so that water runs in urban rivers or in green strips. Applying this to secondary roads instead of primary ones ensures that primary roads are always available.



Residential streets will be connected with storm water roads and turned into green streets. This means storm water should be collected, delayed and channeled towards the storm water roads. The green streets should be established with a combination of small scale channels, (open) gutters, storm water planters or permeable paving, dependent on the space available.



Retention areas are proposed in the squares and parks of the Rivierenbuurt. These areas delay the storm water, so that storm water roads can be established in smaller dimensions. Interventions that could be applied in these areas are a bioswale, infiltration meadow, rainwater pond or water square. Alternatively, underground storage can be created with infiltration crates. Retention areas will be placed in connection with adjacent storm water roads.

**Fig. 5.56**: The four types of public space which will be applied to the Rivierenbuurt (Author, 2018)




Legend

- surface water
- green
- building
- bird's eye view
- storm water road
- retention road
- green road
- retention area

**Map 5.8**: Concept proposal for Rivierenbuurt (Author, 2018)

**Fig. 5.57**: Collage of what a retention road could look like (Author, 2018)



**Fig. 5.58**: Collage of what a retention road could look like during rain (Author, 2018)

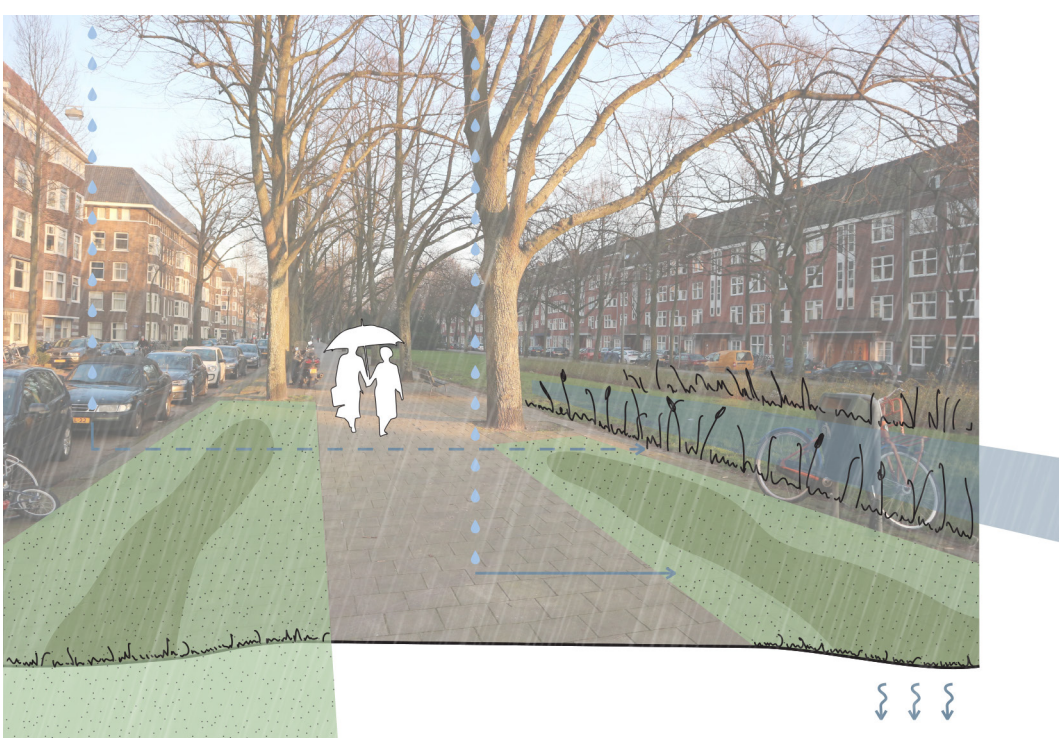




**Fig. 5.59**: Collage of what a storm water road could look like (Author, 2018)



**Fig. 5.60**: Collage of what a storm water road could look like during rain (Author, 2018)

**Fig. 5.61**: Collage of what a green road could look like (Author, 2018)



**Fig. 5.62**: Collage of what a green road could look like during rain (Author, 2018)





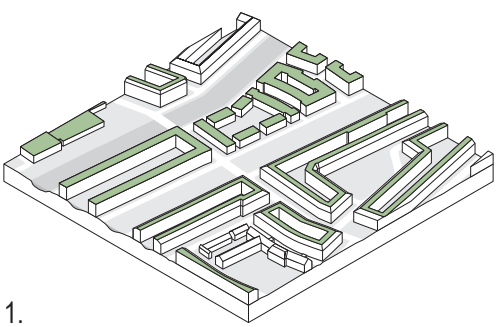
**Fig. 5.63**: Collage of what a retention area could look like (Author, 2018)



**Fig. 5.64**: Collage of what a retention area could look like during rain (Author, 2018)

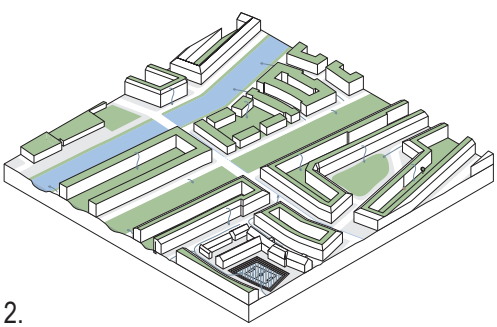
The isometric figure on the right shows which interventions could be implemented to create a storm water resilient network in a part of the Rivierenbuurt. The arrows indicate how this area would function during heavy rainfall (Figure 5.66). This network consists of the four types of public space described before and interventions on the building scale. The interventions are divided by the type of capacity they create (infiltration or storage capacity) and by the stakeholder who implements them (residents or municipality). The series isometries below shows how the area would function during and after heavy rainfall. The isometries indicate which areas will be activated first and where the water goes when maximum capacities are being reached.

**Fig. 5.65**: The four phases the area goes through during and after heavy rainfall (Author, 2018)



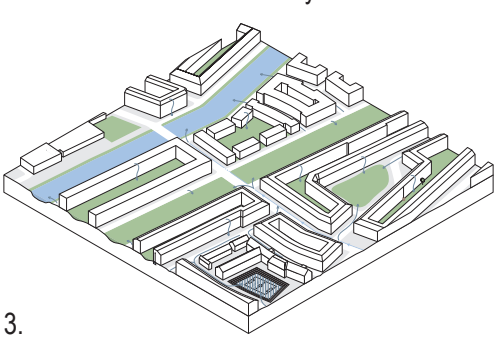
1.

During extreme precipitation the blue-green roofs will be activated first, as they collect clean rainwater directly from the sky. The first flush of rainwater falling on the streets will be drained towards the sewer system, as this water is contaminated with oil, soot and dog dirt. Small rain showers will completely be drained towards the sewer system.



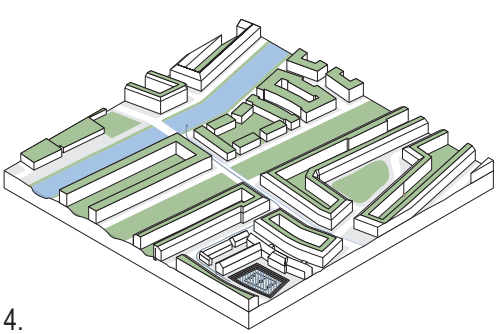
2.

After a while, the runoff from the blue-green roofs will flow towards the storage capacity on the building scale (rain barrel, rainwater tank), if present, or the streets and inner courtyards. The green roads wil drain towards the storm water roads via V-shaped street profiles and open gutters. The retention roads and areas will start to infiltrate the rainwater.



3.

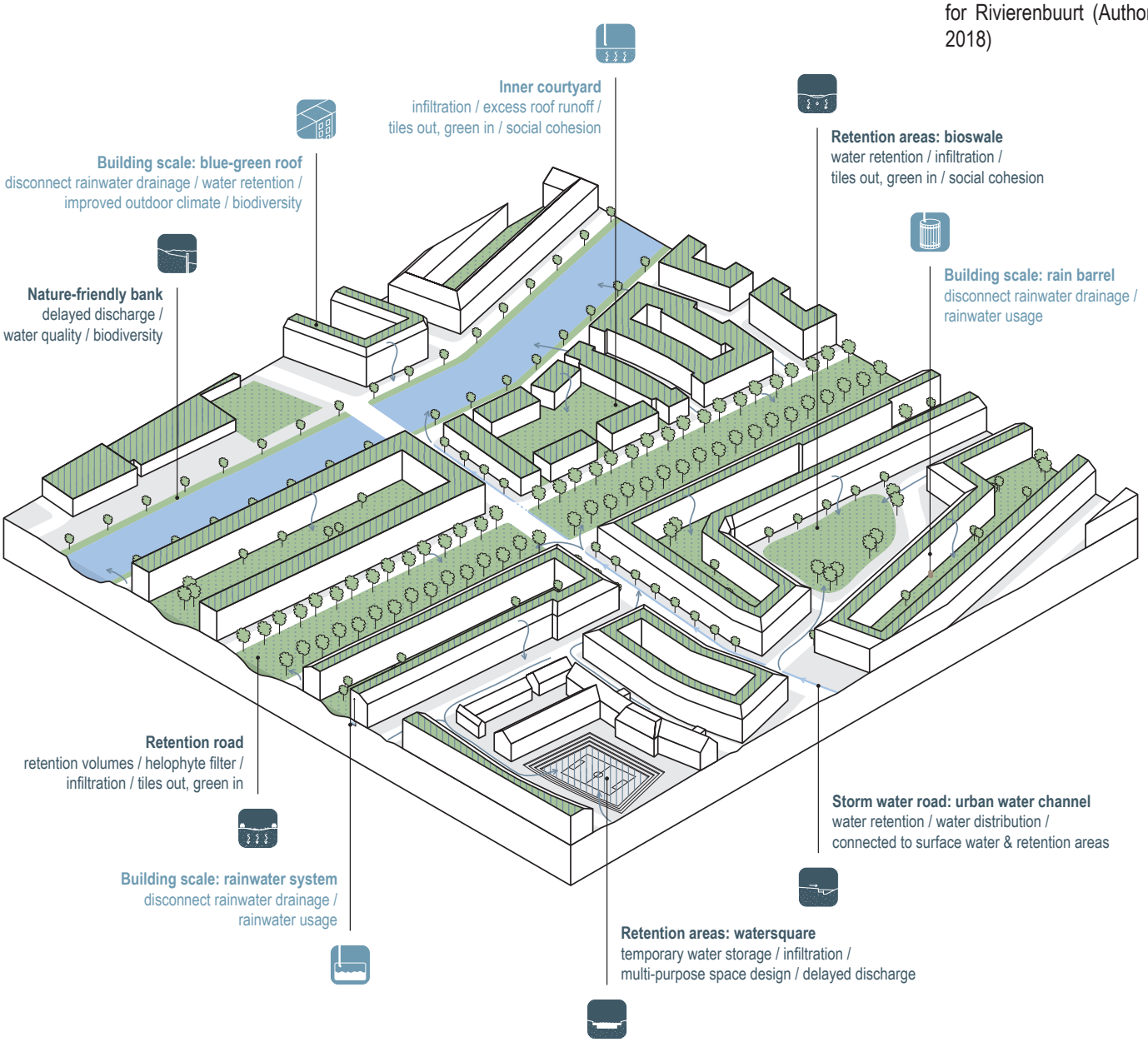
The storm water roads start to discharge to the retention roads, retention areas and surface water when their storage capacity is being reached. As there are not enough height differences to lead all the rainwater from the storm water road towards the surface water, the storm water road discharges to the retention road and areas too.



4.

When the rain has stopped, the sewer system is relieved and the (ground) water level dropped again, water storage like the water square can be emptied on the surface water. The blue-green roofs will drain their water buffer towards the sewer system when there is a new rain shower coming up, making use of smart technology.

**Fig. 5.66**: Design proposal for Rivierenbuurt (Author, 2018)




Legend

- surface water
- green
- infiltration capacity
- storage capacity
- urban water channel
- rainwater runoff
- implemented by residents
- implemented by municipality

### 5.5.4 Evaluation of the design

Transforming the Rivierenbuurt according to the above mentioned network principle adds up to several qualities of the neighbourhood. All interventions mentioned in the previous sections and locations could be implemented in this area, as the approach leaves space for interpretation and several options. A retention area could be established as a water square, but also as a bioswale or a rainwater pond. And a storm water road could include an urban water channel, but also just a V-shaped street profile combined with raised curbs. Furtermore, some of these interventions will have a positive impact on local aspects like social cohesion and traffic safety. This means both environmental and social additional benefits will be met, like shown in the qualitative evaluation scheme on page 121.

A quantitative evaluation has been done too, but about the water related interventions only. This evaluation shows the possible route of a raindrop falling on a roof in the Rivierenbuurt. Future water nuisance is predicted by the KNMI climate scenarios, of which the extreme scenario forms the basis for these calculations. This means the designs have been tested to an extreme rain shower of 60 millimeter in two hours, which equals 60 liters of water per square meter (section 4.1 elaborates on the origin of this number).

The blue icons in the flowchart refer to the isometric figure on the previous page. If the raindrop falls on a blue-green roof, 20% of the drop will remain and flow to other storage or infiltration capacity via the disconnected rain pipe. If these supplementary interventions are not available, the raindrop continues to the street. Via the V-shaped profile of the street, the drop is supplemented with rainwater flowing from other roofs and the street itself. This water flows to the closest retention area, like a water square. The quantitative evaluation shows that the biggest challenge is to reduce the water flow coming from the street itself, especially when the roofs are transformed into blue-green roofs. Every part of the street that could be turned into green is valuable infiltration capacity.

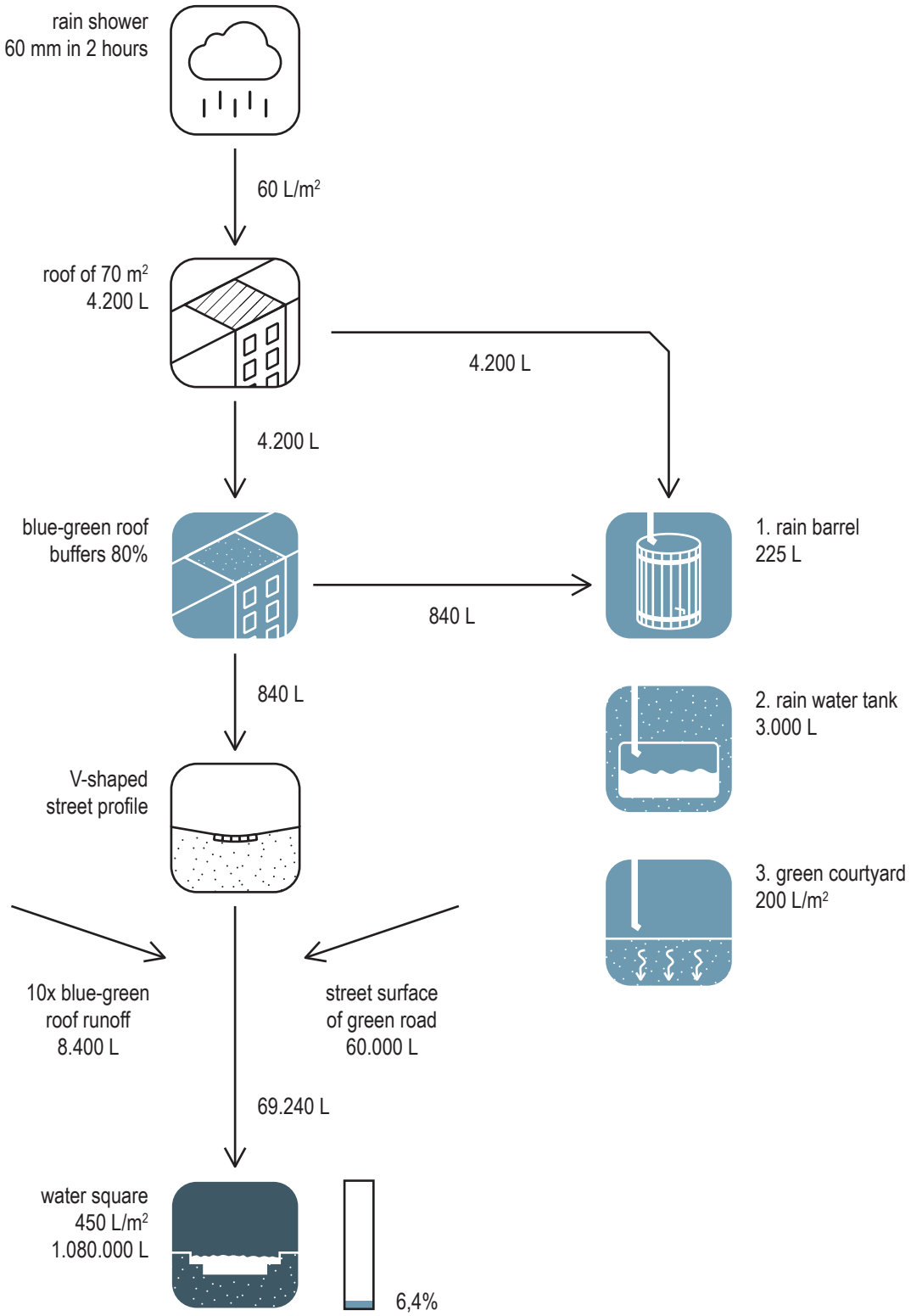



**Fig. 5.67**: Possible route of a rain drop in the Rivierenbuurt (Author, 2018)

# 5.6 Applicability

The four previous sections show in what way different types of locations can be transformed in order to improve the storm water resilience and liveability at that location. Within Amsterdam there are multiple locations comparable to the four design sites. These comparable locations can be transformed using the same kind of methodology and interventions.

**OLVG west**
Regarding the hospital OLVG west, similar buildings are spread out through the city. Other hospitals like VU University Medical Center and AMC and large buildings like the Foodhallen and buildings in industrial areas suffer from water nuisance too. The idea of OLVG west is applicable to these locations as well, although the ultimate goal would be to find a solution that matches with the characteristic, functionalities and requirements of the building too. The other locations might rather ask for a catering function or an energy roof instead of a (vegetable) garden as proposed for OLVG west. Finding the right function can be supported by a comprehensive analysis, neighbourhood research or a trend study. Initiatives like Rooftop Revolution (2017) can be a fruitful source of inspiration.

**Javastraat**
The Javastraat is a street which is very typical for Amsterdam. The closed building blocks and the alternation between residential streets and shopping streets is of frequent occurance in the city. The Javastraat and the neighbourhood around it are part of the most common typology in Amsterdam (mid rise, hight compactness, low density), which is mainly located in the ring of neighbourhoods around the inner city. The proposed interventions for the Javastraat are therefore easily applicable to similar situations, especially because the design addresses a buiding block, shopping street and a residential street. Of course there are hundreds of alternatives possible, but at least the same methodology and way of working could be applied. Transforming all similar situations in the city will largely increase the storm water resilience of Amsterdam. An overcapacity is fairly easy to reach, especially when a street or building block is being transformed anyway. In this way, the typology can form a buffer in the city.

**Rokin**
When it comes to Rokin, comparable streets should have two similar characteristics: the street should have retail functions on the ground floor and the pressure on public space should be high. These two characteristics are important to consider, as they determined the kind of interventions which have been applied. A shopping street is often intensively used, especially in the city centre. Furthermore, these streets are often completely paved and a lot of shopfronts have glass facades to the ground. In combination with a high pressure on public space, these aspects result in water storage below the surface as main intervention. Applying this to residential streets, for example, would be a shame, as interventions below the surface do not offer any additional beneftis to public space. Therefore, shopping streets in the city centre, which currently experience water nuisance, are selected as similar streets which could undergo the same kind of transformation as Rokin. These streets include the Westerstraat, Spuistraat and Waterlooplein. The size of the storage capacity can vary per location, just like the exact integration. At least the storage capacity will be large enough to store the rainwater from the street itself, as Rokin turned out to have a large overcapacity. Streets with the same characteristics which do not experience water nuisance at the moment could be transformed in the same way, in order to prevent future water nuisance from happening.

**Rivierenbuurt**

The remaining part of the Rivierenbuurt could be transformed according to the same principle, as the whole neighbourhood contains the same hierarchy in the street network which forms the basis for the design proposal. However, the sequence of parks and squares might be completely different. Without a retention area in close surroundings, the system of storm water resilient interventions will work differently. Infiltration capacity should be found elsewhere, or rainwater has to be moved over a further distance. This might be a challenge to overcome in other locations in the neigbhourhood.

The same strategy could also be applied to other neighbourhoods which are of the same typology. The analysis showed that the concerning typology occupies a large part of the city, especially in the ring of neighbourhoods around the inner city. These areas can make use of the same principle as the Rivierenbuurt, but with the same footnote as mentioned above, regarding the availability of space.

Transforming similar locations in Amsterdam in the same way will largely increase the storm water resilience of the city. This is especially the case since the typology which is of most frequent occurance is part of the transformation process. Transformation will solve the water nuisance on location and can most probably create an overcapacity too, given the many possibilities. In this way, a lot of buffers are being created, which can store rainwater surplus from the surrounding areas.

In practise, this requires interaction between the several scales, projects and actors. The conditions of a location determine if and how the proposed interventions are applicable. Then, the municipality can take action in a suitable way. The municipality fulfills an important role, as they facilitate most of the interventions. They do need to communicate their plans to the water authority, but these two actors have been working pretty well together for several years now. When large projects are planned, the municipality is looking for synergetic projects that can take place simultaneously. Residents, however, often only take action when they have had a negative experience with water nuisance. They can establish a team that actively is looking for storm water resilient ideas and interventions and organise neighbourhood meetings, for example. The municipality can promote this by utilising a lot of different actors, like a garden center to show the possibilities for residents who own a garden, and a playground association to transform playground into green oases. In this way, they can reach a lot of residents and activate them, also when they did not have a negative experience with water nuisance yet. Every drop of water that is not going to the sewer system anymore helps, so the more people contribute, the better.

**Larger context**

When looking at the larger context, the problems described in the problem statement occur in various other cities as well. Climate change and urban growth are global phenomena, which means all cities of similar size, topography and climate can make use of the conclusions and methodology. In practise, this means cities located within the Randstad region are especially suitable, like Rotterdam, Utrecht and The Hague. These cities are of similar size or smaller and urban growth is clearly going on (Centraal Bureau voor de Statistiek, 2017). Furthermore, the topography and soil type are similar: mainly flat without a lot of exceptional areas and a mixed urban soil type. In conclusion, the conclusions and methodology of this thesis may function as a reference and inspiration for other cities facing similar issues, especially when they are of similar size and topography such as the cities located in the Randstad region.

# 06

# Conclusion

This chapter will first answer the sub research questions of this graduation project, after which the main research question will follow. The answers to the questions include references to the chapters of this document where these questions are extensively answered. A final qualitative evaluation scheme shows what additional benefits can be reached with the design proposals.

# 06 CONCLUSION

The goal of this graduation project is to show how the city of Amsterdam can be transformed in order to create a future-proof, storm water resilient city, with interventions which simultaneously improve local and sustainable urban aspects. In order to do this, several sub research questions have been formulated, which are divided into five phases. These questions will be answered briefly, after which the answer to the main research question will follow.

Phase 1:
Historic systems

*How did the urban development of Amsterdam evolve over time?*
The urban development of Amsterdam has always been related to water in a certain way. The city originates in a peat polder city with a dam as its dry core. Prosperity and growth led to expansion of the surrounding wet soil, after which the city grew via a system of canals. This ring of canals is an integral design of a street plan and a new water system. The relationship between land restructuring, surveying and water management forms the basis of urban design in the Netherlands.

*How has the role of water in the city changed over the years?*
In order to answer the main research question it is important to know what role water plays in the contemporary city. This role has changed a lot over time and shifted from a source of income in the 17$^{th}$ century, to a redundant urban element in the 19$^{th}$ century. After a cultural revaluation of water in the cityscape, the urban water of Amsterdam is the city's most important trademark, attracting millions of tourists per year. However, storm water poses a threat to cities too, and in the future probably even more because of climate change. Finding new forms of water management became of great importance to survive.

The answers to the questions of phase 1 are elaborated in chapter 2 of this document.

Phase 2:
Current systems

*How does the storm water system of Amsterdam function?*
The functioning of the water system of Amsterdam is shown by several maps, which can be found in Appendix 1 of this document: The Maps Manual. These maps include the functioning of the drainage system, the different types of land reclamation, the polders and polder and boezem water. These maps have shown that the water system of Amsterdam is working well on the city scale. Furthermore, the grachtengordel is completely water nuisance-free.

*What are relevant systems in relation to storm water resilience and how do they function?*
Systems that could have a relevant relation with the storm water system of the city are included in The Maps Manual too. These systems include the non-residential functions, spatial typologies and housing plans. A transparant layer of water nuisance, included in the appendix too, showed that there is correlation between water nuisance and streets with a predominant retail function, and between water nuisance and the most common spatial typology. These correlations form the basis for the chosen design locations.

The answers to the questions of phase 2 are elaborated in chapter 4 of this document.

Phase 3:
Current challenges

*What are the challenges in the urban design and planning of storm water resilient cities?*
The challenges from case studies include, among others, costs, ownership, motivation and implementation time. These challenges are derived from four scales: building scale, street

scale, neighbhourhood scale and city scale. General challenges, derived from literature, include fragmentation, legal framework, spatial design and different time horizons. External uncertainties that should be considered when designing and planning storm water resilient cities include climate change, demographic changes and urban growth.

*Where does the storm water system of Amsterdam ask for improvement?*
As the water system of Amsterdam is functioning well on the city scale, the system mainly asks for improvement of the locations which currently experience water nuisance. These locations are included in a map, which distinguishes three levels of urgency: urgent, very urgent and extremely urgent situations. The urgency is based on the amount of water on the streets and the functions of the area and the buildings.

The answers to the questions of phase 3 are elaborated in chapter 3 and 4 of this document.

Phase 4:
Future challenges

*What are the effects of climate change on the storm water system of Amsterdam?*
The climate scenarios of KNMI have been used to predict an extreme rain shower in the future. This extreme rain shower has been based on the most extreme climate scenario and an extreme rain event which took place in the Netherlands in 2014. This resulted in a future rain shower of 60 millimeter of rain, falling in two hours. For the future challenges this means that serious steps should be taken in urban water management in order to infiltrate and store this large amount of rainwater and to prevent water nuisance from happening.

The answer to the question of phase 4 is elaborated in chapter 4 of this document.

Phase 5:
Future systems

*What are possible spatial interventions related to storm water resilience?*
There are so many interventions which contribute to the storm water resilience of a city, that it is impossible to include them all in this project. An extensive analysis of the possible interventions and the design sites resulted in a selection of interventions which suit the design sites best. These interventions are combined into a qualitative evaluation scheme, which can be found on the next page.

Phase 5a:
Solutions

*What are strategic locations to implement these interventions to and what is the best way to do this?*
The four design sites which are elaborated in chapter 5 of this document are examples of strategic locations which could be transformed. These locations are chosen based on the urgency of water nuisance, their typology and/or their main function. The best way to transform these locations is to extensively analyse them first, in order to include local and environmental aspects in the storm water resilient design too. In this way, a synergetic and comprehensive design will improve both the storm water resilience and the liveability of that location.

Phase 5b:
Network

*How does the implementation of these interventions influence the storm water system on city scale?*
Implementing interventions on several scales creates a network of interventions which should work together. In practise this means that when the storage or infiltration limit of an intervention has been reached, other interventions should compensate. In this way, interventions on smaller scales can create a network of interventions which functions on the city scale. If locations similar to the four

strategic design sites are being transformed too, this network arises and the whole city will be storm water resilient.

*What will be the effect of these interventions on the sub objectives?*
The effect of the applied interventions on the subobjectives has been visualised by the qualitative evaluation scheme on the opposite page (Figure 6.1). The lines between the design components and the additional benefits indicate a possitive relation: the thicker the line, the bigger the impact. Most of the design components contribute to the storm water resilience of the city, but address another, additional benefit as well. Apart from environmental benefits, socio-economic benefits are included in the scheme as well. Even though most of these socio-economic benefits are addressed by non-water-related interventions, some of them have synergies with water related interventions too.

The answers to the questions of phase 5 are elaborated in chapter 5 of this document.

Based on the above mentioned answers to the sub research questions, the main research question can be answered.

*Main research question*

*How can applying interventions on several scales reinforce the urban water system of Amsterdam, in order to create a storm water resilient city, while deriving additional, environmental and socio-economic benefits from this?*

First of all, the design site has to be extensively analysed to find out what aspects of that location are in need of improvement, apart from the storm water resilience itself. This analysis has to be done on several scales and will reveal guidelines for the desirable interventions, related to environmental and socio-economic urban aspects. As interventions will be applied on several scales, a network of interventions will be created. This means interventions are able to compensate whenever a part of the network is overloaded or fails.

**Recommendation**
To what extent the interventions contribute to other environmental and socio-economic urban aspects is largely dependent on the space available at the design site. Therefore, it is really important to consider storm water resilience and its synergies with other aspects in an early stage of the design process, especially now the city of Amsterdam is growing so fast. If storm water resilience is integrated in the design process of the expansion areas, required space can be reserved and water nuisance will be a thing of the past.

In conclusion, the most important lesson learnt is that storm water resilience is an urban aspect that needs change at the very start of the whole process it is part of. When the most important parties involved, so municipalities, urbanists and residents, are educated in the right way, storm water resilience will become a part of daily life, rather than it will be forgotten. The municipality creates conditions, which the urbanists can fill in and the residents can carry out and enjoy. In this way, future-proof, storm water resilient and liveable cities are created together.

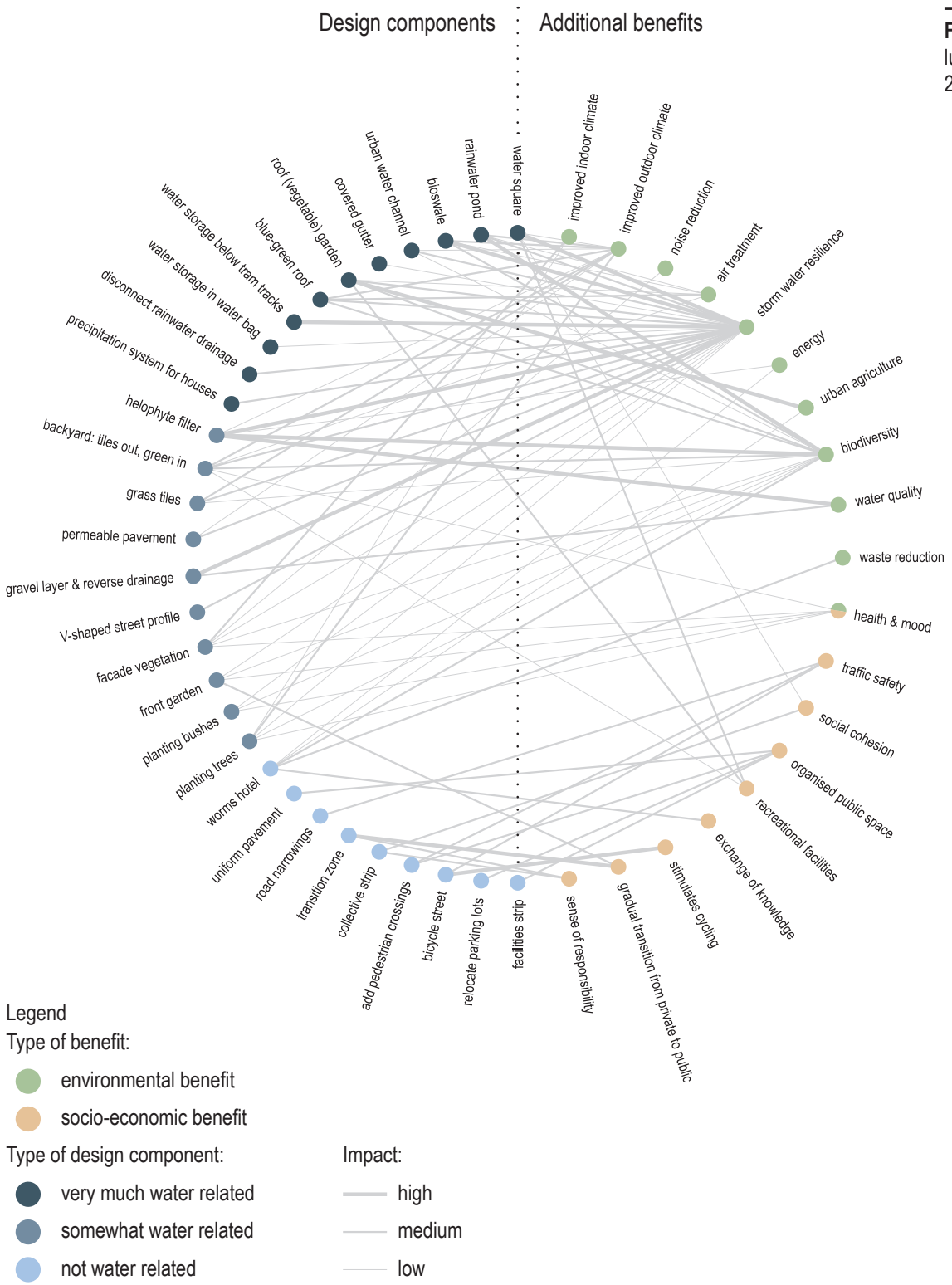



**Fig. 6.1**: Qualitative evaluation scheme (Author, 2018)

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Literature
Figures

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# Appendices

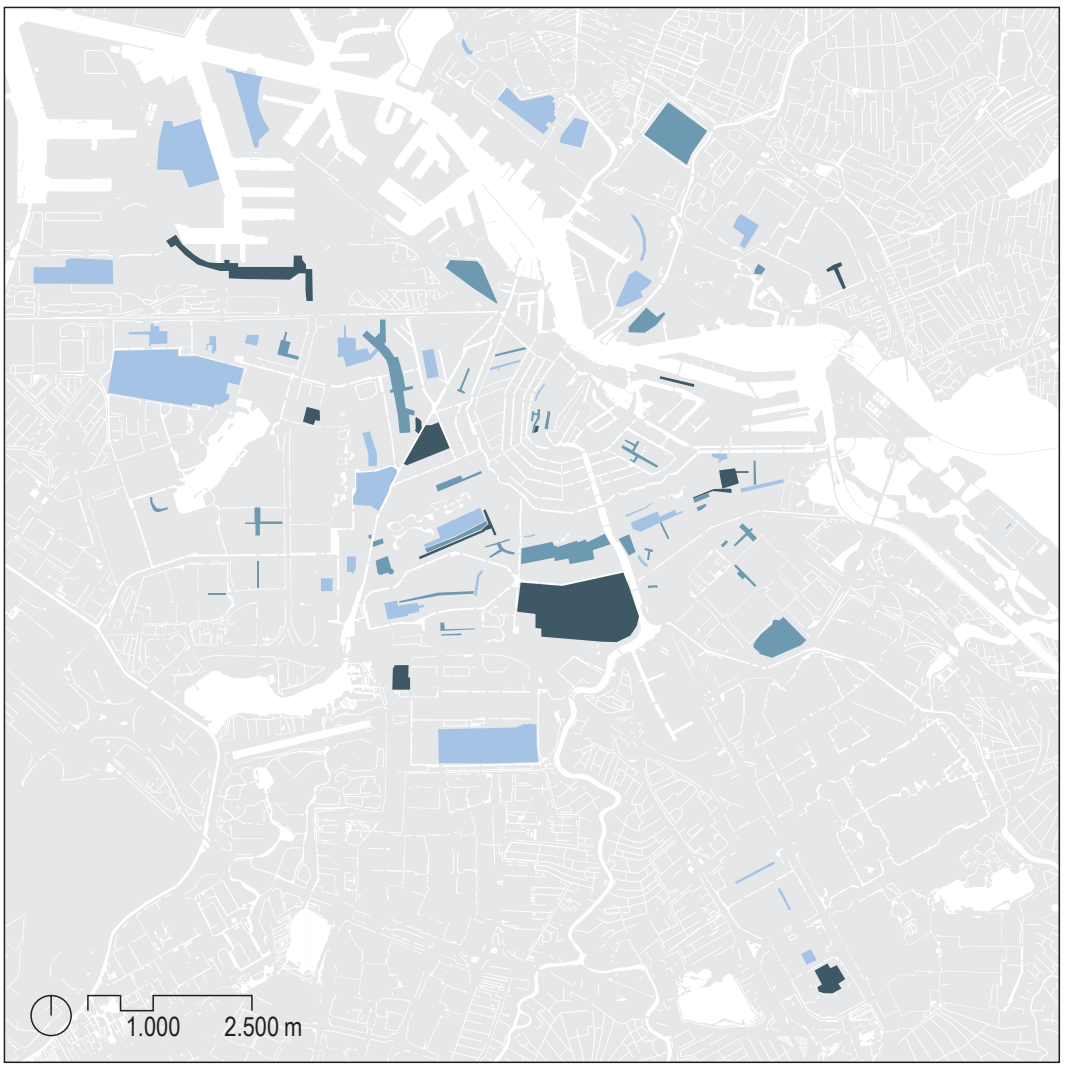
Appendix 1: The Maps Manual
Appendix 2: The Section Collection
Appendix 3: Reflection

# APPENDIX 1: THE MAPS MANUAL

The Maps Manual includes maps of all the systems that have been relevant for the analysis of Amsterdam. Some of these maps are related to the water system, but others are not. The maps include the following systems:

- Water nuisance
- Green and water
- Drainage system: normal situation and high water
- Polder and boezem water
- Polders
- Embankments
- Soil quality
- Non-residential functions
- Spatial typologies
- Housing plans
- Primeval gulch
- Development maps: origin, late 19th century and post WWII

The hard copy of this appendix includes a transparant layer that indicates the current water nuisance in the city. This sheet can be placed over the other systems to reveal the relation between the concerning system and the water nuisance. The systems that have a strong relation with the water nuisance are included in the Analytical Framework of the report.




**Map A1.1**: Current water nuisance (Author, 2018)

Legend

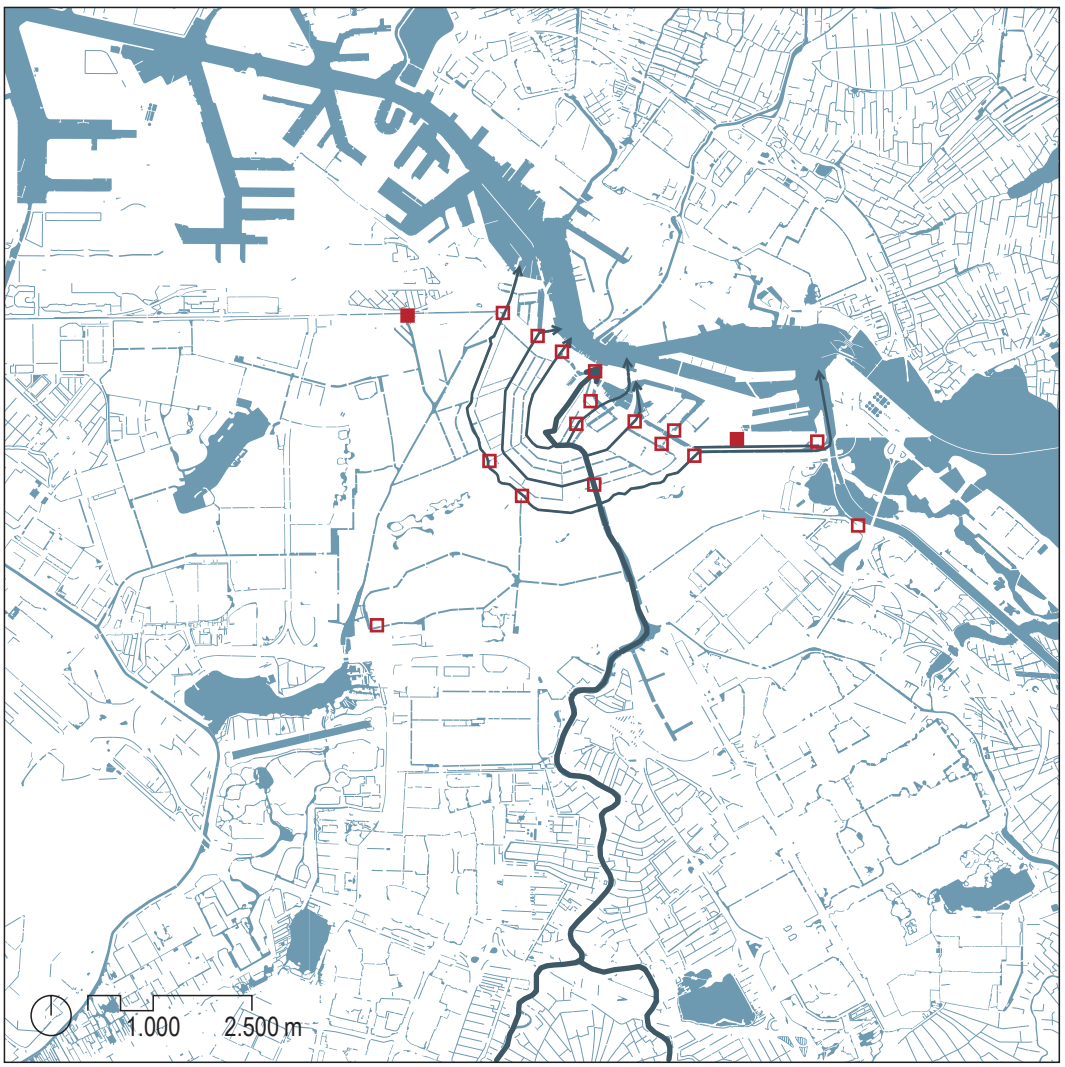
- extremely urgent: chance of severe damage to real estate (a lot of water), critical infrastructure, hospitals and museums and disruption of accessibility (>30 cm water on main roads).
- very urgent: chance of damage to real estate and severe traffic disruption.
- urgent: chance of damage to real estate.

**Map A1.2**: Green and water (Author, 2018)




Legend

- urban green
- green landscape
- water




Legend

opened lock

closed lock

**Map A1.3**: Drainage system: normal situation (Author, 2018)

**Map A1.4**: Drainage system: high water (Author, 2018)




Legend

opened lock

closed lock




Legend

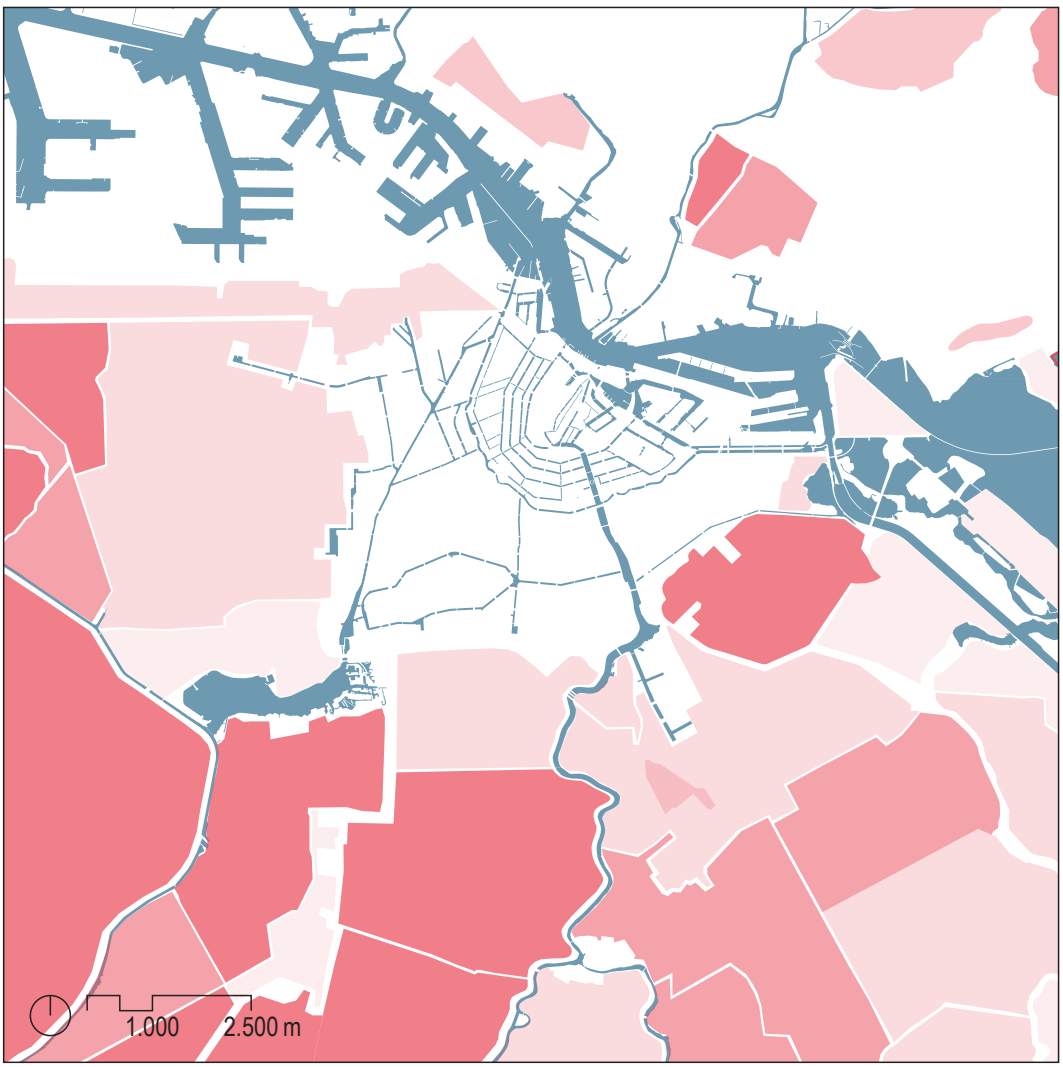
boezem water

polder water

exchange point

**Map A1.5**: Polder and boezem water (Author, 2018)

**Map A1.6**: Polders (Author, 2018)



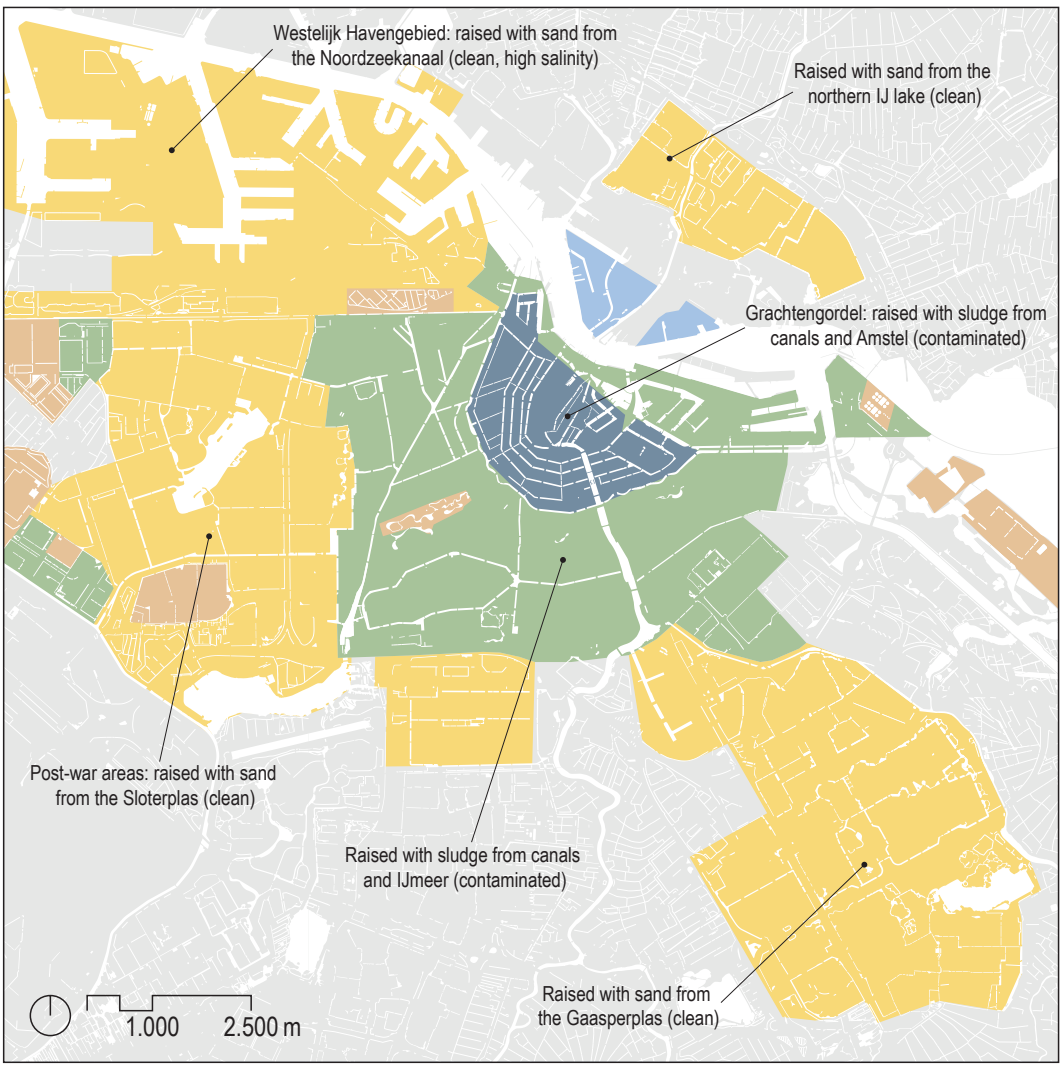


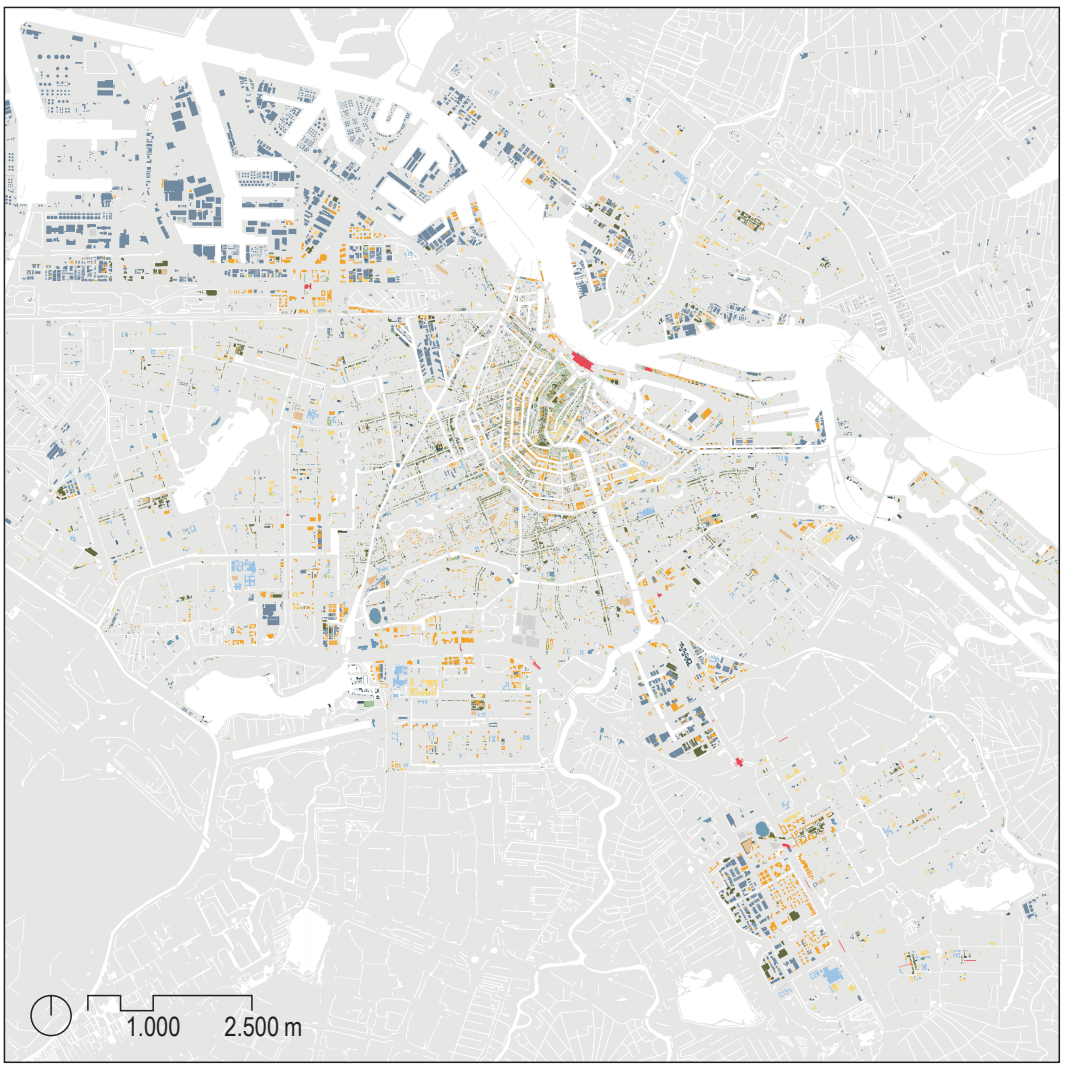

Legend

- dikes
- ontginningen
- verveningen
- droogmakerijen
- aanplempingen

**Map A1.7**: Embankments (Author, 2018)

**Map A1.8**: Soil quality (Author, 2018)



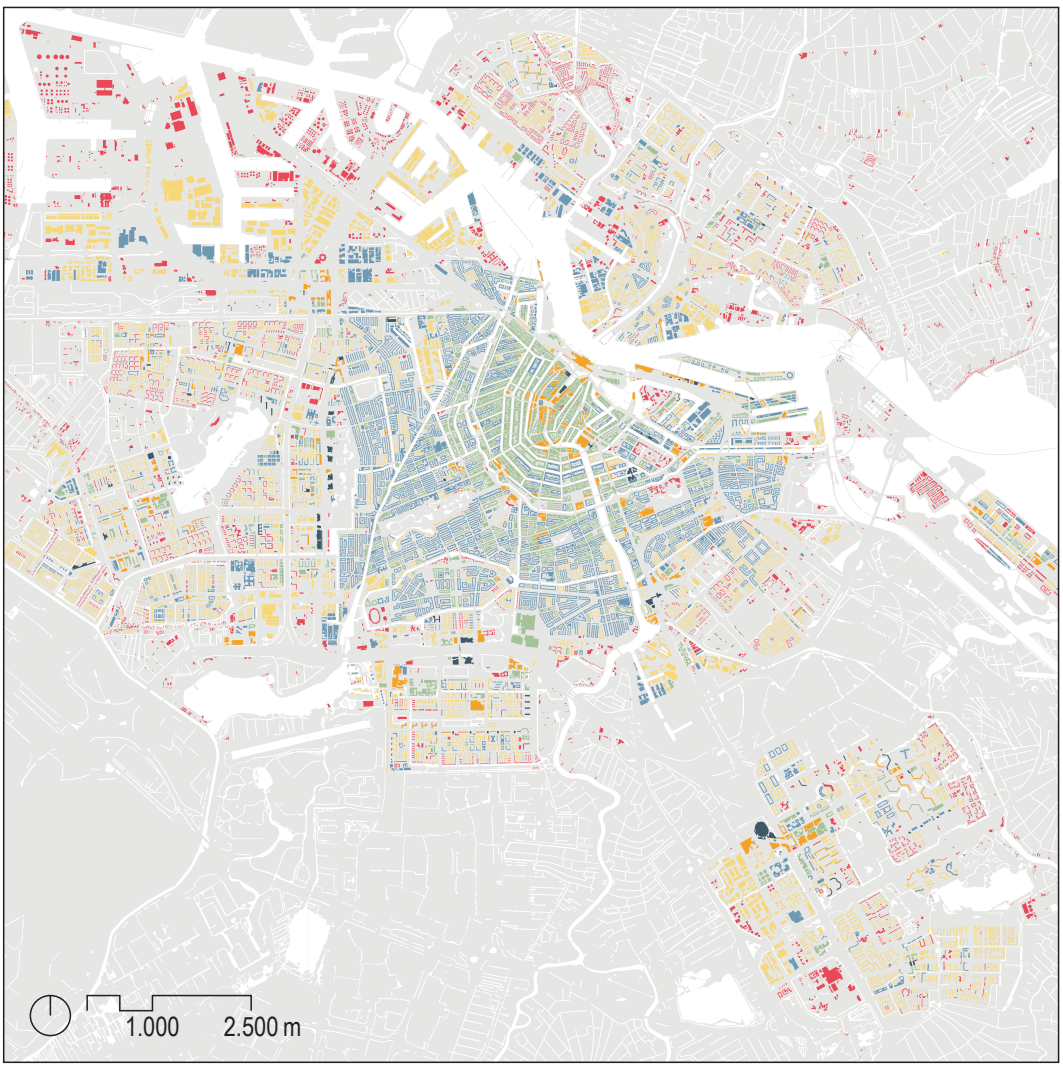



Legend

- activities & meeting
- businesses
- education
- entertainment & tourism
- healthcare
- horeca
- offices
- parking
- public transport
- religion
- retail
- sports

**Map A1.9**: Non-residential functions (Author, 2018)

**Map A1.10**: Spatial typologies (Author, 2018)




Legend

- low rise, medium compactness, medium density
- low rise, low compactness, low density
- mid rise, high compactness, low density
- mid rise, medium compactness, medium density
- high rise, medium compactness, high density
- high rise, medium compactness, medium density




Legend

- exploration / planning
- investment decision taken
- under construction
- completed

**Map A1.11**: Housing plans (Author, 2018)

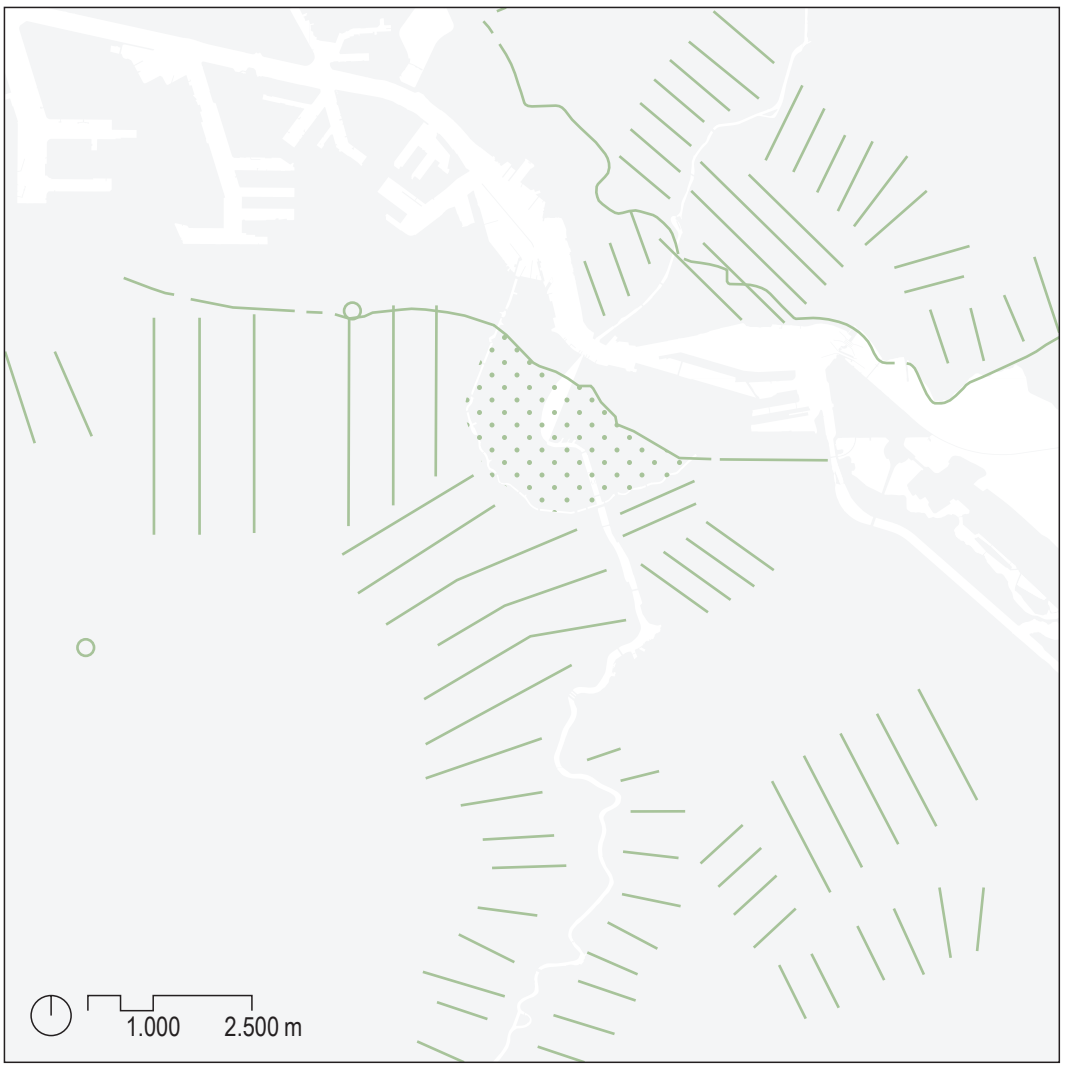
**Map A1.12**: Primeval gulch (Author, 2018)




Legend

main gulch

side gulch or sea hole




Legend

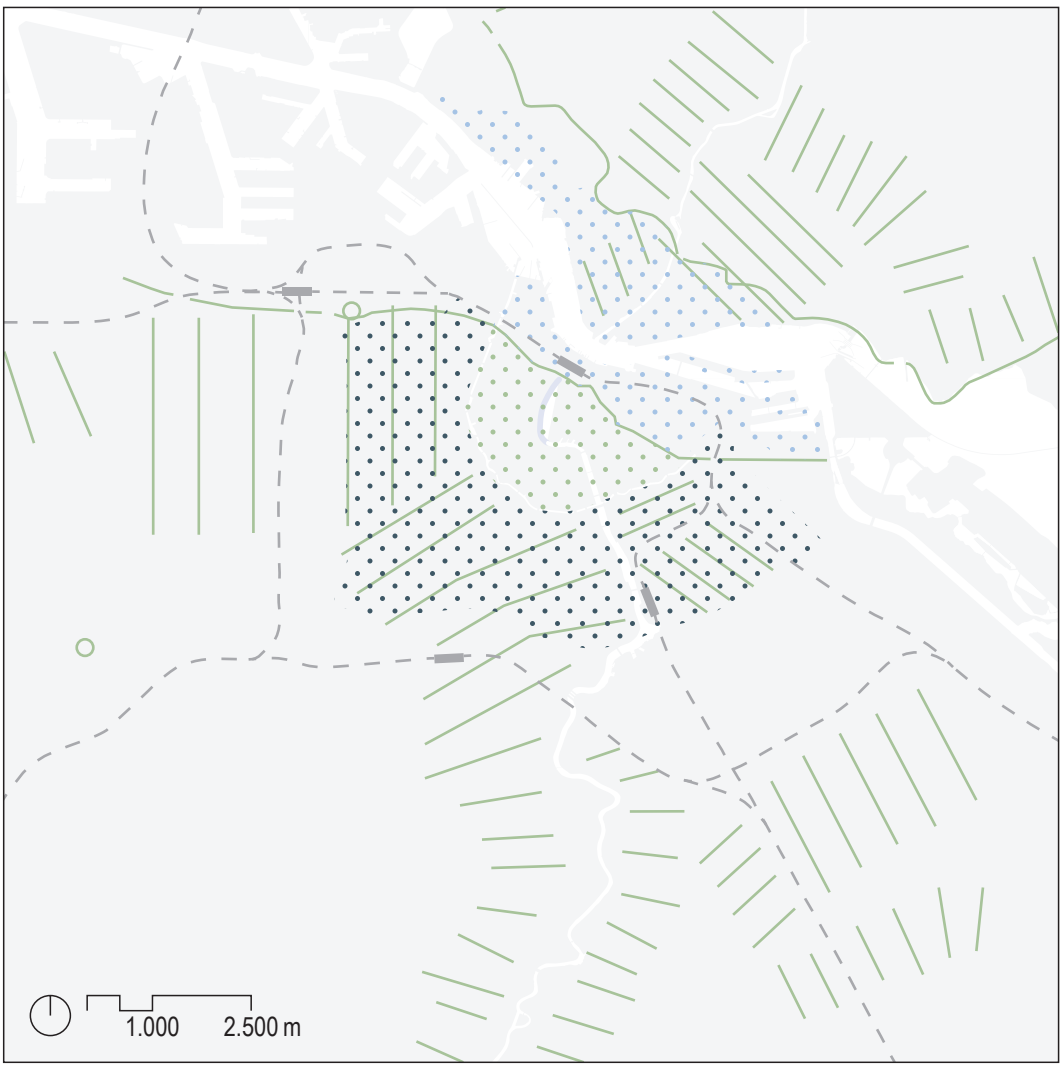
peat reclamation landscape

Spatial development determined by:

river & reclamation landscape

**Map A1.13**: Spatial development: origin (Author, 2018)

**Map A1.14**: Spatial development: late 19th century (Author, 2018)




Legend

peat reclamation landscape

railroad

Spatial development determined by:

river & reclamation landscape

railroad lines & stations

new docks along the IJ




Legend

- peat reclamation landscape
- railroad
- highway

Spatial development determined by:

- river & reclamation landscape
- railroad lines & stations
- new docks along the IJ
- relocation of the docks
- ringroad & motorways

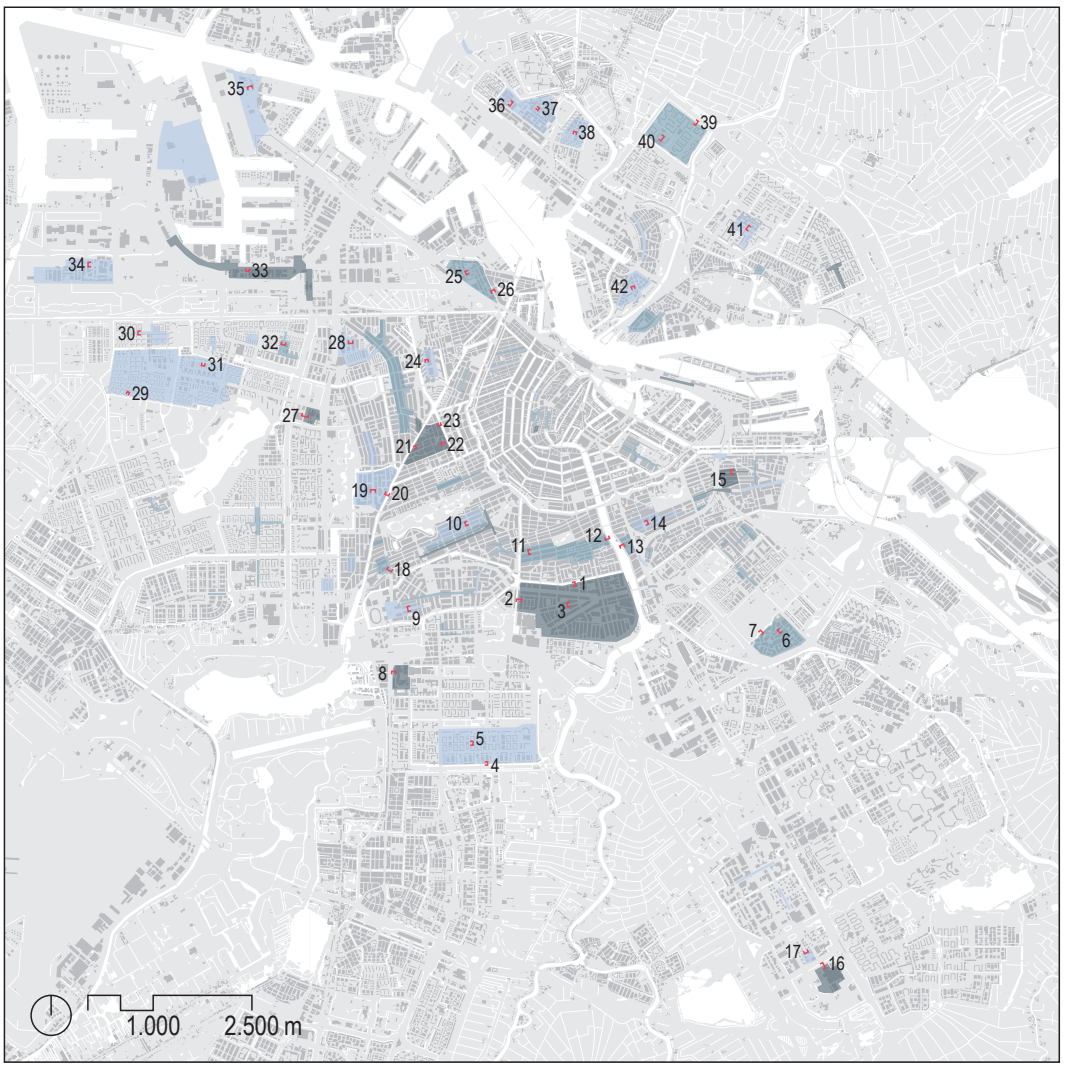
**Map A1.15**: Spatial development: post WWII (Author, 2018)

# APPENDIX 2: THE SECTION COLLECTION

The Section Collection includes 42 sections of streets throughout the entire city that experience water nuisance during heavy rainfall. The locations of the sections are indicated in Map A2.1. In every section the water drainage is indicated by a blue drop, together with the possible reason for water nuisance in that location indicated in pink. These reasons for water nuisance include:

- Curbs in the wrong location
- Streets descending in the wrong direction
- Too long distance to the nearest surface water
- Streets being completely paved

These sections and conclusions have been used to get an understanding of the circumstances on locations that experience water nuisance. Often, these practicalities are implemented unconsciously without knowledge of the possible consequences.



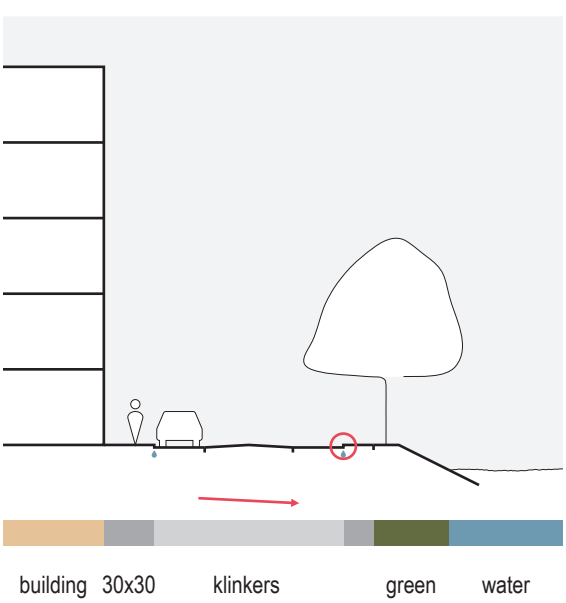

Legend

- extremely urgent: chance of severe damage to real estate (a lot of water), critical infrastructure, hospitals and museums and disruption of accessibility (>30 cm water on main roads).
- very urgent: chance of damage to real estate and severe traffic disruption.
- urgent: chance of damage to real estate.
- section

**Map A2.1**: Spatial development: post WWII (Author, 2018)

**Fig. A2.1**: Amstelkade 77, extremely urgent (Author, 2018)





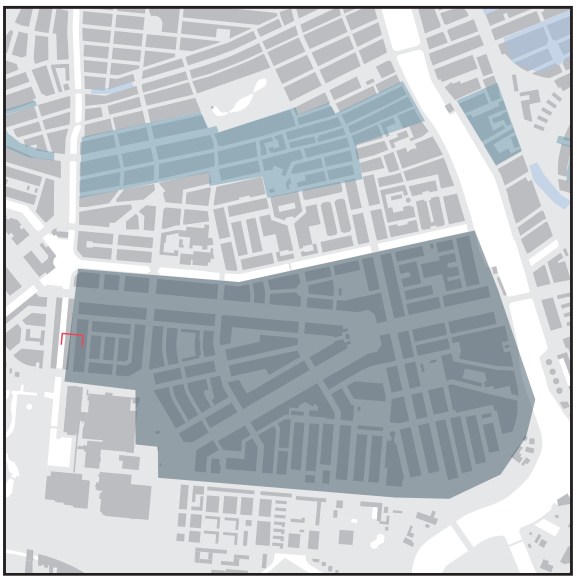


**Fig. A2.2**: Haringvlietstraat 37, extremely urgent (Author, 2018)



**Fig. A2.3**: Biesboschstraat 39, extremely urgent (Author, 2018)



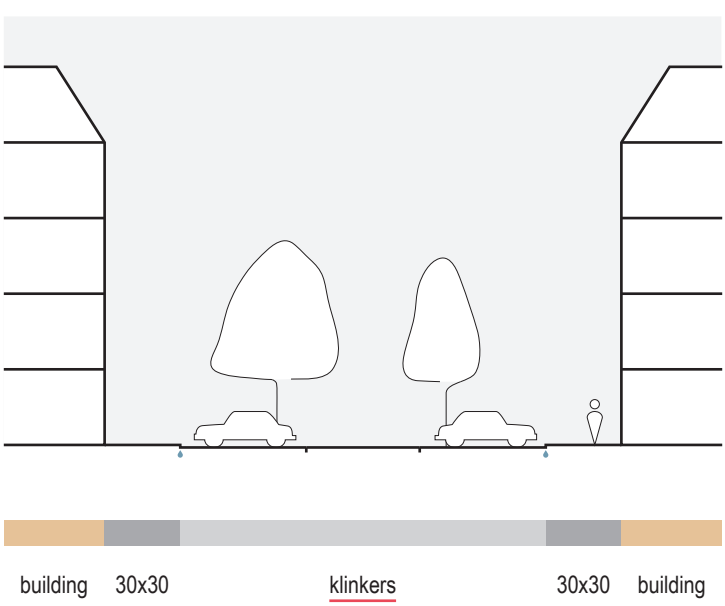




**Fig. A2.4**: Daelenbroek 3, urgent (Author, 2018)

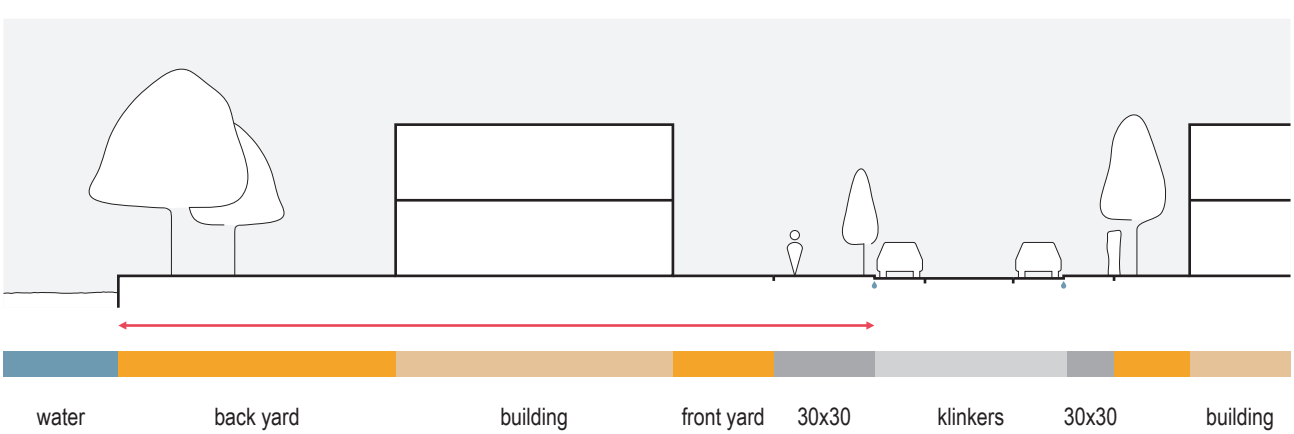
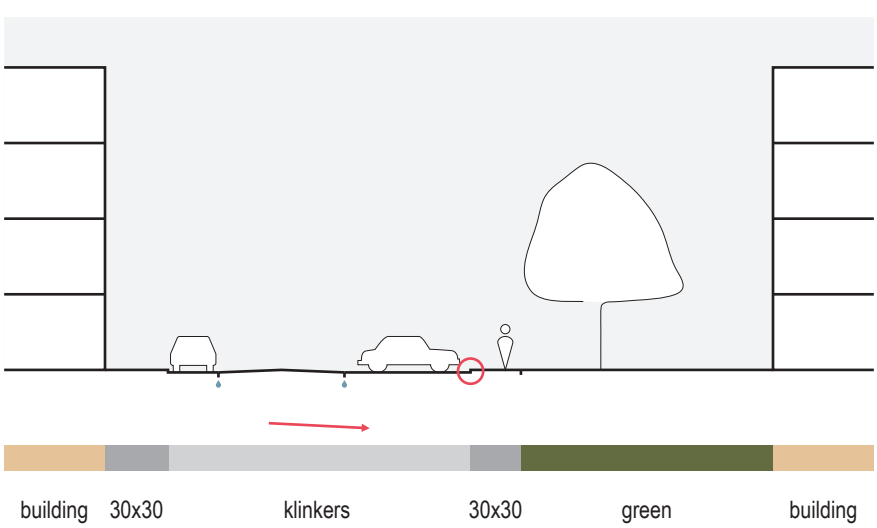


**Fig. A2.5**: Kastelenstraat 155, urgent (Author, 2018)





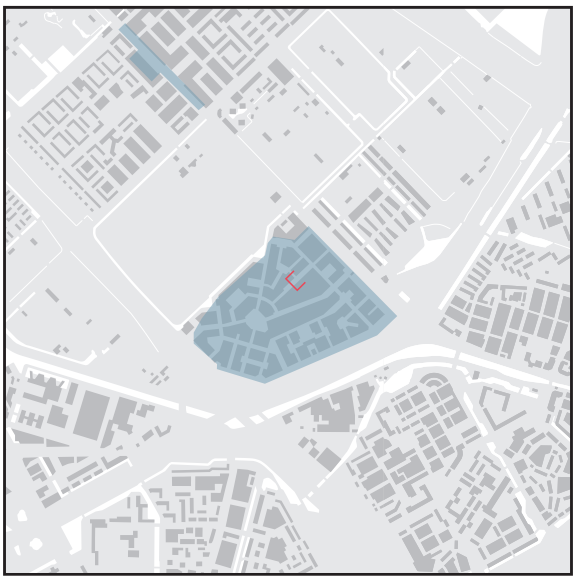


**Fig. A2.6**: Brinkstraat 87, very urgent (Author, 2018)

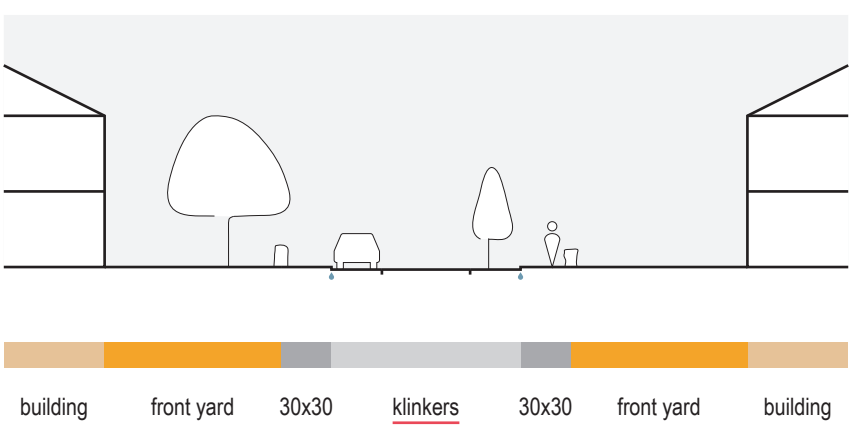
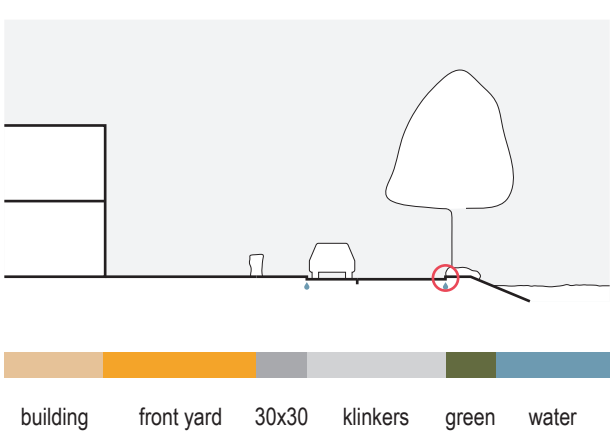


**Fig. A2.7**: Zaaiersweg 125, very urgent (Author, 2018)







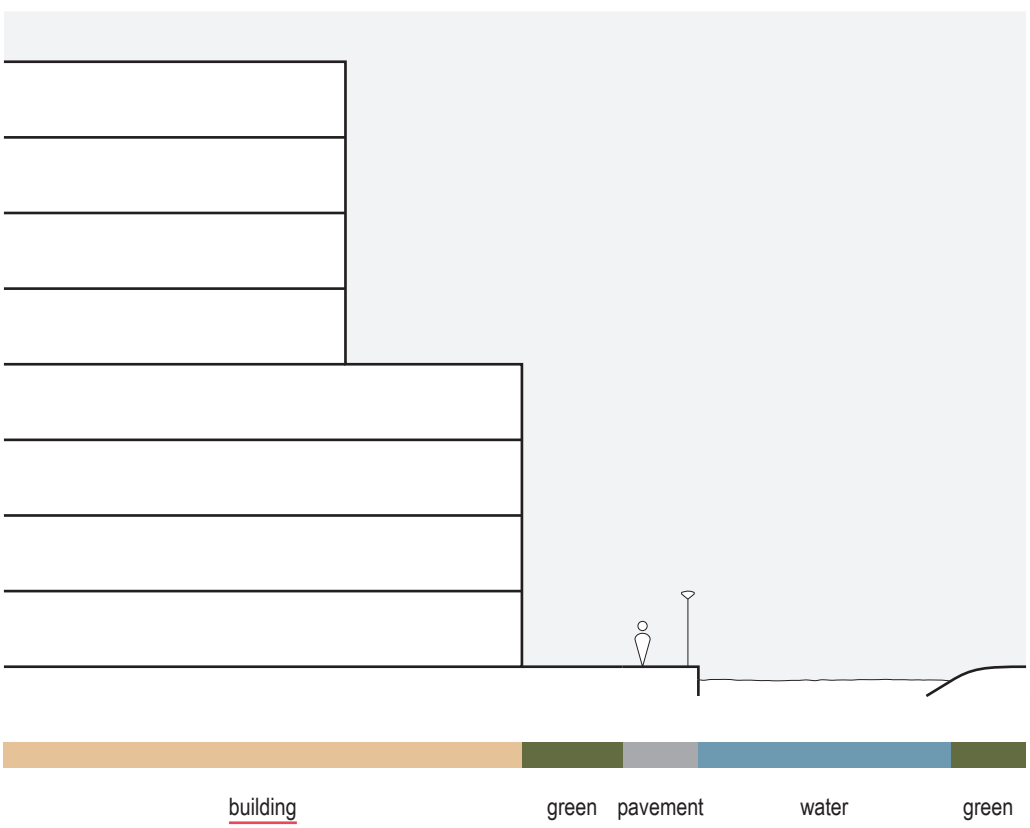
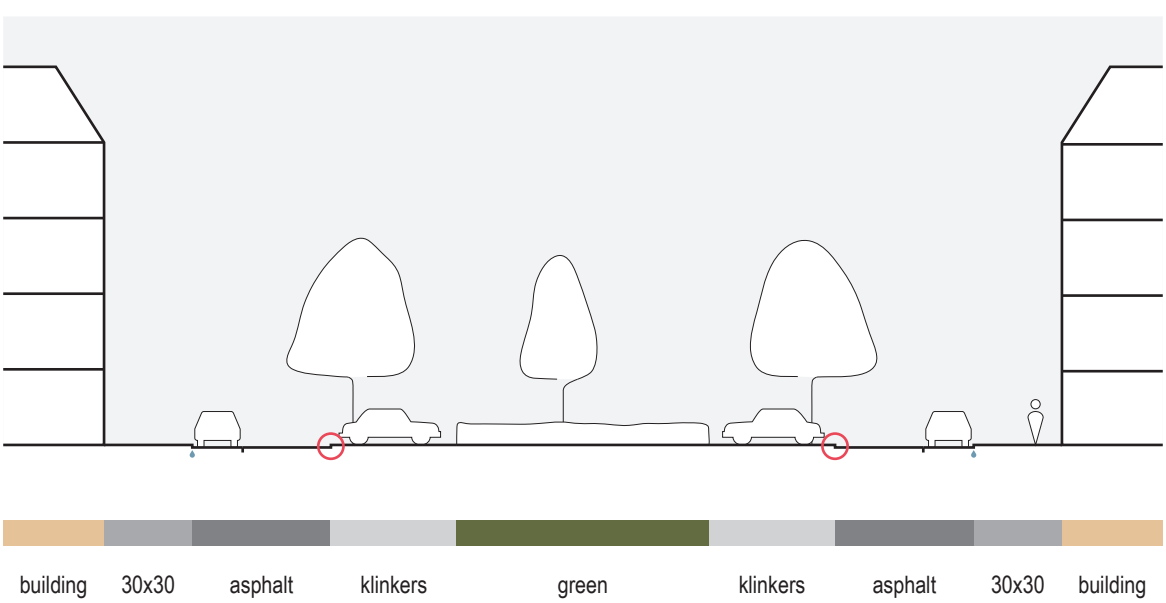



**Fig. A2.8**: De Boelelaan 1118, extremely urgent (Author, 2018)

**Fig. A2.9**: Van Tuyll van Serooskerkenweg 57, urgent (Author, 2018)





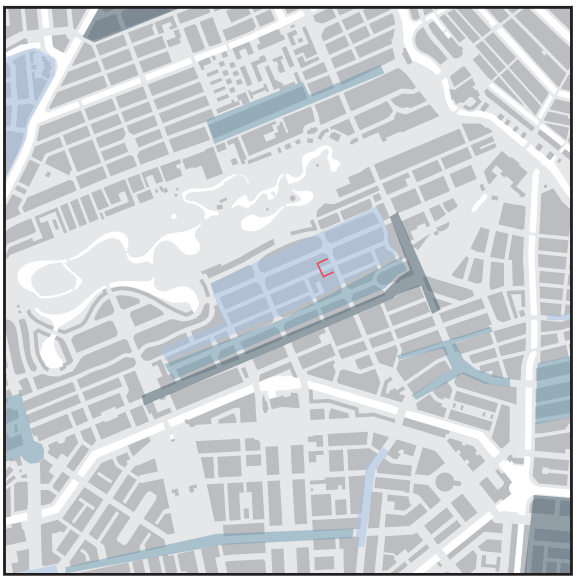


**Fig. A2.10**: Van Breestraat 78, urgent (Author, 2018)

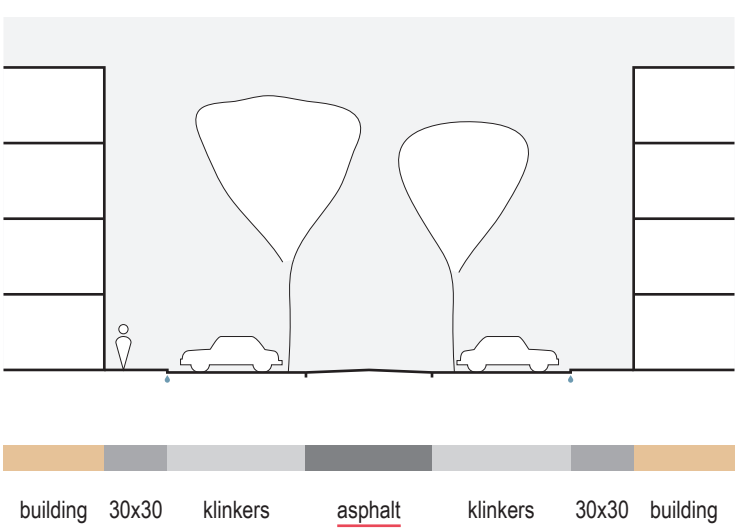
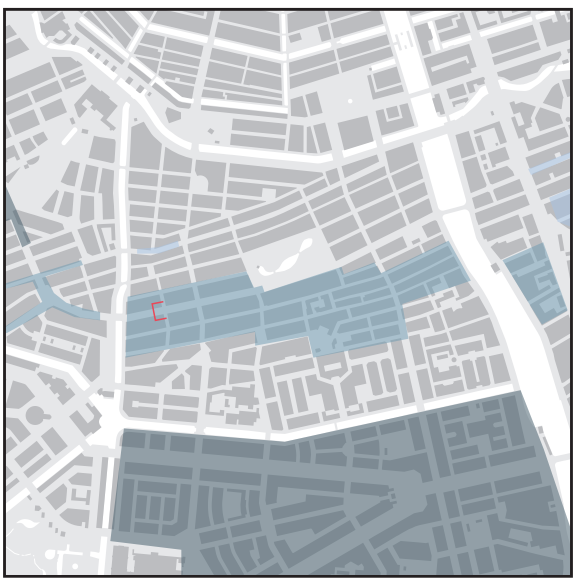
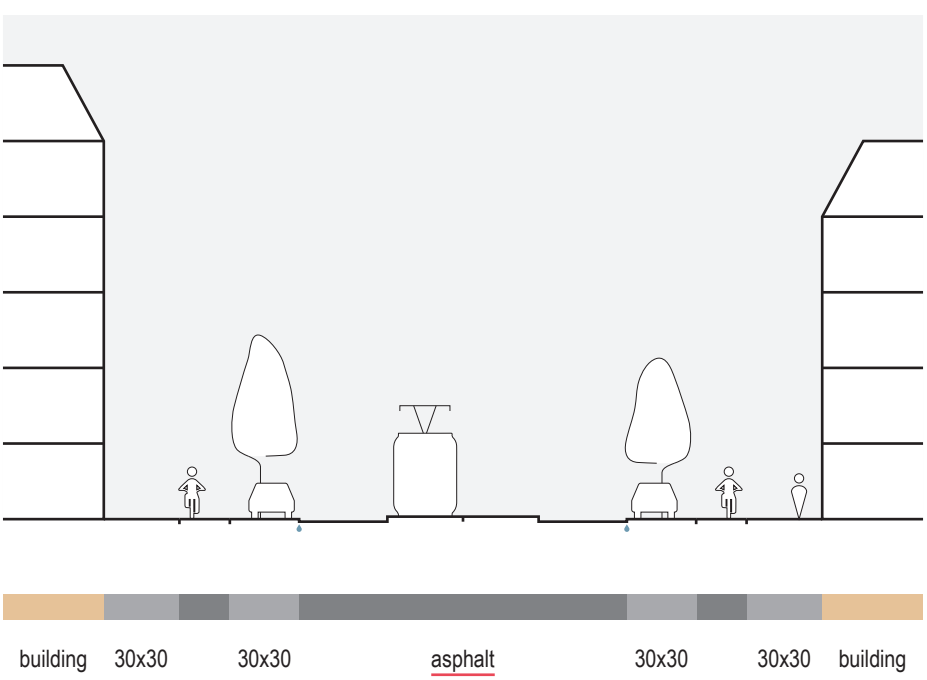


**Fig. A2.11**: Ceintuurbaan 45, very urgent (Author, 2018)





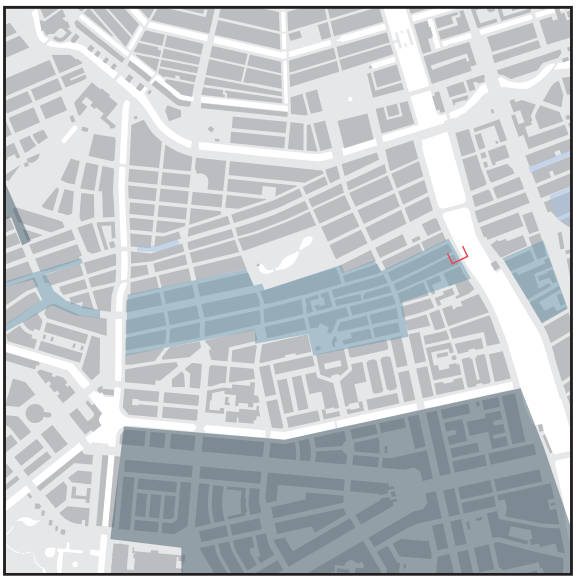


**Fig. A2.12**: Amsteldijk 55, very urgent (Author, 2018)

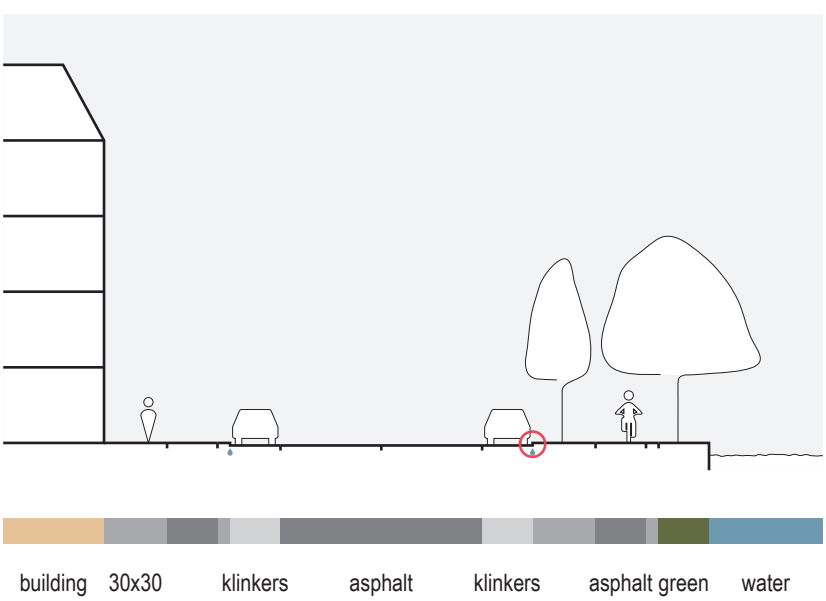
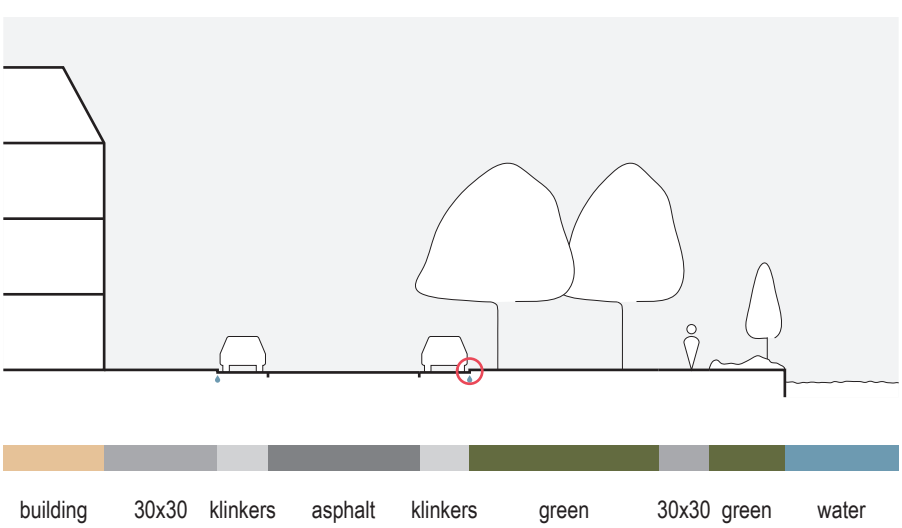


**Fig. A2.13**: Weesperzijde 71, very urgent (Author, 2018)





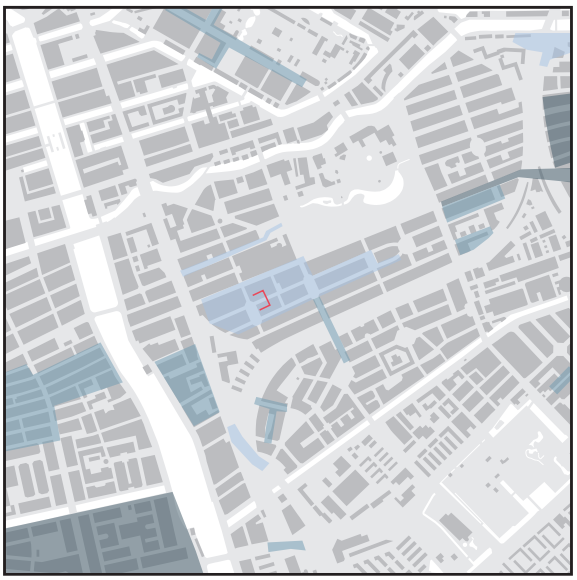


**Fig. A2.14**: Tweede Oosterparkstraat 72, urgent (Author, 2018)

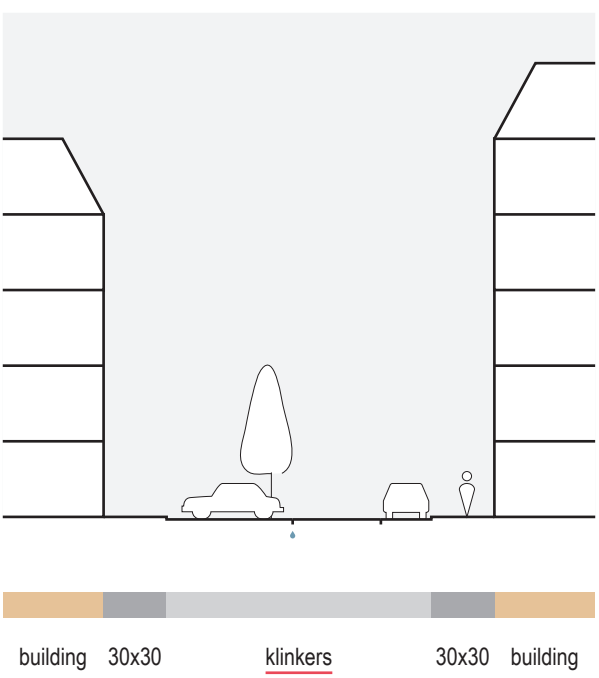
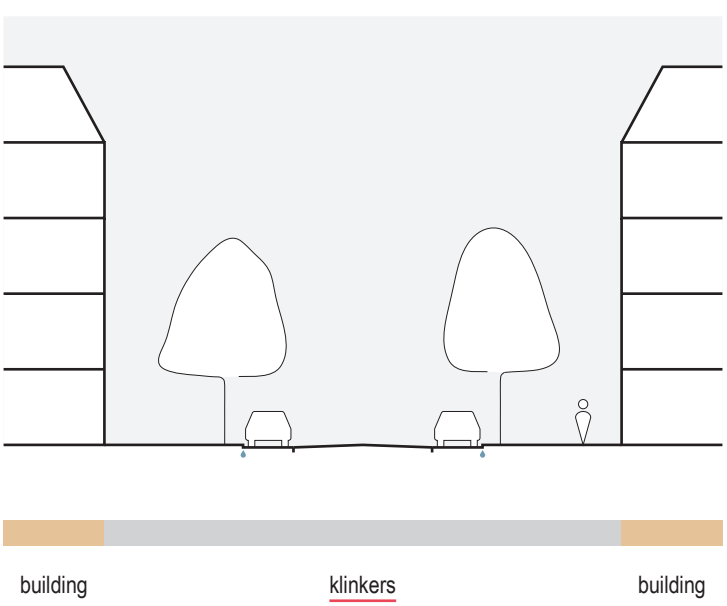


**Fig. A2.15**: Javastraat 62, extremely urgent (Author, 2018)





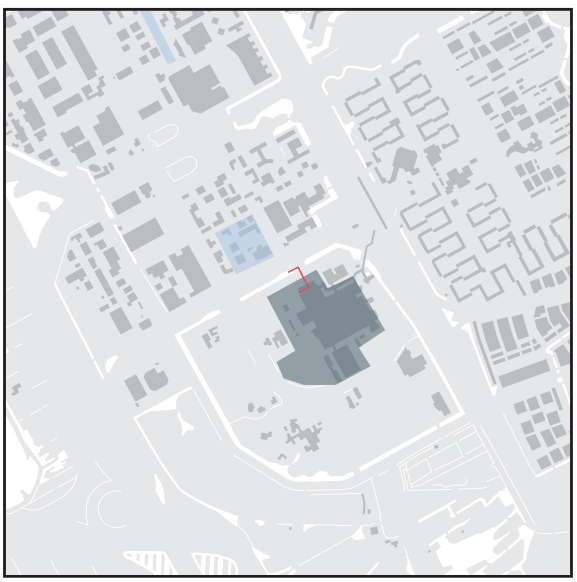


**Fig. A2.16**: Meibergdreef 9, extremely urgent (Author, 2018)

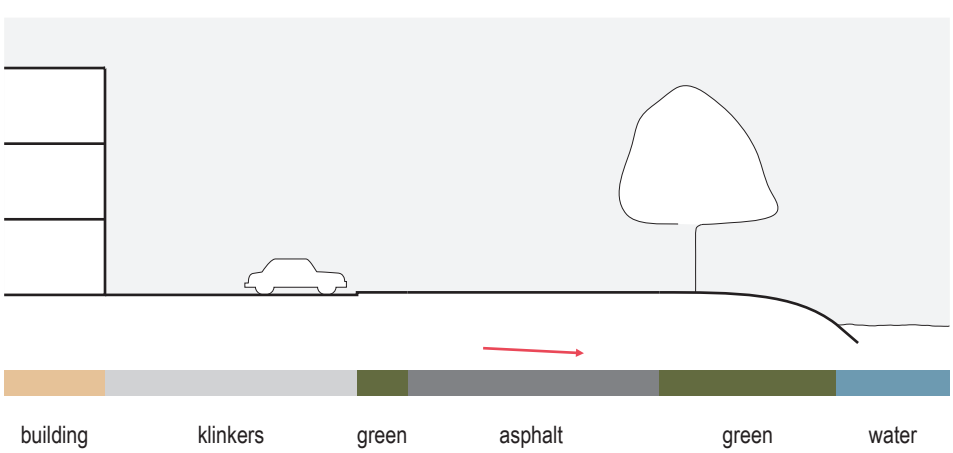
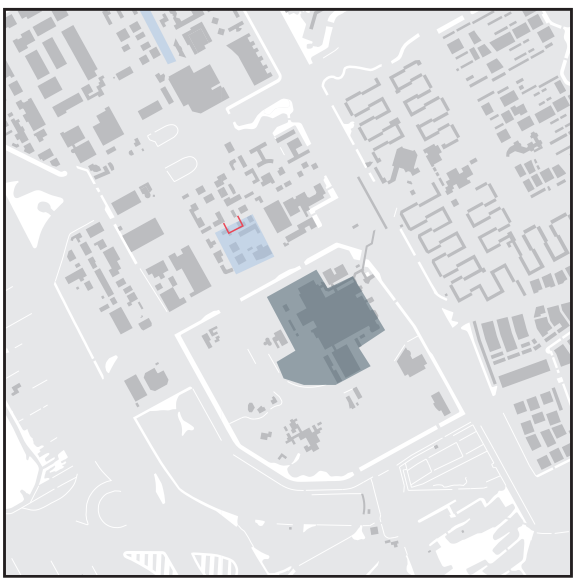


**Fig. A2.17**: Paasheuvelweg 36, urgent (Author, 2018)



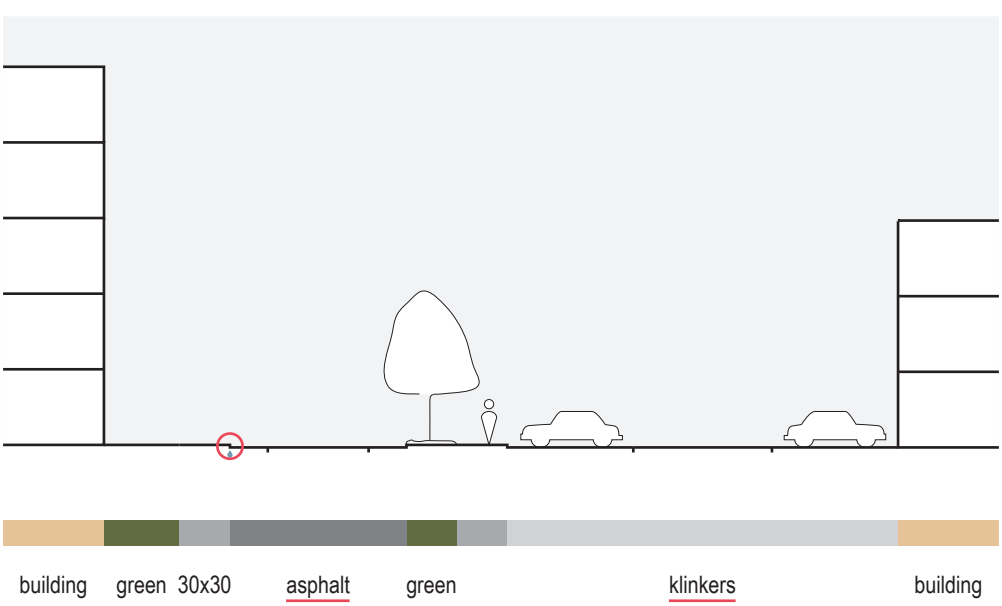




**Fig. A2.18**: Amstelveenseweg, Haarlemmermeerstation, very urgent (Author, 2018)

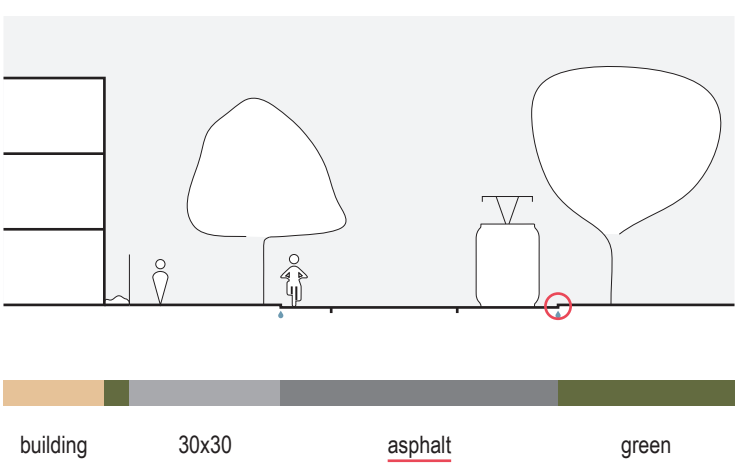
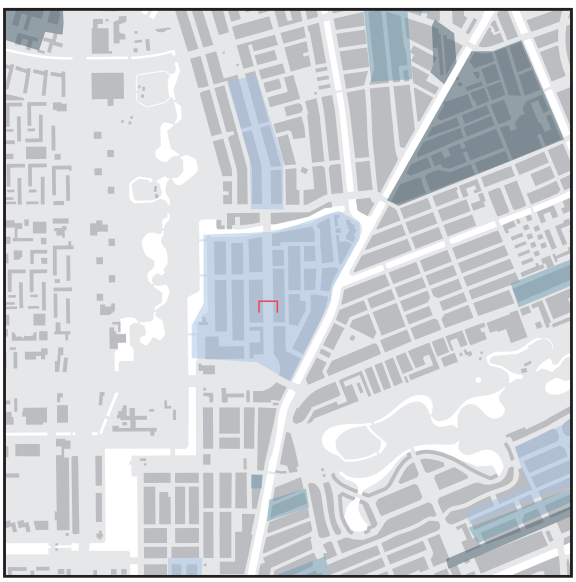
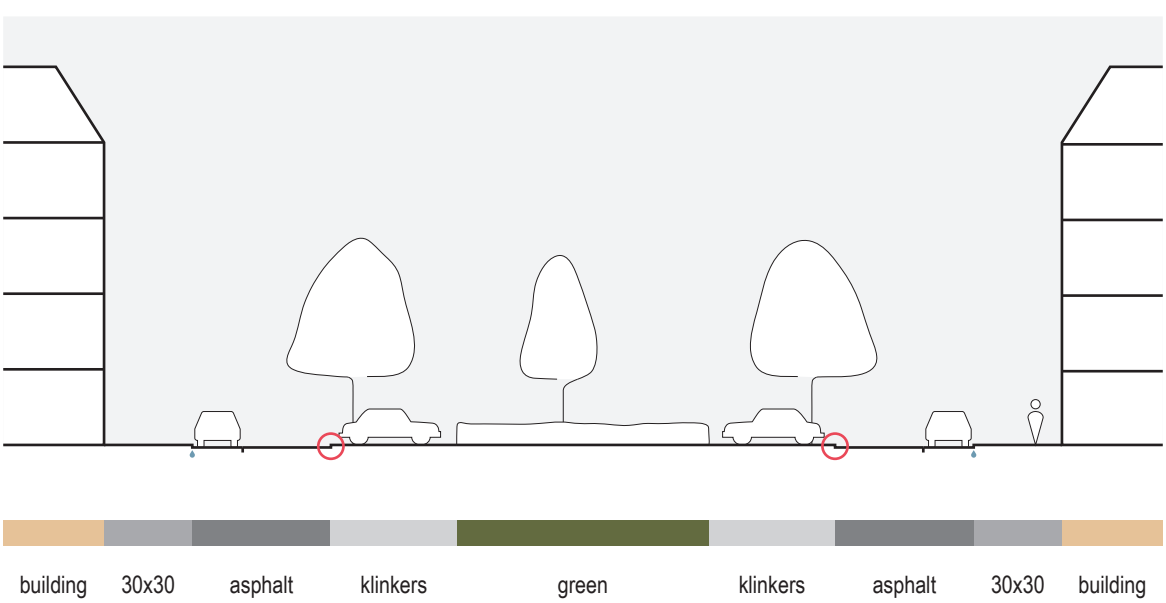


**Fig. A2.19**: Hoofdweg 50, urgent (Author, 2018)





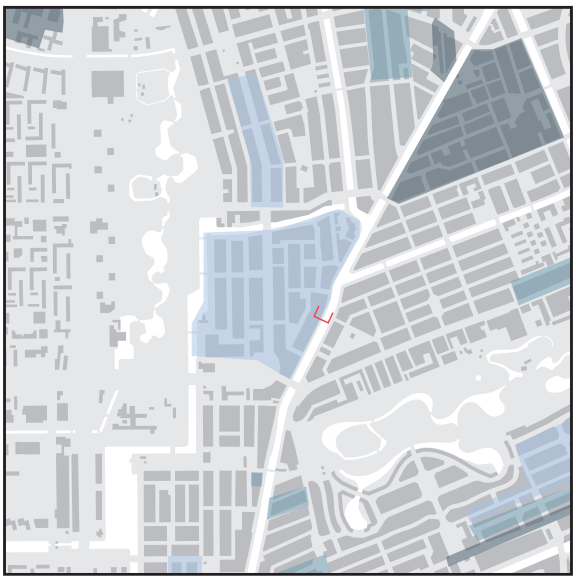


**Fig. A2.20**: Baarsjesweg 275, urgent (Author, 2018)

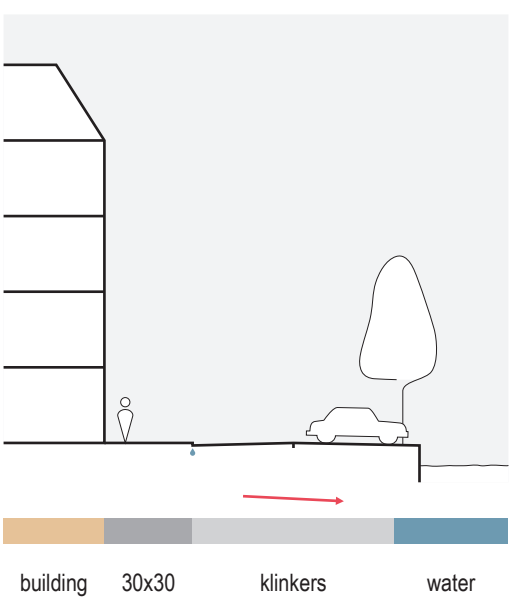
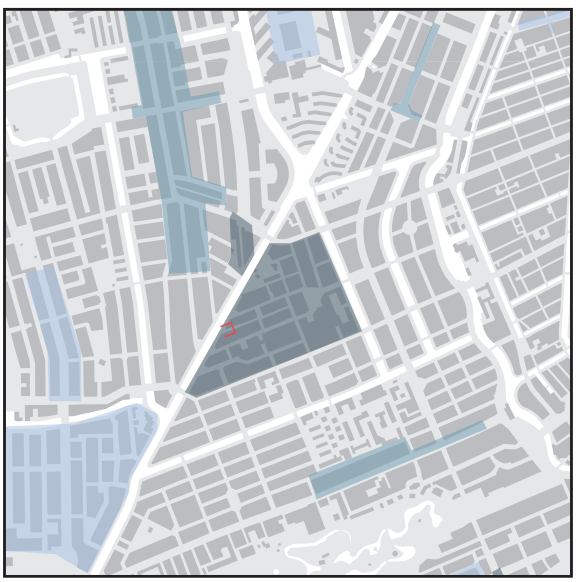
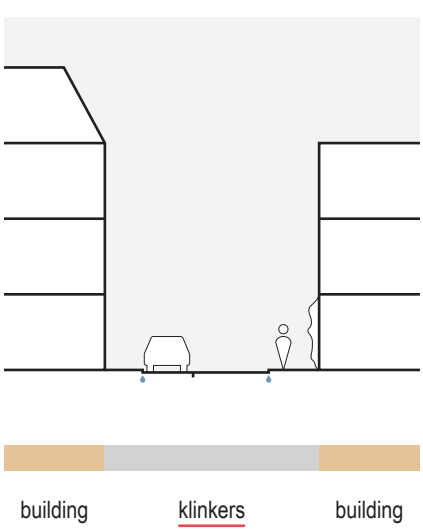


**Fig. A2.21**: Wenslauerstraat 75, extremely urgent (Author, 2018)





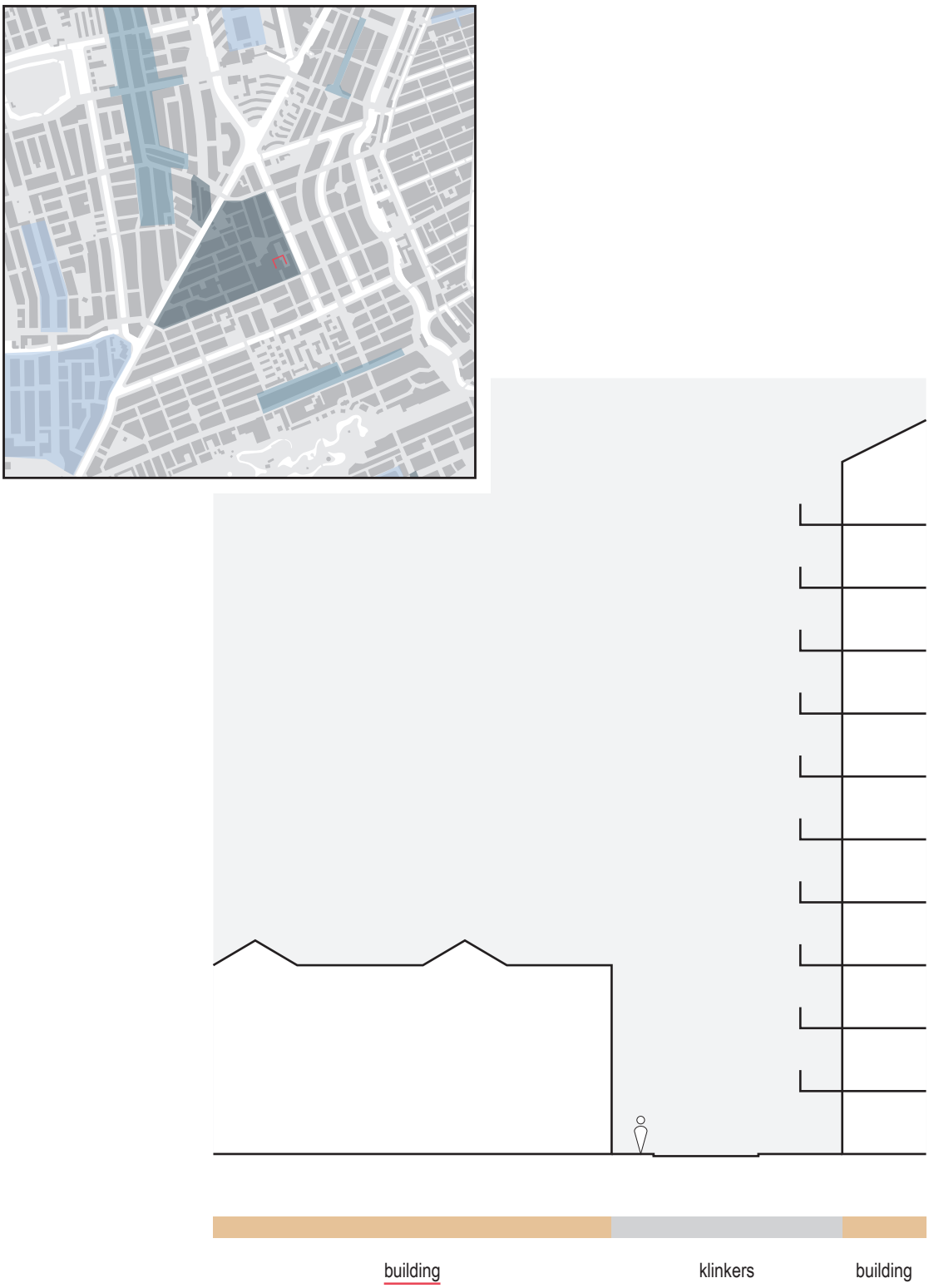
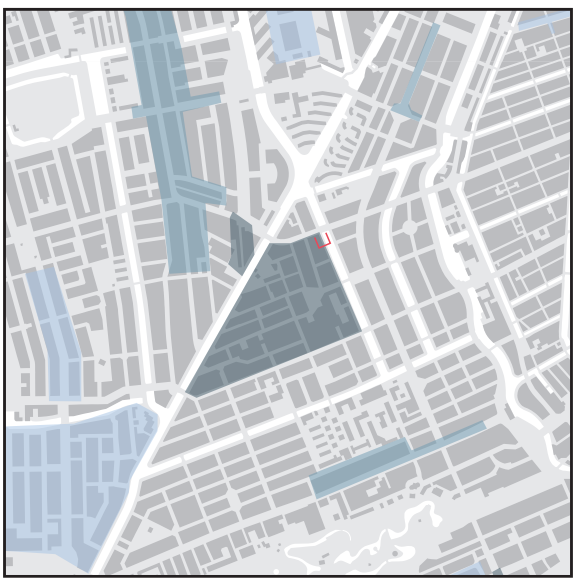
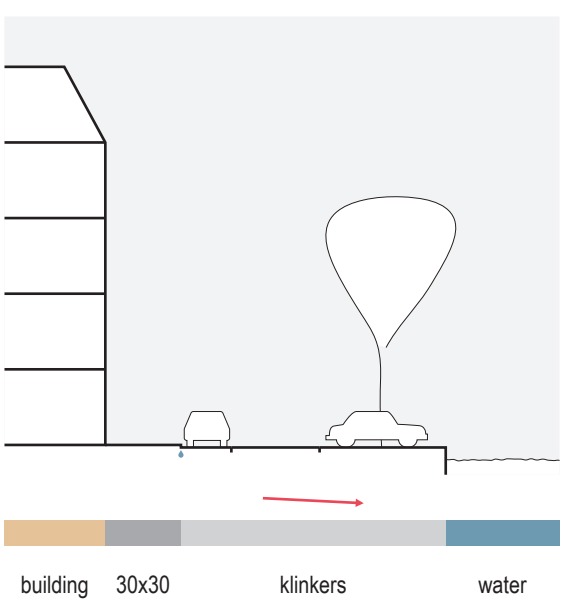



**Fig. A2.22**: Tollenstraat 47, extremely urgent (Author, 2018)

**Fig. A2.23**: Bilderdijkkade 24, extremely urgent (Author, 2018)





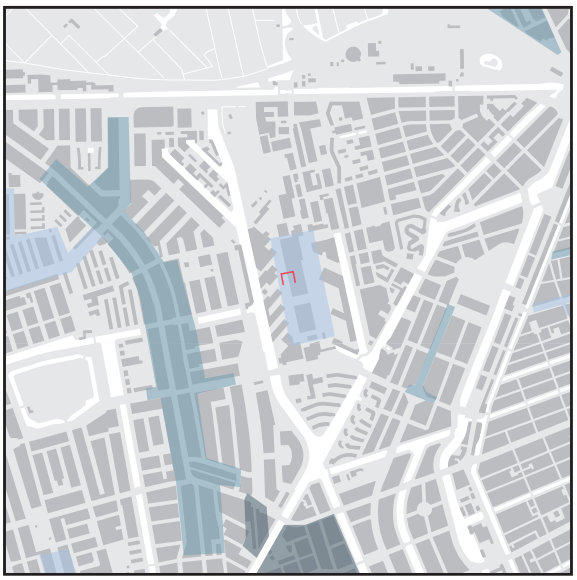


**Fig. A2.24**: Centrale Markthallen, urgent (Author, 2018)

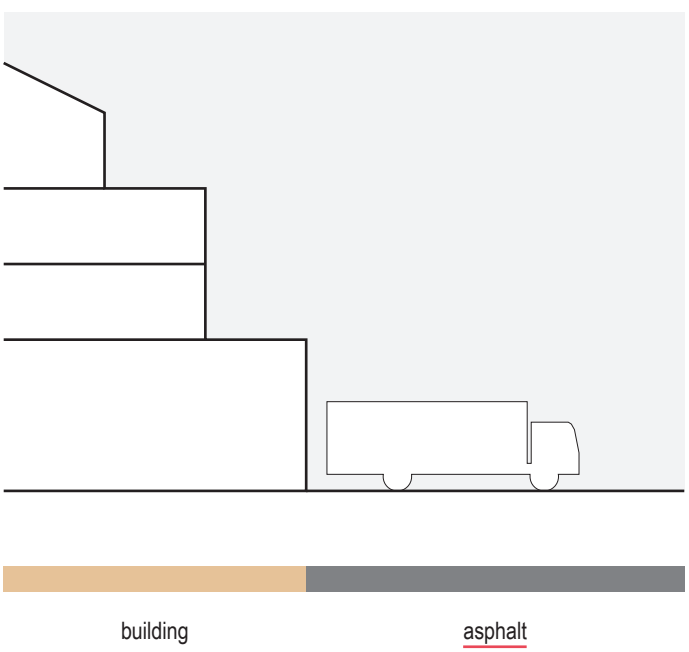
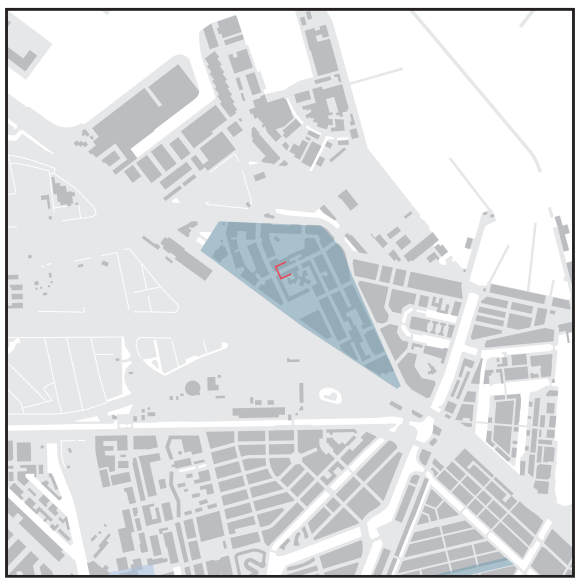


**Fig. A2.25**: Hembrugstraat 225, very urgent (Author, 2018)



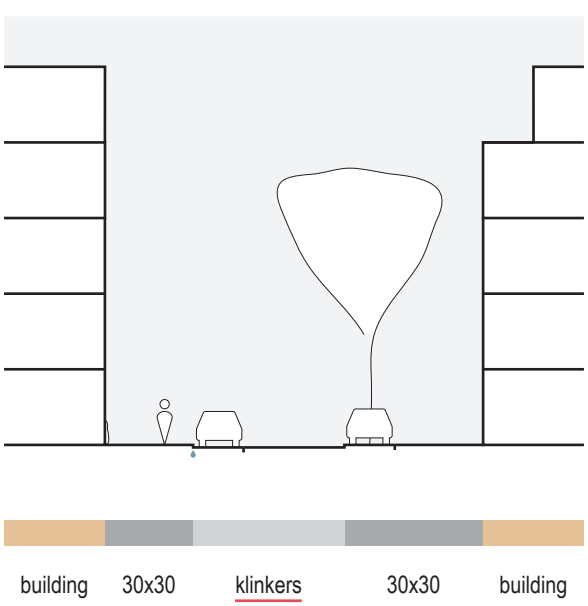




**Fig. A2.26**: Spaarndammerstraat 27, very urgent (Author, 2018)

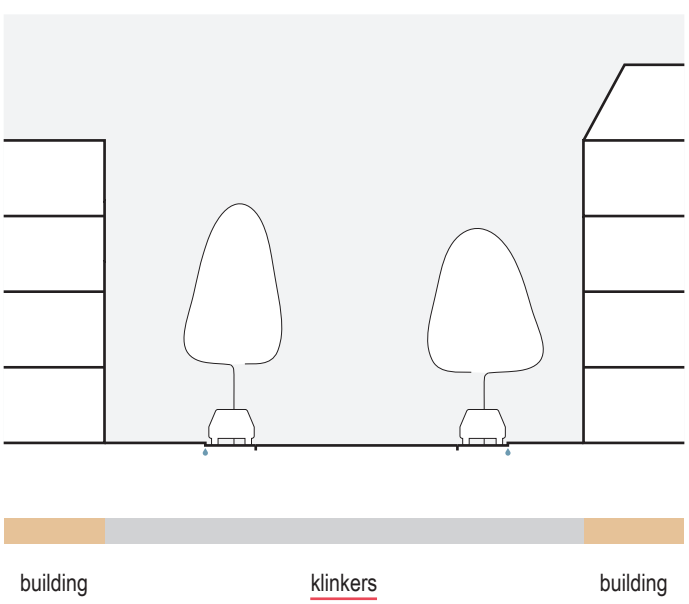


**Fig. A2.27**: Jan Tooropstraat 164, extremely urgent (Author, 2018)



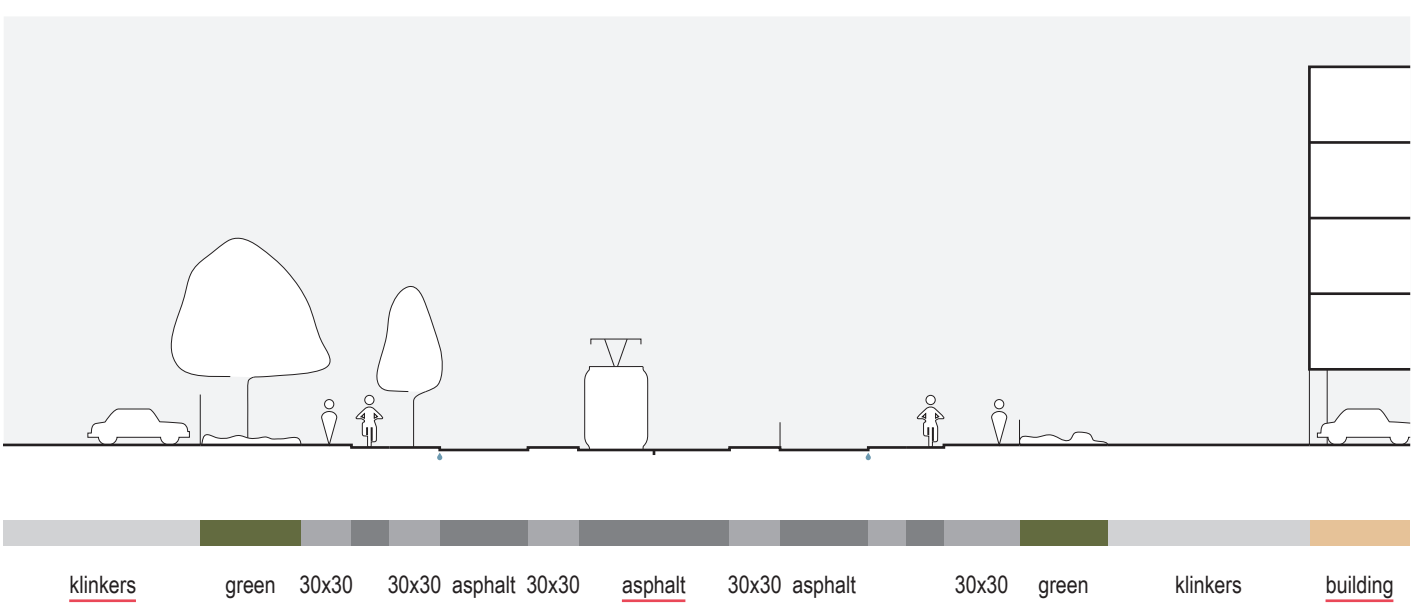




**Fig. A2.28**: Granidastraat 76, urgent (Author, 2018)

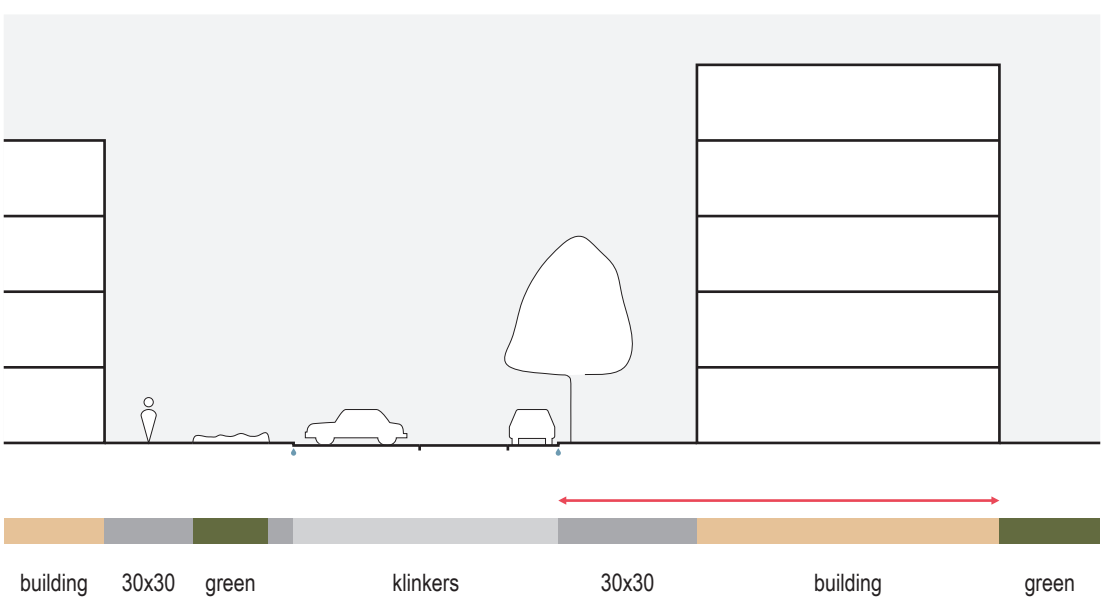
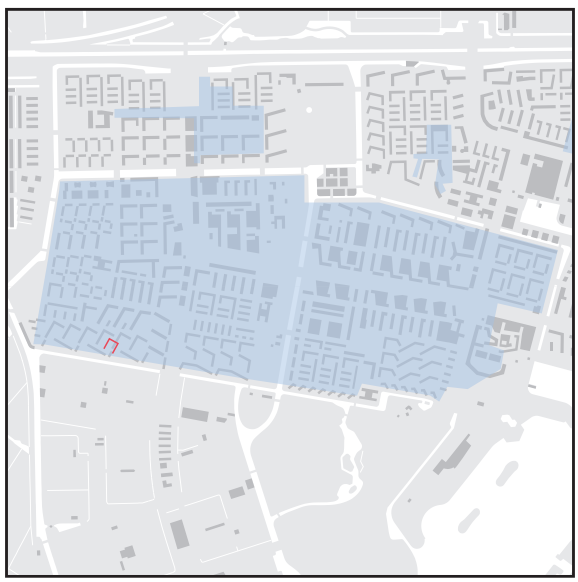
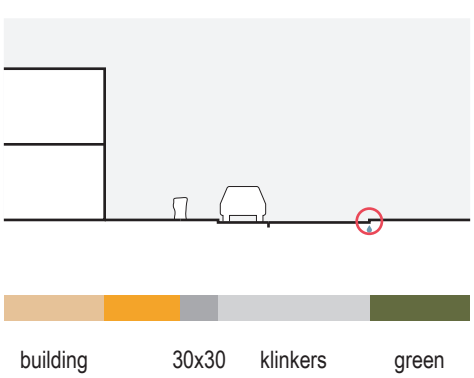


**Fig. A2.29**: Jaap Edenstraat 8, urgent (Author, 2018)





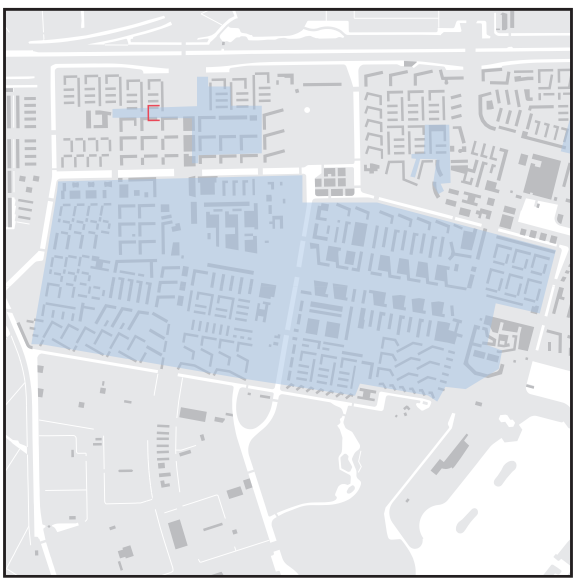


**Fig. A2.30**: Ruys de Beerenbrouckstraat 147, urgent (Author, 2018)

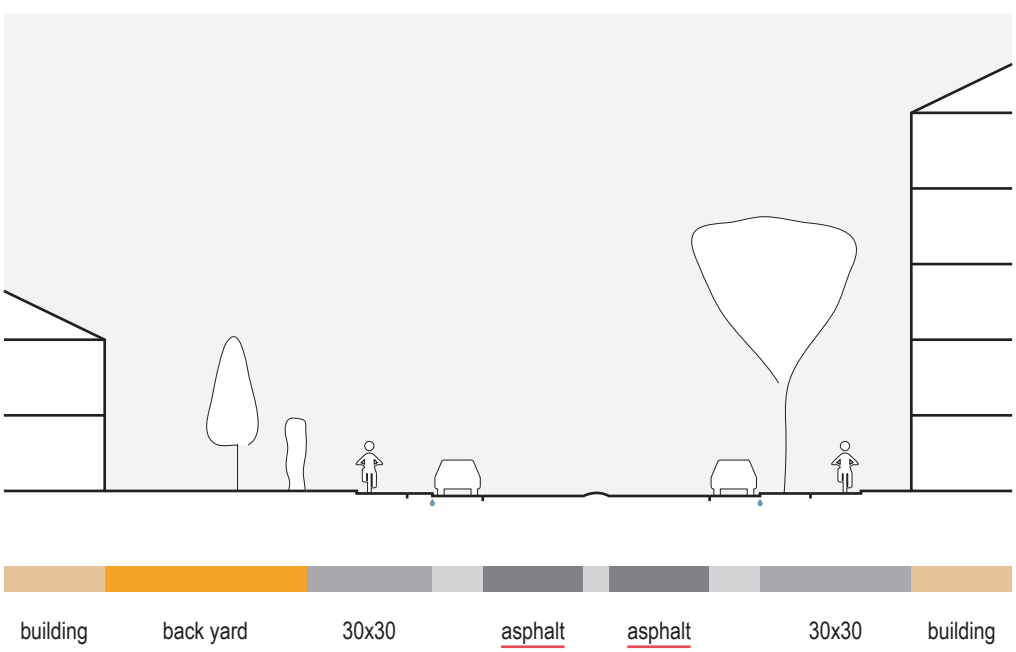


**Fig. A2.31**: Jan van Beersstraat 8, urgent (Author, 2018)

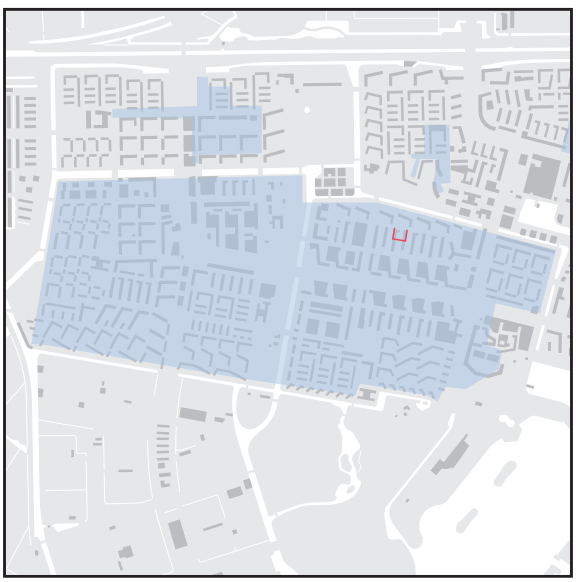






**Fig. A2.32**: Burgemeester Fockstraat 56, very urgent (Author, 2018)

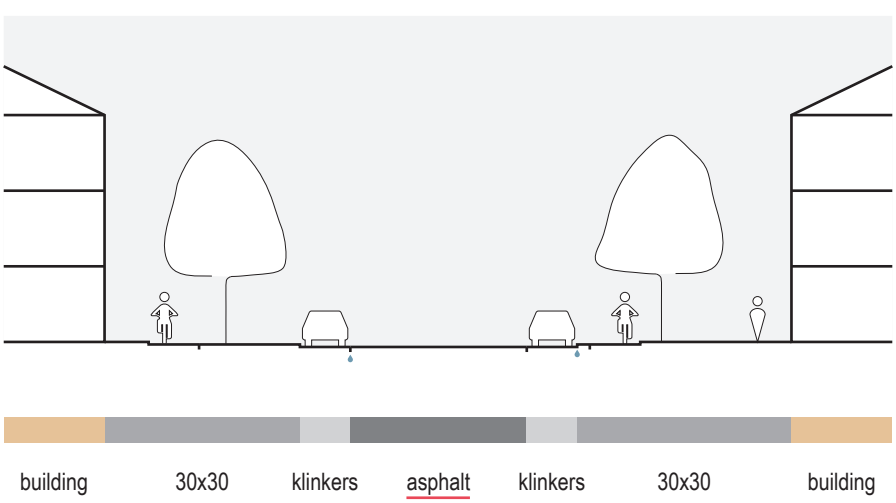


**Fig. A2.33**: Mekongweg 10, extremely urgent (Author, 2018)



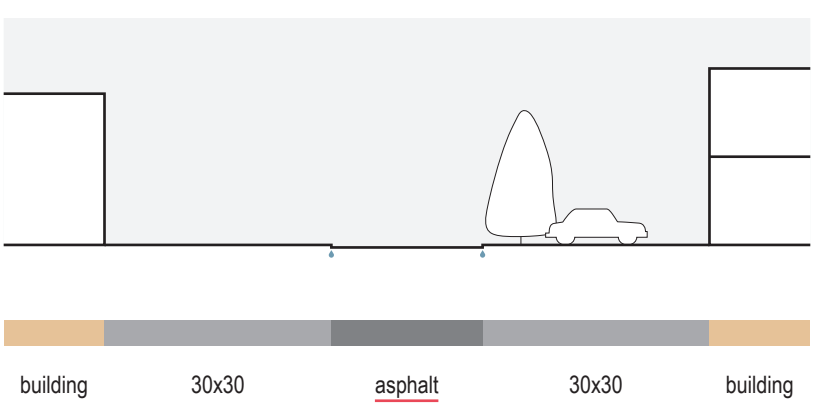




**Fig. A2.34**: Abberdaan 56, urgent (Author, 2018)

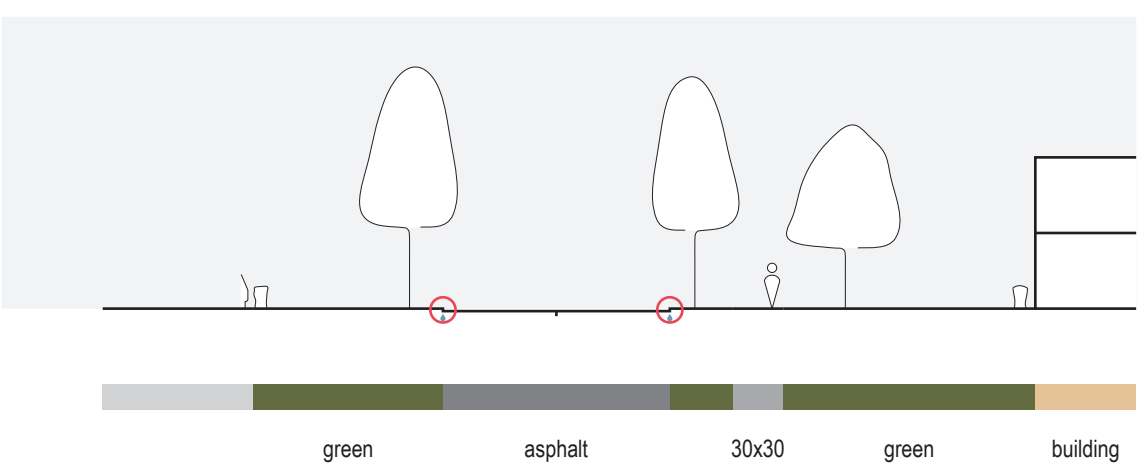


**Fig. A2.35**: Dukdalfweg 38, urgent (Author, 2018)



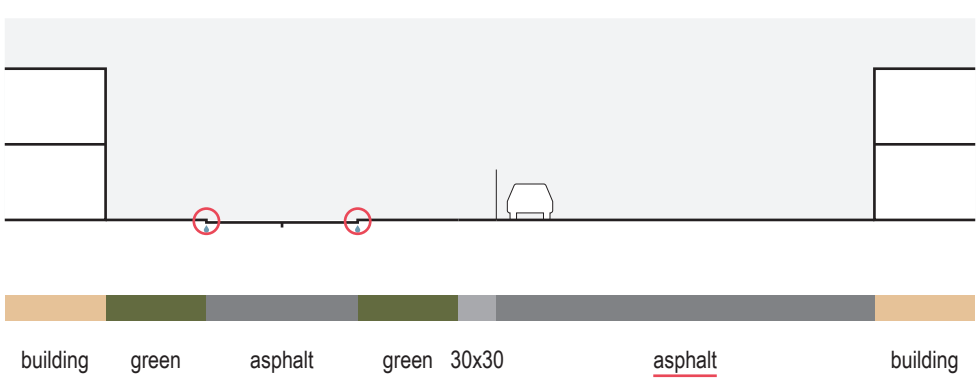




**Fig. A2.36**: Mercuriusplein 7, urgent (Author, 2018)

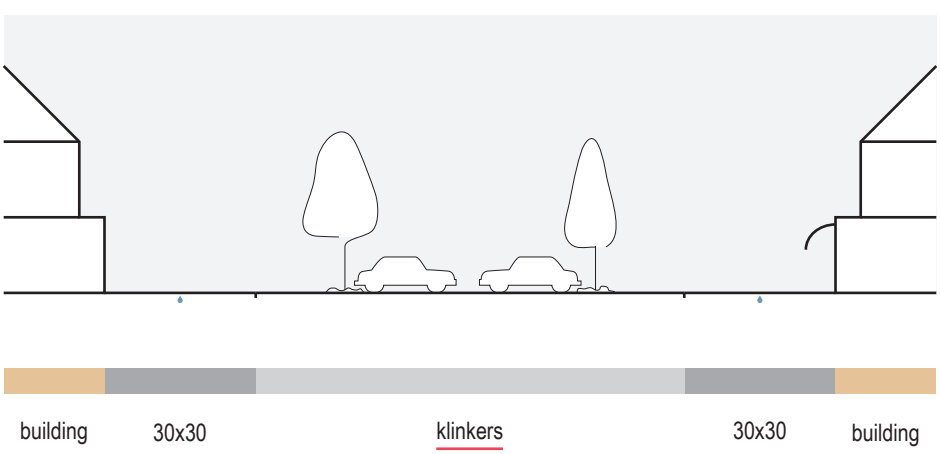


**Fig. A2.37**: Argostraat 34, urgent (Author, 2018)



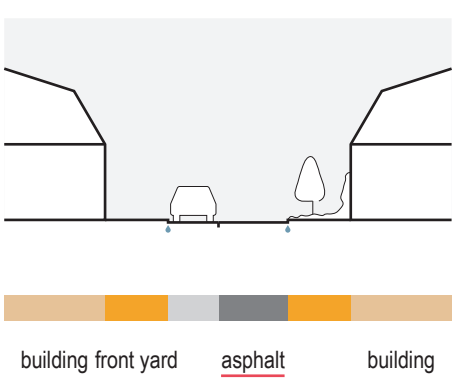




**Fig. A2.38**: Abrikozenstraat 43, urgent (Author, 2018)

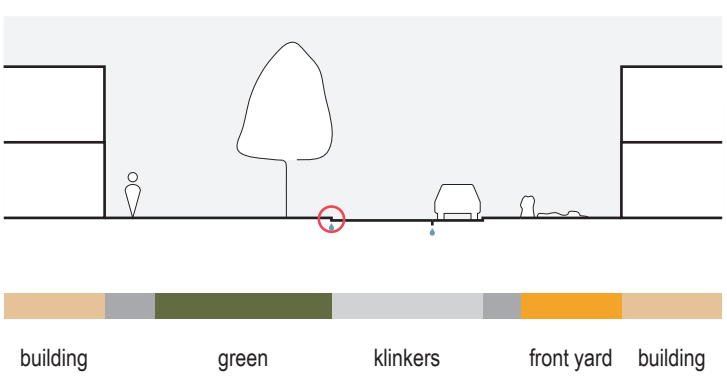
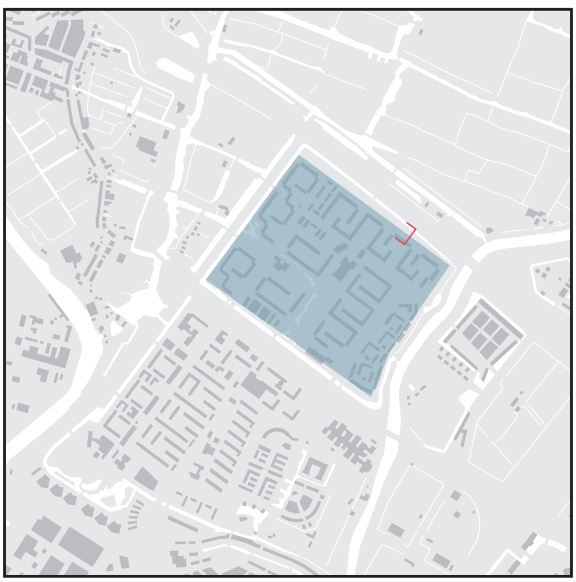
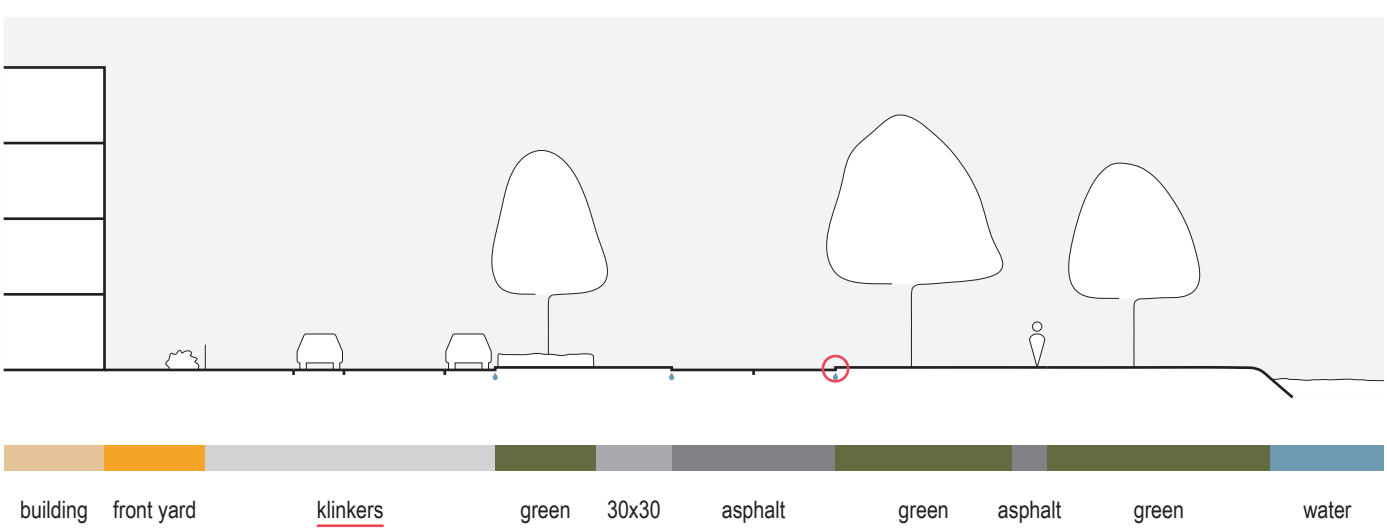


**Fig. A2.39**: Noorderbreedte 57, very urgent (Author, 2018)





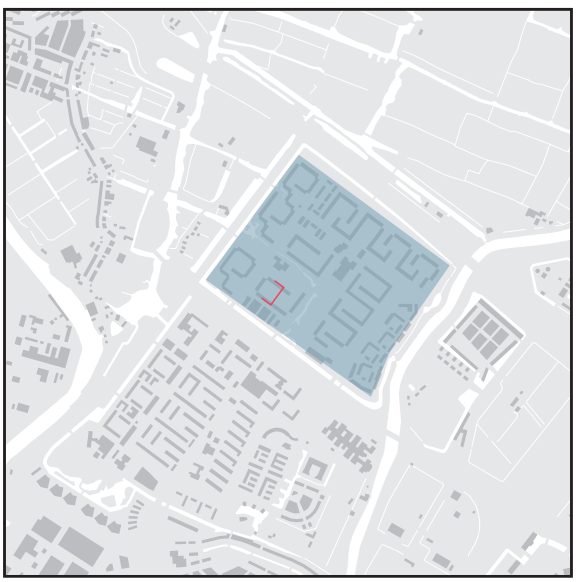


**Fig. A2.40**: Overslaghof 109, very urgent (Author, 2018)

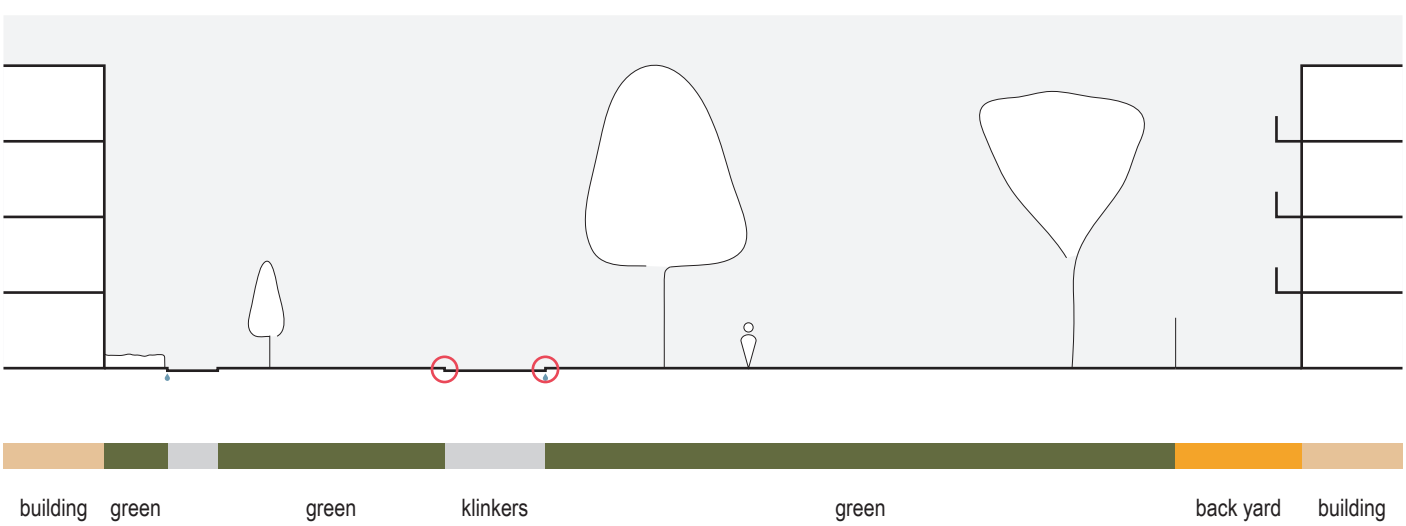
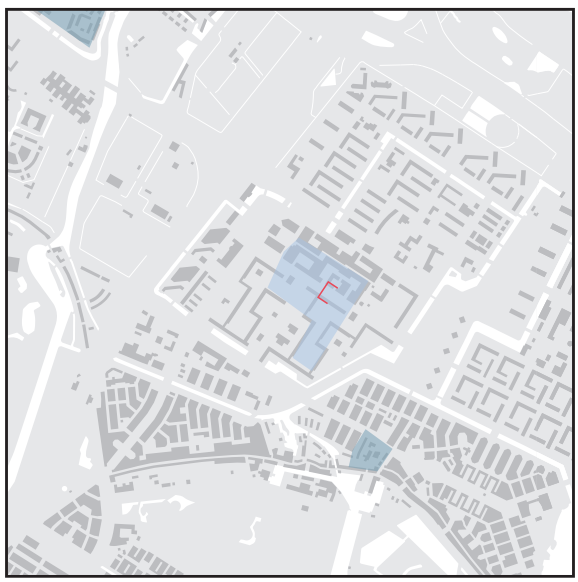
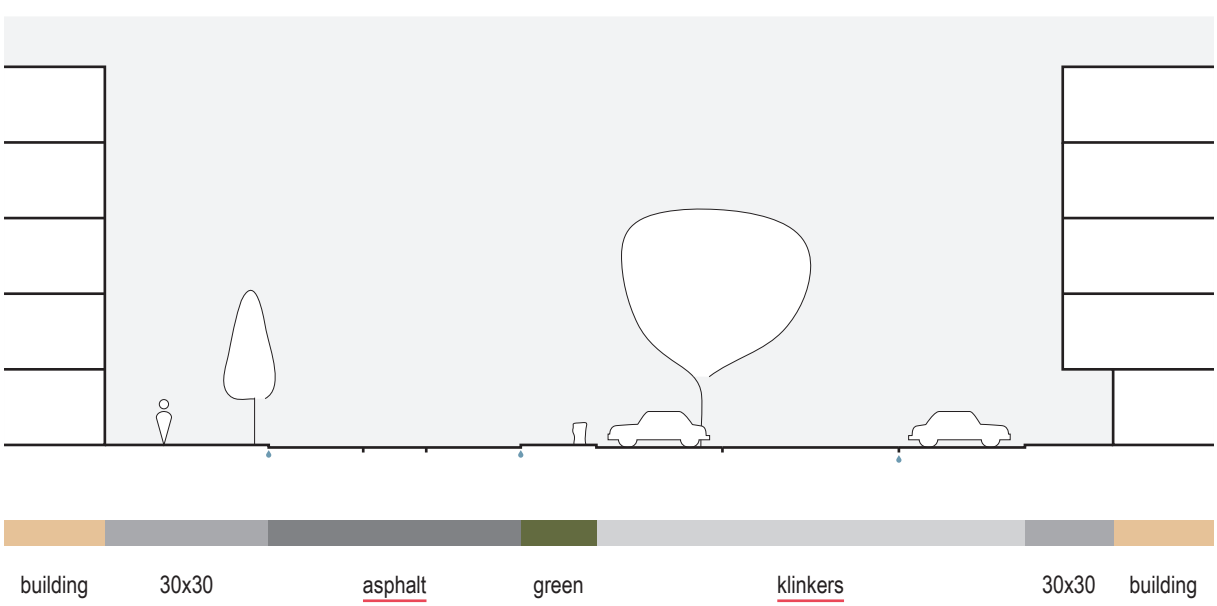


**Fig. A2.41**: Buiksloter-meerplein 244, urgent (Author, 2018)





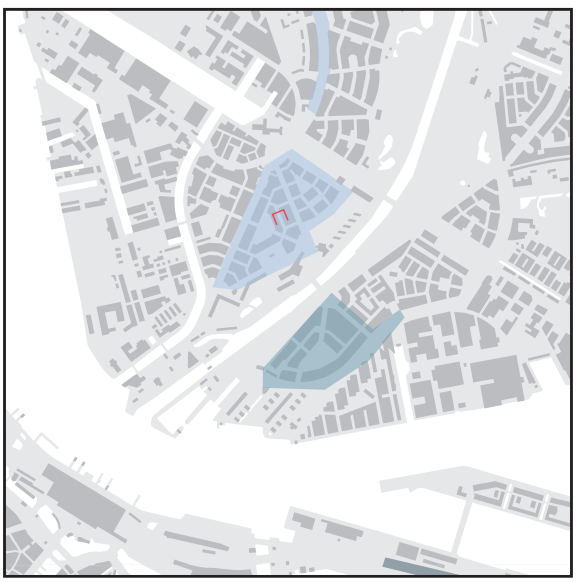
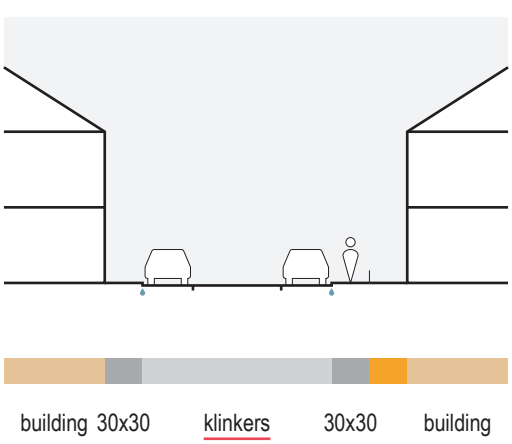


**Fig. A2.42**: Silenestraat 24, urgent (Author, 2018)



# APPENDIX 3: PERSONAL REFLECTION

This design and research project addresses possible interventions that can contribute to the creation of a storm water resilient city, while providing urban growth. This goal arised from two major developments which are currently going on: climate change and urban growth. These developments counteract each other, as climate change is causing extreme weather conditions and urban growth brings a larger paved area. This is partly why water nuisance and sewage overflows caused by heavy rainfall occur more and more often. By finding the right intervention for the right location, the city of Amsterdam can become storm water resilient, now and in the future. By finding synergies between storm water resilience and other local sustainable urban aspects, other challenges can be tackled simultaneously. This approach will contribute to the development of a future-proof city.

**Relation between graduation topic, studio topic and master track**

The Department of Urbanism at Delft University of Technology is concerned with the analysis, design and planning of cities and regions, with the goal to create more sustainable, resilient and fair societies. Since its establishment in 1948, the department has promoted the 'Dutch approach to urbanism', integrating the creativity of design methods with the rationality of academic research (TU Delft, n.d.). Knowledge and skills from urban design, spatial planning, landscape architecture, environmental technology and geoinformatics are combined. There are five principles that lay out the foundation of the present education at the department of Urbanism (Nijhuis, Stolk & Hoekstra, 2016):

1. Seeing the urban landscape as a multiscale interdisciplinary research object.
2. Gaining theoretical understanding, improving frame creation.
3. Dealing with unpredictability.
4. Designing across scales by visual thinking.
5. Exploring the various relations between research and design.

The strongest link between my thesis topic and the master track Urbanism at TU Delft is the Dutch approach to urbanism which is being used. The five characteristics are all visible in the process I went through. Especially the fourth characteristic, designing across scales by visual thinking, is very important for my project, as an urban system like the water system is acting on all scales. Exploring the various relations between research and design played an important role too. This aspect will be explained later in this reflection.

Within the Department of Urbanism, I am affiliated with the research group Smart Cities and Urban Metabolism. This research group investigates the performance of infrastructures, environmental technology and systems in relation to spatial quality, environmental sustainability, liveability and the social wellbeing of future cities (Smart Cities and Urban Metabolism, n.d.). The aim of this graduation project is to allocate interventions and improve one of the systems: the storm water system. The urban metabolism approach has been used to analyse how urban areas function with regard to the relationship between human activities and the (natural) environment. Then, interventions have been implemented on several scales: the city scale, neighbourhood scale, street scale and building scale. The interventions have been related to other aspects, like biodiversity, air quality and heat, in order to find synergies. This means several themes of the research group have been covered. By finding the most advantageous combination of interventions for both the storm water system and other sustainable urban aspects, a future-proof city will be developed.

**Relation between research and design**

In this graduation project the relation between research and design had multiple forms. The design research strategy started as Research for Design. This research strategy feeds the design process, with the ultimate objective to improve the quality of the designed object and increase its credibility (Frankel & Racine, 2010). In terms of the graduation project, this research strategy consists of the theoretical and analytical framework, which provided necessary information for the design phase. In this context I believe the term "research to enable design", used by Downton (2003), fits the research strategy best.

When the design phase of the graduation project started, the research strategy shifted towards *Research through Design*. In this strategy, design is used as a vehicle to make spatial problems visual and spatial, to explore possibilities and to generate solutions (Frankel & Racine, 2010). By sketching dozens of variants, considering multiple scenarios and going through several scales, problems, potentials and solutions are found. I believe experimenting and going through an iterative process multiple times is the most important part of the design process. This process of iterations is illustrated by Figure A3.1.

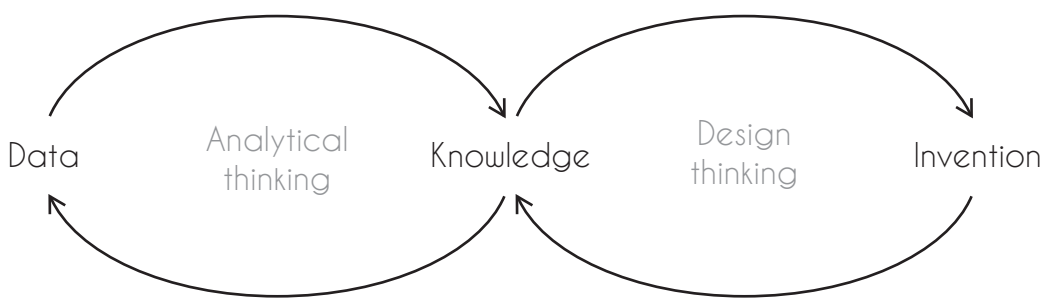



**Fig. A3.1**: Relation between research and design (Author, 2018)

**Value of way of working**

By using a well developed city like Amsterdam as design and research site, you do not have to worry about the availability of data. Useful and extensive spatial, demographic and technical data is published by several organisations, like the municipality of Amsterdam or Statistics Netherlands (CBS). Apart from this online data, there are plenty of printed sources in the form of books, magazines and reports. That is why I would state I had access to too much data, rather than too little. Even in the last few weeks of the graduation project I still found useful sources which I had never seen before, despite the fact I had been looking for it. It turned out that dealing with such a large amount of data is only possible when a clear library is created and when the data is critically assessed.

The methods I used for data collection are literature study, case study, trends study and historical research. These methods could have been supplemented with interviews with the municipality and surveys among residents, in order to get more site specific information. Instead, I collected this kind of data myself by observing the design sites during site visits. This could be seen as a gap in the information I compiled. As an outsider, and an urbanist, you focus on other things than residents might do.

The methodology is being optimised by including iterative processes. Going through different scales is one of them. By applying interventions on several scales and by switching between these scales, the design solutions can be optimised and embedded in their location. Going through different times is another iterative process. By switching between the past, present and future, and thus between analysis and design, the design solutions are both connected to the past and ready for future changes. I think these iterative processes make the methodology used a valuable part of the graduation project.

The approach used could have been extended with a more extensive actor analysis and feasibility study, in order to make the project more realistic. By doing this, it would be easier for municipalities and urban designers to make use of the conclusions and methodology. This was not included in the current research due to the focus on additional (sustainable) benefits of the design, and thus due to time limitations.

My personal goal for this graduation project was to learn more about the spatial implications of creating a storm water resilient city. Furthermore, I think learning more about other sustainable and socio-economic aspects is very valuable, as the discipline of urbanism is so closely linked to other disciplines. My mentors could both help me very well with this. Their feedback has been very valuable and they always gave me imput to improve both my process and design. Especially after each presentation there was enough time for evaluation with my mentors and peers. This brought me new insights and inspiration.

**Relation between graduation topic and the wider social, professional and scientific framework**
The main concept of this graduation project is water resilience in relation to urban growth, in the context of Amsterdam. There are many studies done about both these topics, since they are highly relevant and topical. However, a project about the relation between the two is relatively unexplored yet. It is expected that by looking at the historical development of the relation between urban water and urban growth, today's role of water in the city can be explained. This will help to design the right intervention for the location. Furthermore, synergies with other sustainable aspects, like urban heat island, biodiversity and air quality, will be investigated in order to create a storm water resilient and future-proof city. Using a clear methodology could help municipalities and urban planners making their cities water resilient while deriving additional benefits from this as much as possible.

There are many projects going on in Amsterdam which are related to the storm water resilience of the city. This is, amongst others, tackled by initiatives like Amsterdam Rainproof and projects of the municipality (Amsterdam Rainproof, 2017a; Gemeente Amsterdam, 2017). Apart from this highly relevant topic, Amsterdam is facing other issues as well. The city is also working on other sustainable urban aspects, like energy generation, cleaner air and waste management, for example. Furthermore, local aspects are being tackled, like traffic safety, parking problems and educational opportunities. It is therefore important to explore synergies between storm water resilience and other aspects of the city and to rethink the way current projects related to water resilience are taken care of. This will safe time, money and effort, and this will make Amsterdam a safer city.

Furthermore, the Dutch government is currently working on the 'omgevingswet'. This law aims

to combine dozens of existing laws and hundreds of existing regulations, in order to make the legislation easier and more accessible. The various plans for spatial planning, the environment and nature will be better coordinated. This also gives the opportunity to finally include various aspects of sustainability in the legislation. Sustainable projects, like wind farms, will be promoted and there will be more space for residents to come up with their own ideas. In this way, local problems can be solved on a local level. Furthermore, municipalities, provinces and water boards will get more space too. They can adjust their environmental policy to their own needs and goals (Rijksoverheid, no date).

One of the main parts of the 'omgevingswet' is the 'omgevingsvisie'. This vision explains the outline of the long term vision for the physical environment. It contains subjects as buildings, infrastructure, water systems, water, soil, air, landscape, nature and cultural heritage. Both a description of the current situation and the preferred future quality of the living environment are included. As so many subjects are included in this vision, it will take years to make and fine-tune it. This graduation project can therefore be a source of inspiration. It shows how synergies can be found between various objectives, contributing to the climate resilience of the city. This emphasizes the relevance of this graduation project. The method can be used by municipalities to reach their several goals.

Although this graduation project specifically focuses on Amsterdam, the problems mentioned occur in various other cities as well. Climate change and urban growth are global phenomena, which means all cities of similar size and topography can make use of the conclusions and methodology of this graduation project. In practise, this means cities located within the Randstad region are especially suitable, like Rotterdam, Utrecht and The Hague. These cities are of similar size or smaller and urban growth is clearly going on (Centraal Bureau voor de Statistiek, 2017). Furthermore, the topography is very similar: mainly flat without a lot of exceptional areas. In conclusion, the conclusions and methodology of this thesis may function as a reference and inspiration for other cities facing similar issues, especially when they are of similar size and topography such as the cities located in the Randstad region.

**Ethical issues and dilemmas**

There is one main ethical dilemma that could have been elaborated. This dilemma is about the line between (economic) feasibility and eliminating risks. By improving private and public space with all the relatively small interventions proposed, a certain risk of water nuisance has been eliminated. However, the repetition time of this risk is relatively short, as described in section 4.1.1, and has not been examined any further. This means when a serious storm water disaster takes place, the interventions applied will be insufficient and dangerous situations could occur. By elaborating on this, a balance can be found between the right interventions and the (economic) feasibility. You could overdimension the infiltration and storage capacity, but when this costs too much money relative to the chance of a disaster, it is not beneficial anymore. Even though one would tend to say safety of people should always go first, it is very hard to define this thin line.