Initiatives Fostering Sustainable Drainage Systems in Cities

A COMPARISON BETWEEN AMSTERDAM RAINPROOF AND WATER SENSITIVE ROTTERDAM

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Colophon

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Marijke Rommelse

Groningen, June 11, 2017

Abstract

Ongoing climate change and rapid urbanization are causing cities to become more vulnerable to extreme precipitation. Heavy rainfall events take place with increasing frequency in the Netherlands, and place strain on conventional drainage and sewerage systems, which are not designed to handle such circumstances.

This research focuses on the rainwater resilience of the two most populated cities in the Netherlands: Amsterdam and Rotterdam. In preparation for the future, both cities have introduced ambitious initiatives to enhance their resilience to extreme weather events, including fostering the implementation of more Sustainable Drainage Systems. This research specifically considers the Amsterdam Rainproof program and the Water Sensitive Rotterdam movement, comparing them using the framework of Restemeyer et al., (2015). The comparison was made using information gathered from a review of recent municipal policy documents focusing on adaptive strategies, and using semi-structured interviews to gather primary information/data on the work of the organizations.

Both initiatives have a strong focus on transformability in the work they do. Their objective is to increase the risk awareness of the public and stimulate participation in the programs of their Rainproof or Water Sensitive ideology or movement. Social capital plays an important role, and although their approach is a very social one, involving interaction with the community and other groups, they also aim to influence policy, and definitely do contribute to the robustness and adaptability of the cities as well.

Policy recommendations are made from the results of this case study. These include combining both top-down and bottom-up strategies when implementing further SuDS projects on the way to becoming Water Sensitive Cities. Furthermore, the multifunctional value of SuDS should be considered in policy, since SuDS often can tackle many problems at once.

Key words: Sustainable Drainage Systems, initiatives, transformability, Amsterdam Rainproof, Water Sensitive Rotterdam, social capital, multifunctionality

Abbreviations

LID	Low Impact Development
RAS	Rotterdam Adaptation Strategy
RCI	Rotterdam Climate Initiative
RRS	Rotterdam Resilience Strategy
SuDS	Sustainable Drainage Systems
WSR	Water Sensitive Rotterdam
WSC	Water Sensitive City
WSUD	Water Sensitive Urban Design

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Chapter 1: Introduction

1.1 Background

In the future, both increased flooding and rapid building and development are expected in urban areas. Due to this, cities will need to find new alternatives to conventional storm water management methods. An alternative, and holistic approach is the use of Sustainable Drainage Systems (SuDS) (Perales-Momparler et al, 2016). SuDS is a term that contains many different techniques to drain water in cities in a more sustainable way (Fletcher et al. 2015). For example, different types of SuDS include green roofs, permeable pavements, and infiltration basins (Perales-Momparler et al, 2015). During a transition to a new SuDS system it is crucial that all stakeholders are represented, and that both governmental and non-governmental multidisciplinary professionals are included in the discussions (Perales-Mompaler et al, 2015).

1.2 Problem statement

Cities in Europe are increasingly vulnerable to extreme precipitation events. For example, on July 2, 2011, Copenhagen experienced flooding from high intensity precipitation, which lead to damage costing an estimated € 800 million (Olsen et al., 2015). Also, urban flooding in the United Kingdom in the summer of 2007 highlights an increasing risk of similar events (Evans et al., 2008).

On July 28, 2014, the Netherlands experienced torrential rainfall with a maximum measurement of 131.6 mm, significantly higher than the criteria for extreme precipitation of 50 mm per day, as defined by the Royal Netherlands Meteorological Institute (KNMI, 2014). On this day, the city of Amsterdam struggled with flooded city streets, the closure of main ring road— the A10 highway— and flight cancellations at Schiphol international airport, as a result of this singular event (Rainproof, 2014).

This study aims to explore current initiatives in Amsterdam and Rotterdam that promote the use of SuDS to combat urban flooding, and what role these initiatives play in fostering societal change.

The definition of an *initiative* according to the Cambridge dictionary is "*a new plan or process to achieve something or solve a problem"* (dictionary.cambridge.org). For this research, an initiative will be defined as an organization with a new plan or process to solve the problem, in this case, of increased urban flooding threats because of more extreme precipitation events, due to climate change. Both Amsterdam and Rotterdam have initiatives fostering the use and implementation of more Sustainable Drainage Systems. These are called Amsterdam Rainproof and Water Sensitive Rotterdam.

The definition of *fostering,* also by the Cambridge dictionary, that will be used is *"to encourage the development or growth of ideas or feelings"* (dictionary.cambridge.org). In this research, the word fostering will be used to describe the way initiatives are encouraging the use of more SuDS.

The main problem that will be addressed in this research is the threats of extreme precipitation events and urbanization, which leads to overwhelming the conventional drainage system.

1.3 Scientific and social relevance of research

1.3.1 Scientific relevance

Much research has been done in the past focusing on SuDS, Water Sensitive Urban Design (WSUD) and Low Impact Development (LID). Also, many of the research done regarding this topic are case studies. The Netherlands is considered a front runner on the field of SuDS, although they may not use the term SuDS often. Both the Amsterdam and Rotterdam initiatives encouraging SuDS that have a unique approach in doing so. So far known there has not been any research done specifically about such initiatives. The research can be used as an example in comparing other cities in the future.

1.3.2 Social relevance

The initiatives that will be investigated both focus on changing society. By comparing the two initiatives and identifying their strong and weak points lessons can be learned on what makes initiatives fostering Sustainable Drainage Systems successful. With this knowledge people can be reached and educated better in the future. Also, the results can be used as an example for other cities in the Netherlands or even in other countries who want to tackle the problem of increasing extreme precipitation events, making this research relevant to society.

1.4 Case introduction

1.4.1 Amsterdam

The most populated city in the Netherlands with 833,624 inhabitants (CBS, 2017), Amsterdam, is well known abroad, and is also the capital of the Netherlands. The program Amsterdam Rainproof was started in 2013 as an initiative of Waternet, the water board of Amsterdam (Naafs, 2016). In preparation for anticipated extreme precipitation in the future, the goal of Rainproof is to increase awareness and preparation within the city using a network approach.

1.4.2 Rotterdam

Rotterdam is the second largest city in the country, with 629,606 inhabitants (CBS, 2017). This delta city lies on very low ground, often below sea-level, and is known for its famous port and modern buildings, having undergone extensive reconstruction after the devastation of World War II. Rotterdam has many ambitious climate change programs, such as the Rotterdam Adaption Strategy (2013) and the Rotterdam Resilience Strategy (2016). The movement Water Sensitive Rotterdam was founded in 2015 by the City of Rotterdam and is intended to be a successor of the current water policy (Ernst, 2016).

1.5 Research question

Main research question:

"What is the role of initiatives in Amsterdam and Rotterdam fostering Sustainable Drainage Systems as a measure to combat urban flooding caused by extreme precipitation?"

Sub-questions:

1. Case study: Amsterdam and Rotterdam
    a. *Which measures are municipalities currently taking in Amsterdam and Rotterdam to retain (rain)water?*
    b. *Who is financing Sustainable Drainage Systems?*

c. *What initiatives are fostering Sustainable Drainage Systems in Amsterdam and Rotterdam?*
d. *With what other organizations are initiatives are working together in realizing water sensitive urban design measures?*
e. *What differences are there between initiatives in Amsterdam and Rotterdam regarding approaches in fostering Sustainable Drainage Systems measures?*
f. *What can initiatives in Amsterdam and Rotterdam learn from each other?*

1.6 Outline of thesis

After the introduction in Chapter 1, Chapter 2 will discuss the theoretical framework, SuDS will be explained, the framework by Restemeyer et al., (2015) which will be used to compare the two cases, and the conceptual model of this research will be introduced. Chapter 3 will elaborate on the chosen methodology, the applied research and data analysis methods. Chapter 4 will discuss the results of the two initiatives used in the case study. Chapter 5 will compare the two initiatives and will discuss the results. In Chapter 6, final conclusions will be presented and discussed. Finally, Chapter 7 will give recommendations for further research and reflect on the process.

Chapter 2: Theoretical framework

In this chapter, the terms *urban floods, extreme precipitation*, *Sustainable Drainage Systems, Water Sensitive City* and *resilience,* as used in the scientific literature, will be defined. Furthermore, the framework of Restemeyer et al., (2015) that will be used to compare the two case study initiatives, will be introduced and explained. Also, the conceptual model of this research will be presented and explained.

2.1 Trends in climate change and urbanization

The outlook for the Northern European climate is one of increasing levels of precipitation and more frequent, heavy precipitation events (IPCC, 2014). Since 1950, precipitation in the region has been on the rise by up to +70 mm per decade (IPCC, 2014). Severe weather combined with an increase in impervious surfaces can change the characteristics of surface runoff, causing a higher volume of runoff water and peak flows (Goontilleke et al., 2005; Barbosa et al., 2012). Figure 1 illustrates the effect of urbanization on the water cycle, showing that cities have reduced evapotranspiration from vegetation and surface water, rapid surface runoff, and limited infiltration into the ground (CIRIA, 2010). As a result, conventional drainage systems are more frequently unable to handle storm water runoff (Perales-Momparler et al., 2015).

Predictions for urban flooding in the Netherlands are given in the abstract of the 2014 IPCC report by the Dutch *Planbureau voor de Leefomgeving* (PBL) and the *Royal Netherlands Meteorological Institute* (KNMI). The report states that in 2100, extreme rainfall will increase by 10 to 60 percent compared to the period of 1961-1990 (PBL & KNMI, 2015). As a result, urban flooding will become more problematic due to sewerage system overflow. The issue is not a higher average rainfall, rather drainage systems will be more frequently overwhelmed by intensive precipitation events (EEA, 2012). With a high percentage of impervious soil in a built environment, excess water will have more difficulty infiltrating the ground and will remain above ground (EEA, 2012).

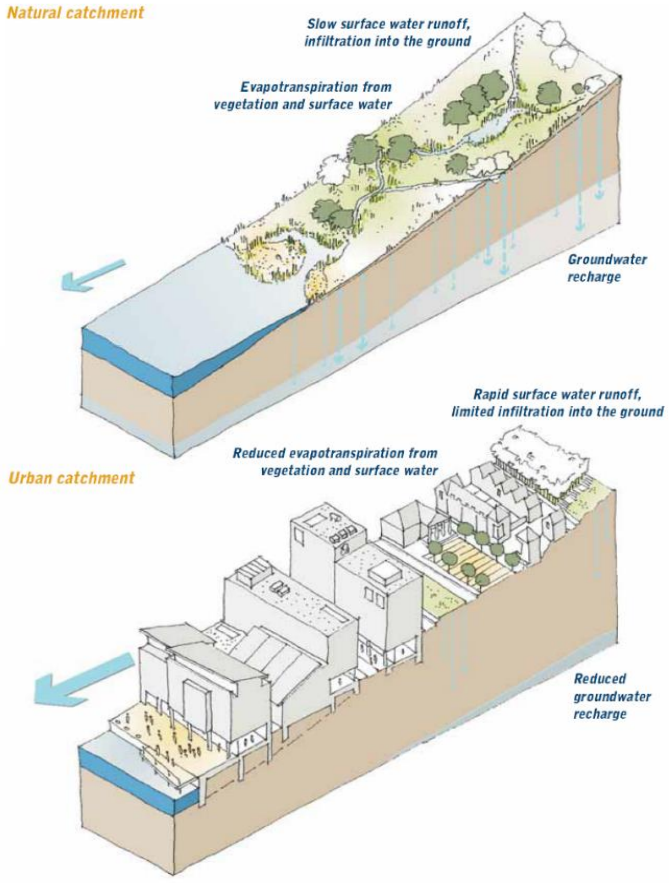


Figure 1: The effects of urbanization on the water cycle (CIRIA 2010, p.6) [larger version in appendix A2]

Defining extreme precipitation

The definitions of extreme precipitation are those used by the *Royal Netherlands Meteorological Institute* (KNMI). The KNMI (2017) classifies *heavy rainfall* as days with more than

50mm of rainfall, and *torrential rainfall* as rainfall of over 25 mm per hour or at least 10 mm in 5 minutes.

2.2 Urban floods

According to Jha et al. (2012), increasing incidence of urban flooding is a worldwide problem, occurring in cities that are densely built and have little soil area to absorb water quickly enough during high intensity rainfall. Urban floods are defined as: *"floods that occur when the urban drainage system becomes drastically overloaded during extreme rainy events, causing untreated combined sewage and storm water to back up into basements and to overflow from manholes onto surface streets."* (Garofola et al., 2017, p.30)

2.3 Sustainable Drainage Systems

Cities rely primarily on conventional drainage systems, such as underground drainage and sewerage systems, to dispose of the excess surface water. There are two sources that put pressure on the conventional drainage systems (Jones & Macdonald 2007). First, urban areas have grown in the past century and lifestyles have changed, increasing the quantity of water being used in cities (Jones & Macdonald 2007). Second, urban areas are increasing in surface area, leading to the reduction of porous surface area and therefor a higher quantity of surface water runoff (Jones & Macdonald 2007). Conventional drainage systems primarily address water quantity and water quality, as illustrated in Figure 2 (a). With conventional drainage systems surface water runoff is guided directly toward piped sewer systems (Jones & Macdonald 2007; Charlesworth 2010). These systems manage runoff by collecting surface water using pipes and sewerage lines, roadside catch basins or gully pots, and water treatment facilities. Likewise, amenity and wildlife are barely a consideration in such systems. In the SuDS triangle (Figure 2b), amenity and wildlife have a more equal role with water quality and quantity. SuDS encompasses a series of methods that encourage surface water to infiltrate the ground and be stored on site (Charlesworth, 2010).

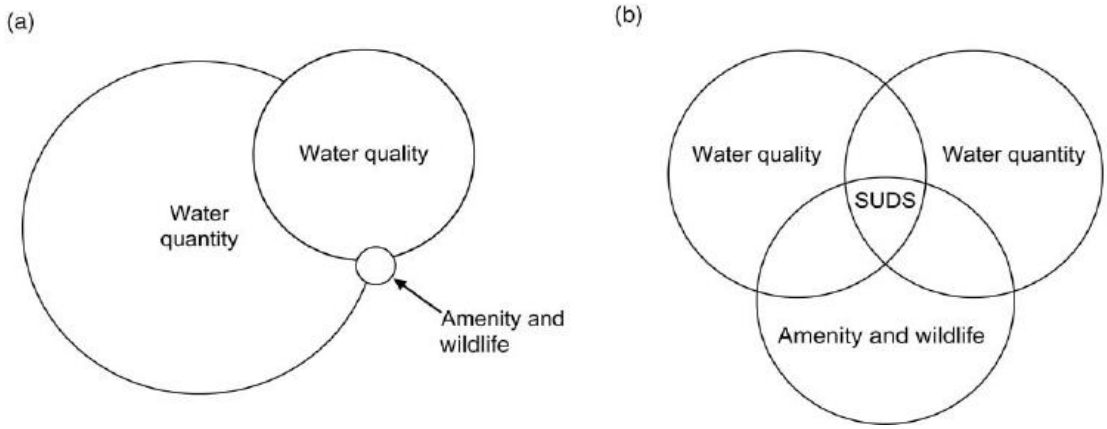


Figure 2 (a) conventional drainage (b) SUDS triangle (after Charlesworth (2010)).

In the Netherlands, an expected increase in both extreme precipitation in winter and high intensity rainfall in summer (KNMI, 2014), will put a strain on the capacity of the current urban drainage systems, and hence cities will be more prone to flooding. By using blue-green spaces, Sustainable Drainage Systems (SuDS) improve the urban environment and help cities to better adapt to the threats of future climate change and urbanization (Semandedi-Davies et al., 2007). A case study in Helsingborg, Sweden was done by Semandedi-Davies et al. (2007), and their research concludes that the use of SuDS could reduce urban floods both now and in future climate change scenarios.

2.3.2 SuDS definition and alternative terminology

Fletcher et al. (2015) identify that urban stormwater management and associated terminology have become increasingly complex over the decades. SuDS is a term that originated in the UK and is defined as: *"a range of techniques to drain storm and surface water in a more sustainable way" (Fletcher et al. 2015, p. 529)*. In 2007, CIRIA (Construction Industry Research and Information Association) published the first manual on the implication of SuDS in the UK (Fletcher et al. 2015). Other countries also use SuDS, but have different terminology for it. For example, the term Water Sensitive Urban Design (WSUD) is used in Australia, whereas Low Impact Development (LID) is used in the United States (Fletcher et al., 2015).

2.3.3 Examples of SuDS

There are many different types of SuDS that can be implemented in cities. For example, adding more green space is already considered a SuDS, this can be in the form of a green roof, a raingarden, or just by removing hardened surface from a garden. Figure 3 shows a strip of greenery which was placed on the sidewalk. The strip is lower than the rest of the area to make sure the rain flows here. The water can be stored here for a maximum of 24 hours, after which it will slowly infiltrate into the soil. If it rains more than the capacity the strip can hold the water will be transported via an overflow to the sewage (Rainproof, 2016).

Figure 3: Water stalling green strip on the Zuidas, Amsterdam (Rainproof, 2016)

Figure 4 shows a water square which was realized before the existence of Water Sensitive Rotterdam. This large-scale SuDS projected was completed in 2013 and combines the functions of water storage with enhancing the quality of open public space. When it is dry, the square can be used for sports, and when it rains it functions as water storage. The project also includes underground storage basins and infiltration devices. The process designing the square was part of an intense participatory trajectory with the local community (de Urbanisten, n.d.).

Figure 4: Benthemplein water square, Rotterdam (C40 Cities)

Besides having a drainage or storage function SuDS often are multifunctional, such as the Benthemplein. Green SuDS measures like in Figure 4, or green roofs also can have added multifunctional value of public green space, and serve as cooling in the city.

A more detailed table with an overview of different SuDS techniques from CIRIA (2010) can be found in Appendix A.

2.3 Transitioning toward Water Sensitive Cities

A Water Sensitive City has adaptive, multi-functional infrastructure and urban design, reinforcing water sensitive values and behaviors, as shown in Figure 2. A Water Sensitive City can be seen as a future goal with increased resilience to climate change. Sustainable Drainage Systems are techniques that can be used to achieve more sustainable urban water management and thus a Water Sensitive City.

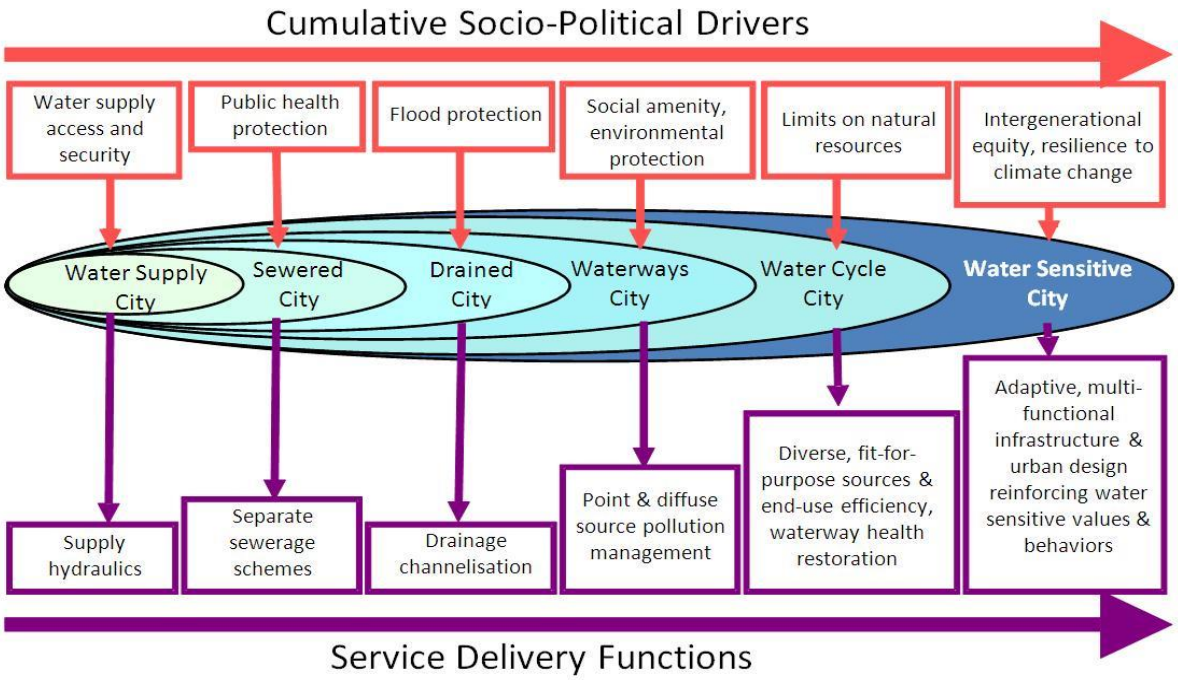


Figure 5: Urban Water Management Transitions Framework (Brown et al. 2009)

Brown et al. (2009) have developed a framework to facilitate adoption of sustainable urban water management, equivalent to a future paradigm shift toward Water Sensitive Cities. The framework is based on the Australian context, yet is also applicable in the Netherlands, Ernst (2016) says. Within the framework there are six phases in transitioning toward a Water Sensitive City. The Netherlands is currently in the transition phase referred to as Water Cycle City, in which the limits of water storage and the absorption capacity of the environment have been reached (Ernst, 2016).

2.4 Defining a flood resilient city

"As growing urban communities seek to minimize their impact on already stressed water resources, an emerging challenge is to design for resilience to the impact of climate change, particularly in regards to ensuring secure water supplies and the protection of water environments." (Brown et al. 2009, p. 01).

	Robustness *'Reduce flood probability'*	**Adaptability** *'Reduce consequences of flooding'*	**Transformability** *'Foster societal change'*
Content Measures and policy instruments	- technical measures (e.g. dikes, dams, barriers) - spatial measures (e.g. river widening)	- discourage vulnerable land use in flood-prone areas - flood-proofing existing buildings and infrastructure in flood-prone areas - warning and evacuation schemes - flood insurance / recovery funds	risk communication and awareness raising among: - private stakeholders (e.g. brochures, public campaigns, early education in school) - public stakeholders (e.g. consensus-building, partnership practices, decision support tools)
Context Strategic issues, Institutional structure and legislation	- Water and climate: water as threat - strong public responsibility for water management - collaboration between water management and spatial planning on specific projects	- Land-use and socio-economic changes: need to create synergies - shared legal responsibility public – private - strong collaboration between water management, spatial planning and disaster management on all projects	- societal changes: need to establish water as asset - informal networks fostering a new 'water culture' - new interdisciplinary networks (e.g. 'think tanks') and learning organizations
Process Intellectual capital	- expert knowledge in engineering and planning	- expert knowledge and local knowledge (vulnerability reduction and adaptation options)	- creativity, openness towards new knowledge, learning
Social capital	- good relations among water managers and spatial planners	- good relations among water managers, spatial planners and disaster managers; civil awareness and willingness to invest in flood risk management measures	- mutual trust between public and private stakeholders and social acceptance of new interdisciplinary networks
Political capital	- strong political and financial support for bigger structures (public funds)	- strong political and financial support for adaptation and a risk-based approach	- change agents, leadership; financial support for informal and interdisciplinary networks

Figure 6: A strategy-based framework for assessing resilience of cities (Restemeyer et al. 2015, p. 49)

Flood resilience is an important factor when transitioning toward a Water Sensitive City. A flood-resilient city is defined as one which can withstand or adapt to a flood event without a loss of functionality (Restemeyer et al., 2015, p.46). Three key characteristics of resilience are identified by Restemeyer et al. (2015): robustness, adaptability, and transformability. Firstly, when a city that is protected, for example, by "hard" infrastructure (Lu & Stead, 2013), e.g., dikes and sluices, it is considered to be robust. Adaptability is referred to by Restemeyer et al. (2015) as the capability of a city to adapt to flooding, for example by controlled flooding. Transformability is defined as the "capacity to change based on new insights, searching for the most appropriate way to deal with flood risk," as well as the ability to cultivate societal change (Restemeyer et al. 2015, p.47).

This research will use the strategy-based framework of Restemeyer et al. (2015), to determine how the initiatives promoting SuDS in Amsterdam and Rotterdam are fostering societal change. In the framework of Restemeyer, which can be found in Figure 6, a distinction has been made between a) content, i.e., measures and policy instruments, b) context, i.e., strategic issues, institutional structure, and legislation, and c) process, i.e., intellectual, social, and political capital.

Both robustness and adaptability play an important role when implementing SuDS. For instance, when considering SuDS as a spatial measure. For example, a water square can be seen as both a robust and adaptive measure. It reduces the flood probability of the area and the consequences of

flooding by simulating a controlled flood, since the water is guided toward the water square. However, this research will focus mainly on transformability, as defined in the Restemeyer framework. This is done for two reasons: both Amsterdam and Rotterdam are transitioning to a greater usage of SuDS versus conventional drainage systems, and both cities are also actively promoting SuDS in an effort to effect societal change. The light blue column in Figure 6 highlights the transformability concepts.

2.5 Conceptual model

Figure 7 illustrates the conceptual model of this research. To start, trends in urbanization and climate change are causing stress on conventional drainage systems, as discussed in the theoretical background, leading to an increased vulnerability of cities to excess urban runoff and flash flooding during extreme precipitation events. This problem can be addressed by focusing on making cities more flood resilient, i.e., enhancing *robustness*, *adaptability* and *transformability*, the three components of resilience as defined in the framework of Restemeyer et al. (2015). Both Amsterdam

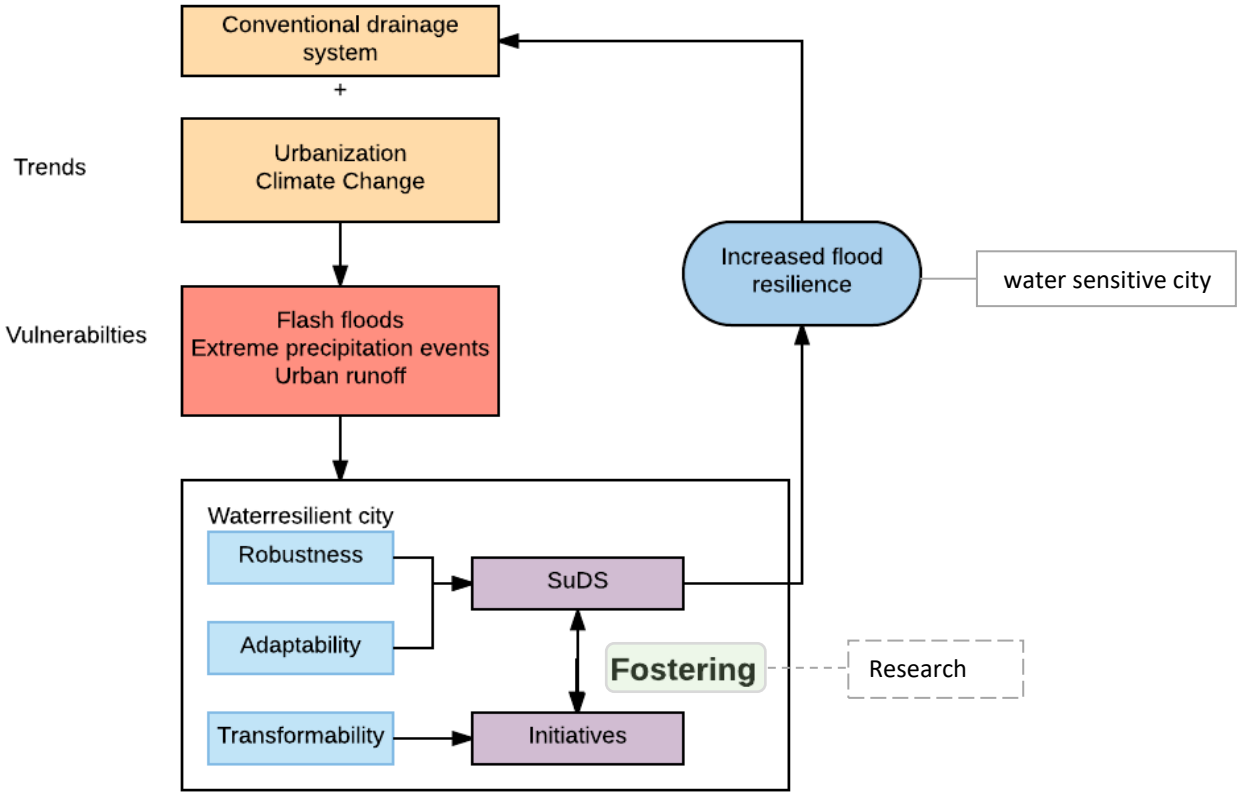


Figure 7: Conceptual model of research (own source)

and Rotterdam have initiatives, respectively, Amsterdam Rainproof and Water Sensitive Rotterdam, whose goal is to make cities more flood resilient by fostering Sustainable Drainage Systems. To this effect, the initiatives focus on the transformability component of the Restemeyer framework, although SuDS systems are primarily robust and adaptive measures. The increased implementation of SuDS projects as promoted by the two initiatives is expected to improve flood resilience and relieve the pressure of urbanization and climate change on the conventional drainage systems in the two

cities. The primary focus of the research thus is on fostering (see Figure 7), which hence is relevant to the main research question: *What is the role of initiatives in Amsterdam and Rotterdam in fostering sustainable drainage systems as a measure to combat urban flooding caused by extreme precipitation?*"

Chapter 3: Methodology

This chapter outlines how this research was conducted and elaborates on the methods used in detail. To enhance the quality of this research, triangulation, i.e., the systematic use of diverse methods, is used to gain a fuller understanding of the main research question (Ma & Norwich, 2007). First, the case study concept will be explained and the method of selection of cases will be elaborated on. After this, the methods used for collecting data will be described, and lastly, the method of data analysis will be explained.

3.1 Research question

This research is cross disciplinary, involving climate change, urban storm water management, flood resilience, and SuDS. A thorough review of background information is undertaken, encompassing literature research and analysis of documents on topics such as SuDS, increased rainfall and runoff resulting from climate change, and city water management. Two specific cases are examined, the initiatives Amsterdam Rainproof and Water Sensitive Rotterdam, to make it easier to explore differences and similarities, and make comparisons. Municipal employees and experts in the field of SuDS were interviewed using semi-structured dialogues, to clarify how initiatives are being used to foster SuDS and tackle the problem of increased rainfall. With these methods the main research question: *"What is the role of initiatives in Amsterdam and Rotterdam fostering Sustainable Drainage Systems as a measure to combat urban flooding caused by extreme precipitation?"* will be answered.

3.2 Case study methodology

- **Case study**

To be able to make the comparison for this case study, part of the framework by Restemeyer et al. (2015) will be used as specified in the previous chapter. In a multiple case study the researcher is enabled to explore differences with and between cases. Since a comparison will be drawn, cases should be chosen carefully. In this way, the researcher can predict similar results across cases, or contrasting results based on a theory (Yin, 2003). Advantages of case studies, according to O'Leary (2004) are that they have intrinsic values and can bring new variables to light.

- **Case selection**

The cities of Amsterdam and Rotterdam were selected as case studies for the following reasons. First, they are the two most populated cities of the Netherlands, and thus have greater urbanization and an increased threat of urban flooding caused by precipitation events. Second, they have the same climate and legal and cultural background. Third, both cities are very active in the field of climate adaptation and have similar initiatives fostering the implementation of SuDS, namely Amsterdam Rainproof and Water Sensitive Rotterdam. Last, both cities already have several functioning public and private SuDS. For example, the *Benthem water square* in Rotterdam and *de tuin van Jan* (Jan's garden) in Amsterdam. These projects are well known internationally and show the leadership of Amsterdam and Rotterdam in adapting to climate change through implementation of SuDS.

By comparing how these two initiatives foster societal change through promotion of SuDS, methods to transform urban water infrastructure and realize more holistic water management are demonstrated and are of educational benefit to other cities around the world.

3.3 Research methods

Within research two different methods can be distinguished: qualitative and quantitative research (O'Leary, 2010). Qualitative research methods are techniques that are used to explore subjective meanings, for example interviews. Quantitative research methods use statistics and mathematical modelling to conduct research (Clifford et al., 2012). This research has a qualitative set up, and the used methods are also qualitative, with both descriptive and exploratory research. The chosen methods for this research are literature research, document analysis and expert interviews which will be used to try to achieve understanding of the main research question.

- **Literature research**

The "Ten Arguments of Reading for Research" by Blaxter et al. (2006, in Clifford et al., 2010) state that literature research can be conducted to gain insight into what other researchers have discovered regarding this topic. Also, the literature research will be the base of a context to position this research in. Furthermore, it is a way to Figure out topics that have not yet been investigated.

- **Document analysis**

Documents from initiatives, organizations, and the municipalities of Amsterdam and Rotterdam have been assessed, to gain background information on SuDS measures already implemented, on initiatives that foster SuDS in the cities, and on the approach the two cities are using to implement their SuDS policy and strategy. This will show in which ways initiatives are fostering SuDS, and provide insight into which organizations are working together. Table 1 gives an overview of which documents were examined.

Document	Organisation(s)	Publication year
Rotterdam Resilience Strategy	100 resilient cities City of Rotterdam Rotterdam Climate Initiative Rotterdam make it happen	2016
Rotterdam Climate Change Adaptation Strategy (RAS)	Rotterdam Climate Initiative	2013
Gemeentelijk Rioleringsplan Amsterdam 2016-2020	Waternet	2016
Agenda Groen 2015-2018	Municipality of Amsterdam	2015

Table 1: Reviewed documents for document analysis

- **Interviews**

Besides literature research and document analysis, interviews have been conducted with experts in Amsterdam and Rotterdam. Semi-structured interviews were held with experts in the field of SuDS, within the municipalities, initiatives, and companies implementing SuDS. *A semi-structured interview is a verbal interchange where one person, the interviewer, attempts to elicit information from another person by asking questions. Although the interviewer prepares a list of predetermined questions, semi-structured interviews unfold in a conversational manner offering participants the chance to explore issues they feel are important. (Longhurst, 2010, in Clifford, 2012, p.103).* The advantage of semi-structured interviews is that they allow a certain flexibility (Macdonald & Headlam, 2009). Expert interviews are the best option for this research because, SuDS is a technical term little people know. Targeting interviews at experts who are familiar with SuDS and the case study initiatives will lead to

higher quality data. In Appendix 2, a list of all experts interviewed is found together with their organization, position, and date of interview.

Interviewee	Position	Organization	Date
Nanco Dolman	Leading Professional Water Resilience in Urban Areas	Royal Haskoning DHV, Amsterdam	April 19, 2017
Matthijs Monkelbaan	Polderdak engineer	Polderdak	April 19, 2017
Irene Poortinga	Community manager	Amsterdam Rainproof	April 25, 2017
Luuk van der Burgt	Technical trainee	City of Rotterdam	April 26, 2017
John Jacobs	Strategic advisor	Water Sensitive Rotterdam	April 26, 2017
Sacha Stolp	Transitie- en innovatiemanager	City of Amsterdam	April 26, 2017
Joris Voeten	Senior Engineer Urban Green Space	Urban Roofscapes	April 26, 2017
Geertje Wijten	Planner at Department of Urban Planning and Sustainability	City of Amsterdam	May 3, 2017
Joeri Schenk **Jurgen Bals**	Policy officer water systems Policy advisor	Hoogheemraadschap Schieland en Krimpenerwaard	May 8, 2017
Tjerron Boxem	Community manager climate adaption	Hoogheemraadschap Delfland	May 8, 2017

Table 2: Expert interviews

All interviews were held face-to-face, on site at the offices of the organizations. The order of interviews was planned intentionally, to facilitate a clear comparison between the two initiatives *Amsterdam Rainproof* and *Water Sensitive Rotterdam*. For this reason, the interview with Royal Haskoning DHV was conducted first, to gain more background on SuDS in general, before concentrating on the experts in the two case cities. Throughout the text the individual interviews are referred to name and organization name. Since the interviewees are representing an organization the organization name will also be used to make it clearer to readers whose opinion it is.

3.4 Data analysis

This paragraph describes in which way the different sources of data were analyzed. Research question a, b and d will first be answered by literature research and document analyses. After general knowledge is gathered about these questions the researcher will strive to confirm the previously obtained information through the interviews. Questions c, e, f, and g will be only be answered by the conducted interviews.

a. *Which measures are municipalities currently taking in Amsterdam and Rotterdam to retain (rain)water?*
b. *Who is financing Sustainable Drainage Systems?*
c. *What initiatives are fostering Sustainable Drainage Systems in Amsterdam and Rotterdam?*

d. *With what other organizations are initiatives are working together in realizing water sensitive urban design measures?*
e. *What differences are there between initiatives in Amsterdam and Rotterdam regarding approaches in fostering Sustainable Drainage Systems measures?*
f. *What can initiatives in Amsterdam and Rotterdam learn from each other?*

Document analysis

When analyzing documents, the researcher will make a notation when important information is discovered, information that provides relevant background prior to the conducted interviews, and aids the researcher in preparing and answering secondary questions, such as which SuDS already are implemented in Amsterdam and Rotterdam, and with which other organizations the initiatives are collaborating. For example, which organization collaborated in the Rotterdam Resilience strategy is listed on this document and are: *the City of Rotterdam, 100 resilient cities,* and *Rotterdam Make It Happen*.

Interviews

All interviews were conducted face to face and were recorded. The transcripts of the interviews can be found in Appendix C. A coding scheme was developed after the interviews were conducted and were based on the sub-questions of this research to analyze the content of the interviews. The codes that were used can be found in Appendix 3. Relevant passages and quotes from the interviews were placed following the codes to bundle the information. This will provide a clear overview to answer the sub-questions in the results chapter. The relevant quotes and information obtained through the interviews were translated from Dutch to English, which might have lead to some loss of meaning, since translation is an interpretive act (Nes et al., 2010).

Ethical aspects

All experts interviewed gave permission for recording and publication of their interviews for this research. Since all experts interviewed are native Dutch speakers, the interview questions were translated from English to Dutch, and all interviews were conducted in the Dutch language. All interviews lasted between 30 to 60 minutes and were conducted face to face on the premises of the organizations. There were no delicate questions and no experts felt uncomfortable to answer certain questions during the interviews.

1.	**Main vulnerabilities**
2.	**Measures currently taken**
3.	**Financing SuDS**
4.	**Initiatives fostering SuDS**
5.	**Goal of initiative**
6.	**Collaboration with which other organizations**
7.	**Differences in approaches fostering SuDS**
8.	**Important quotes**

Table 3: Codes used (own source)

3.5 Quality of collected data

During the interviews, there were a few problems. Often, the experts would talk much without having to be steered by the researcher's questions. This was very pleasant because the experts in general were very passionate about the topic and enjoyed talking about it. On the other hand, this also makes

it harder to analyze the data since it was often hard for the researcher to steer the conversation. Furthermore, some interviews were more valuable than others. For example, one interview was accidently not recorded. By doing eleven interviews the researcher could get a less biased view about the topic and explore the differences and similarities between the two initiatives in a more objective way. To conclude, almost all the data is of high enough quality to use for this research.

Chapter 4: Results

In this chapter, the Amsterdam Rainproof and Water Sensitive Rotterdam case study results will be examined, with specific consideration of the components content, context, and process of the Restemeyer et al. (2015) framework. The two initiatives that are focused on both foster the implementation SuDS. The terms they use though differ. Amsterdam Rainproof talks about Rainproof measures, while Water Sensitive Rotterdam speaks of water sensitive measures or project. In practice, these terms are similar and all fall under the category of different types of SuDS.

4.1 Amsterdam Rainproof

Background information Rainproof Amsterdam

The primary initiative that fosters SuDS in Amsterdam is Amsterdam Rainproof, a program initiated by Waternet, the city water board. The city's ambition to become rainproof in the future was evident in their 2013 publication: *Plan Amsterdam Waterstad*, with subtitle "Amsterdam Waterstad visie, veilig en rainproof." (Amsterdam water city vision, safety and rainproof). In 2014, Amsterdam Rainproof was founded with the mission to guide the city to a target of becoming rainproof by 2050. According to Irene Poortinga (Appendix C3), this goal was chosen in relation to continuing road upkeep in the city; by 2050, all roads will have undergone scheduled maintenance during which rainproof measures may be integrated.

Figure 8: Rainproof projects Green= complete Orange = in development Blue = Planned. (Rainproof)

Rainproof Amsterdam is promoting a network approach in their efforts to guide Amsterdam to become rainproof. By connecting the right people and organizations—the municipality, Waternet, businesses, research institutes, and others— to each other, Rainproof is creating a coordinated team to facilitate SuDS implementation. Also, Rainproof has many examples of completed and planned SuDS projects on their website, as can be seen in Figure 8.

Water board

The aim of Waternet, the water board of Amsterdam, is to provide their customers with clean drinking water, a sanitary sewer collection and treatment system, and storm and flood water defense

systems. Waternet's organization is unique in the Netherlands, being the only water board with the responsibility to deliver drinking water in their area of operation.

4.1.1 Content – measures and policy instruments

Website

On their well-developed website, Amsterdam Rainproof strives to educate the community and raise awareness of the risks of extreme precipitation. Their goal is to collect "as many projects as possible in the city so that everyone can participate", according to Irene Poortinga, community manager for Amsterdam Rainproof, and former employee of Waternet (Appendix C3). The website offers a toolbox of SuDS measures that show citizens how to rainproof their own environment, home, garden, and/or neighborhood. Figure 9 shows one illustration, using interactive raindrop buttons that direct the user to various measures to use in the garden. Raindrop number nine, for example, suggests a green roof installation to retain and store water on a shed, thus reducing runoff. A more detailed explanation for the other measures can be found in Appendix A3.

Figure 9: Rainproof measures for gardens (Rainproof)

On their website and during interviews for this thesis, it is evident that Rainproof believes a catastrophic high intensity rainfall incident, such as happened in Copenhagen in 2011, could also occur in the Netherlands. Rainproof is stimulating citizens and organizations to work together to prevent such a disaster.

Communication and campaigns

Nanco Dolman, urban water resilience specialist at Royal Haskoning DHV, mentions how Rainproof is skilled at communication and promotion of existing third-party projects. For example, the project *de tuin van Jan* was not initiated or financed by Rainproof, but is promoted widely as a relevant example of a possible rainproof solution. Rainproof has also taken part in events open to the public at Pakhuis de Zwijger, as mentioned by Geertje Wijten (Appendix C7), a planner at Department of Urban Planning and Sustainability for the City of Amsterdam who also works for Amsterdam Rainproof one day a week. One of these events was *Water Republic 2025,* an open event in which people out of the Rainproof network came inspire people and talk about how they are contributing to rainproof city.

In March 2017, Rainproof held a campaign named *Natuurlijk! De Watervriendelijke Tuin*, at garden centers to set the waterproof garden in the spotlight (Rainproof, 2017). This targeted campaign had a dual benefit: it expanded the Rainproof network to include local garden centers, stimulating them to promote and sell SuDS rainproofing products, and it brought the Rainproof message to the consumer gardener, raising their awareness of the threats of increased rainfall. As Poortinga from Rainproof says: "*Not everyone is our target group, for example people living in an apartment building on the third floor will not experience a flooding cellar, and do not own a garden."*

4.1.2 Context – Institutional structure and legislation

Rainproof uses a network approach, connecting people together to foster societal change, according to Irene Poortinga (Appendix C3).

Policy

Although their organization is well known for their communication skill and strategy, Rainproof states that they are trying to influence policy as well. For instance, Rainproof asserts that citizens should be required to store water in their own locale. Today, it is widely accepted that energy-neutrality should be a requirement in future building and project design. Rainproof lobbies for an increased consideration of water-neutrality as well. Objectives and funding for Rainproof are set forth by the City of Amsterdam in policy documents such as, "*Agenda Green"* (Agenda Groen). In this document, the aim of the Rainproof program is stated to help Amsterdam adapt to climate change and take action to achieve a decrease in paved surface and, correspondingly, an increase the amount of green surface area in the city. The Rainproof funding model— the use of a portion of municipal sewage tax revenues to fund programs that provide positive stimulus, convincing individuals and businesses to implement rainproof measures and thinking— is innovative and needs further study (Gemeente Amsterdam, 2015). *Agenda Green* specifically discusses a green roof subsidy, a SuDS system, as a specific program goal for the year 2015-2018, (Gemeente Amsterdam, 2015). A subsidy amount of € 25 – € 50 for every square meter of green roof is provided to building owners depending on the water storage capacity, according to Matthijs Monkelbaan (Appendix C2), engineer at Polderdak. Joris Voeten (Appendix C6) believes that this subsidy is attractive for roof owners and finds it smart to adjust amount of subsidy based on the water storage capacity.

The Waternet publication, "Municipal Sewage Plan 2016-2020" (Gemeentelijk Rioleringsplan 2016-2020), frequently mentions the Rainproof program and states that the program will be maintained intensively until 2017 to assure a rain proof Amsterdam (Waternet, 2016). Goals mentioned include 1) stimulating and supporting the permanent integration of the Rainproof way of thinking amongst private and public parties, 2) increasing the insight into problems and opportunities at the neighborhood level, 3) making business cases to gain further insight into the construction and management costs of rain proof measures, and 4) incorporating the Rainproof way of thinking within municipal organizations, at water boards, and within Waternet.

Shared responsibility

Joris Voeten (Appendix C6), Senior Engineer Urban Green Space at Urban Roofscapes, discusses how it should be everyone's responsibility to adapt to the consequences of climate change. The problem with sustainable urban drainage and blue-green solutions is that the investments must be made by one individual, Voeten says. On the other hand, the advantages of less flooding, a cooler city, space for more biodiversity, and cleaner air are there for everyone. In Voeten's opinion, the municipality

should play a key role in setting the right example through implementing SuDS. Monkelbaan (Appendix C2) identifies the same problem and speaks of a split incentive, where the costs-benefit ratio is unfair. For example, a green roof is beneficial for the entire neighborhood but one person or company needs to make the investment.

4.1.3 Process – intellectual, social and political capital

Intellectual and social capital

Nanco Dolman (Appendix C1) mentions how Rainproof is creative and likes to think "out of the box." An example Dolman gives is that Rainproof once brewed beer using collected rainwater at a gathering/meeting. Such a stunt contributes little to actually rainproofing the city, but it can be compelling for people who are not interested in technical issues. Poortinga mentions Rainproof's involvement in educational community evenings (buurtavonden), in which the public learns how they can contribute to making their city more rainproof. Such participation in the neighborhood adds to Rainproof's local knowledge. Appointment of Rainproof ambassadors also increases Rainproof's local knowledge. According to Poortinga, the ambassadors are Amsterdam inhabitants in touch with what is going on in the neighborhood and who spread the Rainproof message. The idea behind this is that if an individual or group has a rainfall related problem, they are able to contact a neighbor who has had similar issues and can connect them to the right people able to help, which can in turn strengthen the mutual trust between private and public stakeholders. Clearly the Rainproof ambassador initiative provides not only intellectual capital but social capital as well.

According to multiple interviewees, Amsterdam Rainproof's success stems in part from not being directly connected to the Municipality of Amsterdam or the water board, Waternet. By working under a different name, the public views them as a separate entity, and mutual trust between private and public stakeholder indirectly develops. Nanco Dolman (Appendix C1) from Royal Haskoning DHV, acknowledges that by making Rainproof appear to be an apolitical organization it leads to their own brand.

Wijten (Appendix C7) of the City of Amsterdam, believes that for Rainproof employees, familiarity with the water board and municipality is advantageous. At the same time because they work at their own separate location at Pakhuis de Zwijger, their organization feels more like an independent initiative than a municipal project. Independence also gives the advantage that Rainproof can determine its own communication strategy and does not have to comply with municipality communication rules, according to Wijten (Appendix C7).

Political capital and financing

Leadership and financial support of informal networks were mentioned as important political capital factors in the framework. Wijten (Appendix C7) argues that the Rainproof approach is both top down and bottom up. She states that: "if there are events organized from bottom up, then municipal directors, aldermen, and managers will see that the public understands the importance of the issues and the municipality will therefore be more likely to implement such things top down." Thus, bottom up events can have an influence on politics.

In Restemeyer et al.'s (2015) framework, strong political and financial support are mentioned as important to expanding flood resilience. Political backing is evident, since Amsterdam Rainproof has tight connections to the municipality and was initiated by Waternet, a governmental organization.

Regarding financial support, initially Rainproof was financed fully by Waternet, and is currently being supported by the sewage revenues of the City of Amsterdam. However, the municipality is starting to pitch in with more direct project funding, since they also acknowledge the importance of the Rainproof program, according to Wijten (Appendix C7). This is supported by Poortinga (Appendix C3), who explains that Rainproof does not finance any projects themselves, but they are involved in other ways in projects funded by the municipality. For example, Rainproof helps connect people in their network to each other when a SuDS project is implemented.

4.2 Water Sensitive Rotterdam

Background information Water Sensitive Rotterdam

The primary initiative that fosters SuDS in Rotterdam is Water Sensitive Rotterdam (WSR), a movement founded in 2015 in the municipality by John Jacobs and André Rodenburg. Water Sensitive Rotterdam was intended to be a follow up to municipal water policy. John Jacobs (Appendix C5) describes the ideology of Water Sensitive Rotterdam: to contribute to a climate proof city by working together with all active organizations in the city. WSR engages in as many projects as possible, such as roadwork, sewer system refurbishment, and realizing increased green space, not only to make the city more physically attractive, but also a better and safer city.

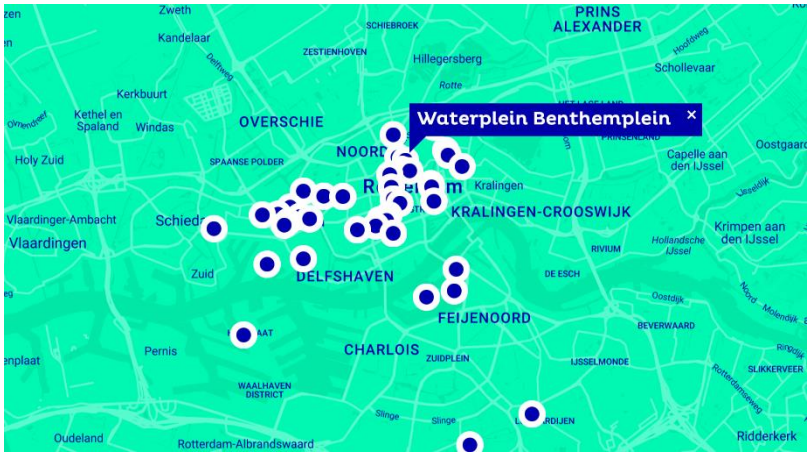


Figure 10: Water Senstive projects in Rotterdam (Water Sensitive Rotterdam)

Early on WSR started with three different types of pilot projects— ones at the street level, ones at the neighborhood level, and a social project with the goal of increasing neighborhood safety by working with inhabitants to transform paved area into green space (Ernst 2016; Jacobs, Appendix C5). Water Sensitive Rotterdam continually tracks all past and present sustainable drainage or water sensitive projects in the city, both their own initiatives and those of other allied organizations. Over time, many projects have joined the WSR movement, and WSR is now able to count over 50 projects in the city, with roughly two more being launched on a weekly basis, Jacobs says (Appendix C5). An overview of project locations in the city, as found on the Water Sensitive website, can be seen in Figure 11. One well-known example highlighted in Figure 11, the Benthemplein, was constructed in 2013, before Water Sensitive even existed.

Water boards

Three water boards operate within the City of Rotterdam: Hoogheemraadschap van Schieland en Krimpenerwaard, Hoogheemraadschap van Delfland, and Hollandse Delta. Service in much of the city center is the responsibility of Hoogheemraadschap van Schieland en Krimpenerwaard, which is involved in multiple SuDS projects, some in collaboration with Water Sensitive Rotterdam. Water

Sensitive Rotterdam is in collaboration with all three to foster SuDS in the city. In addition, the three water boards work together via a platform called “water and climate” (Bals, Appendix C).

4.2.1 Content - measures and policy instruments

Website

The Water Sensitive Rotterdam website contains information about their current projects, as seen in Figure 10. Each project contains information about all parties that collaborated in realizing a certain project. For example, in the Benthemplein project *the city of Rotterdam, Hoogheemraadschap van Schieland en Krimpenerwaard, and De Urbanisten* collaborated.

Figure 11: Water Sensitive walking route through Spangen (Water Sensitive Rotterdam)

The website aims to inspire the public in a number of ways: by introducing examples of how individuals can help Rotterdam prepare for climate change, by promoting a walking route passing various Water Sensitive projects in the Spangen neighborhood (see Figure 11), and by promoting various events, often using video media, for example, one about the functionality of water squares in the city.

Communication and campaigns

Via a collaboration with movie theatre KINO in Rotterdam, Water Sensitive Rotterdam contributes to risk communication and awareness. The theater programming at KINO is avant-garde, which generally appeals to a progressive audience. Such a group is often aware of environmental issues and

their ideals may overlap those of Water Sensitive Rotterdam. According to John Jacobs, the theater audience closely fits the target group of Water Sensitive Rotterdam. Various activities organized by WSR at the theater include a *Water Sensitive Café* get-together, and promotion of a *water sensitive walk* in Spangen— a tour in which people can see and learn about water sensitive projects up close. The theatre owner is supportive, having also suggested use of a trailer about Water Sensitive Rotterdam before films are shown.

4.2.2 Context – Institutional structure and legislation

Policy

The City of Rotterdam is known for its long-term vision plans (Ernst, 2016). After producing multiple *Waterplan* documents (2001 and 2007), the municipality made a decision to strive to become a climate proof city in the year 2025. To make this happen, the *Rotterdam Climate Initiative* (RCI) was started in 2007. Within the RCI the program *Rotterdam Climate Proof* was begun in 2008, and later, the *Rotterdam Adaptation Strategy* (RAS) was created in 2013, in collaboration with the municipality. The RAS includes policy information regarding urban flooding in the city, according to Luuk van der Burgt, municipal technical trainee who works on the RAS (Appendix C4). Van der Burgt monitors progress of implementation of the RAS, and makes recommendations to keep implementation on track. A goal of Water Sensitive Rotterdam is to contribute to helping RAS achieve their goals (Jacobs, Appendix C5).

Rotterdam Adaptation Strategy (RAS)

The purpose of the RAS is to help Rotterdam become 100% climate proof by 2025. More specifically, the first paragraph of the RAS (RCI, 2013) states: "*The goal is to create a climate-proof city for all the people of Rotterdam, both now and for future generations - a city that is both attractive and economically prosperous*" (RCI 2013, p.5). The document includes six primary objectives for climate change adaptation:

1. The city and inhabitants are protected from the rivers and the sea;
2. The city and its inhabitants experience minimal disruption from too much or too little rainfall;
3. The port of Rotterdam remains safe and accessible;
4. The inhabitants of Rotterdam are aware of the effects of climate change and know what they themselves can do;
5. Climate change adaption contributes to a comfortable and pleasant city in which to live and work;
6. Climate change adaption strengthens the economy of Rotterdam and its image.

The ideology of the Water Sensitive movement is most compatible with goals 4 and 5 of the RAS.

Rotterdam Resilient Strategy

The Rotterdam Resilient Strategy (RRS) was published in 2016 in which many resilience goals were formulated. Water Sensitive is part of the RRS mentioned under goal number 4: climate adaptive Rotterdam to a new level. This section of the RRS describes how the contribution of Water Sensitive Rotterdam "*—the construction of small and larger water storage combined with greening often initiated by citizens— is contributing to the resilience of Rotterdam*" (Gemeente Rotterdam 2016, p.38), demonstrating that Water Sensitive Rotterdam is adding resilience to the city. "*We especially want to seed a new way of thinking. To not see rain water as a problem or a threat but to recognise it*

as a valuable raw material that should be utilized as much as possible locally. We want to move further toward fully integrated water cycle management – integrating the water cycle into our urban environment including collection (attenuation), treatment and conveyance." (Gemeente Rotterdam 2016, p.80)

Shared responsibility

In a city with a program with a specific climate-proof purpose, civil servants in other departments may feel less obliged to take initiative in finding solutions, because they feel that the issues are already being covered elsewhere (Jacobs, Appendix C5). In Jacobs' opinion, the Water Sensitive ideology should be heard and acted upon by everyone.

4.2.3 Process – intellectual, social and political capital

Intellectual capital and social capital

Water Sensitive is also endeavoring to strengthen communities on a neighborhood level, Jacobs says (Appendix C5), and have sought contact with already existing neighborhood initiatives. For example, in Spangen, a neighborhood that has been known for a high crime rate. Water Sensitive sought contact with three active women within the neighborhood initiative, *Natuurlijk Spangen*, and helped them become involved in realizing more green space in their neighborhood. This is a prime example of Water Sensitive using existing networks of other people who have joined their movement. Now Spangen has become more attractive and the feeling of safety has increased, according to Jacobs (Appendix C5), who says, *'If we start to design together with the inhabitants of neighborhoods, for example by undertaking sidewalk garden maintenance together, then people will see and greet each other more often. With such project, the feeling of safety is increased because of social capital.'* This is an example of how SuDS is multifunctional: solving a social problem and making a neighborhood more water resilient.

Robert Fruinstraat example

Van den Burgt (Appendix C4) mentions the *Robert Fruinstraat* project as an outstanding SuDS project in Rotterdam. The Robert Fruinstraat is a street in Rotterdam where the sewer lines are in need of renewal and a new electricity network is planned to for installation within a few years. While these improvements are carried out, the collaborating partners—Water Sensitive Rotterdam, City of Rotterdam and Hoogheemraadschap Schieland and Krimpenerwaard— seek to make this street climate proof. In this local project, the street inhabitants have been involved in the planning process (van der Burgt, Appendix C4). Their wishes, for example creating more green space on their street, are taken into account in the new design. This is another good example of increased social capital and enhancement of the mutual trust between stakeholders.

Political capital and financing

Van den Burgt (Appendix C4) describes how Rotterdam is frontrunner when it comes to SuDS projects. Both van den Burgt and Jacobs (Appendix C5) mention how every year 80 international delegations come to Rotterdam to visit projects such as water squares or "roofgardens" (dakakkers), a project in which people grow their own food on city roofs, such as can be seen in Figure 12. This demonstrates Rotterdam leadership role in SuDS implementation.

Figure 12: Dakakkers (Stichting de Luchtsingel)

The Water Sensitive organization receives it's financing from the sewerage tax revenues Dolman (Appendix C1) says, about € 1.6 million, or 10% of the entire sewerage budget of Rotterdam. This money is reserved for SuDS projects and the fostering of SuDS in the city. Often Water Sensitive co-finances projects as well. The typical responsibilities of a water board mostly involve managing water transport and defense works. They do not usually contribute to projects such as green roofs and water squares, but it was easy to convince the three water boards of Rotterdam to work together with Water Sensitive, according Jacobs (Appendix C5). The water boards have acknowledged that these SuDS measures are sometimes the only solution available to solve the complex water problems in the city, they have started to reserved investment budgets for these programs, and they are often willing to contribute up to 50% of the financing for a project, Jacobs says.

Chapter 5: Comparison and Discussion

This chapter compares the similarities and differences between the two case study initiatives and discusses the results published in Chapter 4. To help simplify the comparison of the two initiatives, Table 4 gives an overview of the most important similarities and differences.

Content

An important difference between Amsterdam and Rotterdam is the amount of surface water present in each city. This requires that different SuDS measures be carried out in the two cities. Rotterdam, with a lack of surface water, is more susceptible to climate change and is forced to implement large scale measures such as water squares, according to Poortinga (Appendix C3). Laced with canals and other waterways, Amsterdam has more surface water making these large-scale measures less necessary. Amsterdam, consequently, has more focus on green roofs and smaller scale projects.

When considering transformability within the Restemeyer et al. (2015) framework, the two initiatives, Amsterdam Rainproof and Water Sensitive Rotterdam, have a different approach to risk communication and raising of awareness. With regards to private stakeholders, both initiatives utilize a social approach. Both have similar goals of making inhabitants more aware of the threat of climate change and providing examples of how to help address the issues by implementing SuDS measures on their own. Amsterdam Rainproof has a clearer online *"do it yourself"* toolbox for individual inhabitants, while Water Sensitive Rotterdam focuses more on stimulating neighborhood initiatives.

With the public stakeholders, Amsterdam Rainproof has been very successful at consensus building. On their website, they announced in May 2017 that they have over 70 partners in their network— research institutes, municipal organizations, neighborhood initiatives, businesses, etc. — spanning many different fields.

On the website of Water Sensitive Rotterdam, it is more of a challenge to ascertain who the cooperative partners are. The projects listed on the site do mention the involved parties, yet there is no clear list of collaborative partners, as is the case for Amsterdam Rainproof.

Through interviews with Water Sensitive and the water board, Hoogheemraadschap Schieland en Krimpenerwaard, information was gained about strong collaboration between Water Sensitive and the three Water boards.

One evident contrast between the two initiatives is a difference in their approach to financing SuDS measures. Water Sensitive co-finances many SuDS projects. Amsterdam Rainproof has a different tactic, leveraging their strong network of partners, thus being involved in many projects without providing any financial backing.

Context

Looking at the context of the initiatives, Rotterdam has a longer history of focusing on long term strategies out of necessity, being more vulnerable to climate change due to their low-lying geography. The city of Rotterdam's main water policy documents started in 2001 with their first *Waterplan.* From 2015 onwards, Water Sensitive Rotterdam is the successor of earlier water policy in Rotterdam, an instrument created to achieve goals previously set by the city. Their goal is to contribute to achieving the Rotterdam Adaptation Strategy goals set in 2013. Furthermore, Water

Sensitive is part of the Rotterdam Resilient Strategy published in 2016. On the other hand, Amsterdam has as shorter history when it comes to water policy and strategy documents. It appears that the extreme rainfall in Copenhagen in 2011 put the risks of climate change higher on the agenda for the City of Amsterdam and Waternet. Amsterdam does not have a clear adaptation or resilience strategy like Rotterdam has. This could mean that they are less prepared to the effects of climate change. Amsterdam Rainproof is part of the policy document "*Agenda Green*" and "*Municipal sewerage plan 2016-2020"* in which many goals are set, such as making the city more resilient to increased rain showers, but there is no strategy or plan fully focused on resilience or adaptability.

Shared responsibility

Both initiatives strive to encourage strong public responsibility for water management. Multiple experts mentioned shared responsibility of both public and private sectors being critical to making progress to alleviate increasing climate change threats. This is necessary because much space is privately owned in cities. The municipality can set the right example by implementing SuDS measures, but to really achieve a climate-proof city, i.e., one that has fully transitioned to being a Water Sensitive City, everyone needs to pitch in, including the private property owners.

Process

Intellectual and social capital

Both initiatives can be described as young interdisciplinary networks comprised of many different stakeholders, from businesses to municipalities and water boards to local neighborhood initiatives. Furthermore, both initiatives want to increase civil awareness and willingness to invest in flood risk management measures.

Amsterdam Rainproof appears to have more connections with research institutes and is also able to gather and spread local knowledge via their Rainproof Ambassadors program. Being viewed as independent from the water board and municipality is beneficial to Rainproof's positive image and social acceptance, and hence enhances their social capital. Although the SuDS program *de tuin van Jan* was set up before Rainproof existed, it is a good example of a project encouraged and advertised by Rainproof, and thus giving their social capital a boost. The program has a strong focus on the transformability aspects of social capital.

Water Sensitive Rotterdam strives to change the way the City of Rotterdam operates and uses more adaptability measures. They have a more integral and holistic approach to climate change adaptation. Key to their success are good relations among water managers, spatial planners, and civil servants are important.

Political capital and financing

Both initiatives have a large amount of political capital, both being funded by governmental organizations, Amsterdam Rainproof by Waternet and Water Sensitive by the City of Rotterdam. Also present in both cities is strong financial support to continue development of additional SuDS projects, with funding coming from the sewerage tax revenues. The water boards of both Amsterdam and Rotterdam acknowledge that implementing SuDS is beneficial in taking pressure off the conventional drainage systems and SuDS has come to be viewed as an extension of the sewage system. This explains the reason for the willingness of the water boards to invest in SuDS measures. Water Sensitive Rotterdam most likely has a higher budget than Amsterdam Rainproof, since WSR is able

to co-finance projects. Amsterdam Rainproof does not finance SuDS measures but focusses more on communication, providing a network and making it easy for local inhabitants to implement measures themselves.

	Amsterdam Rainproof	Water Sensitive Rotterdam
Type and duration	Program, temporary but initial four years has been extended	Movement, undetermined
Initiated by	Waternet	City of Rotterdam
Water board	Waternet	– Hoogheemraadschap Schieland en Krimpenerwaard – Hoogheemraadschap Delfland – Waterschap Hollandse Delta
Financing SuDS	– Financed by Waternet from sewarage tax revenue – No budget for SuDS projects	– Financed by City of Rotterdam from sewerage budget – Budget for SuDS projects, mainly co-financing
Collaborations[1]	– Govermental organisations – Green sector – Neighborhood initiatives – Research institutes – Entrepeneurs – Design and consultancy firms – Real estate owners – Network organisations	– Water boards – Neighborhood initiatives – KINO movie theatre
Communication	– Online "*do it yourself*" toolbox – Campaigns – Community meetings	– Neighborhood community – Communication within municipality
Goal	A Rainproof Amsterdam by 2050	Climate proof city by 2025 Aims to reach goals of RAS Change way municipality operates
Types of SuDS	More green roofs, smaller projects	Just starting with green/blue roofs, more big projects like water squares

Table 4: Comparison initiatives Amsterdam Rainproof and Water Sensitive Rotterdam (own source)

[1] Assumingly Water Sensitive Rotterdam has many more organizations in which they collaborate. Unfortunately, it is hard to figure out which these exactly are.

Chapter 6: Conclusion

In this chapter, the results from both case studies (Chapter 4), and the comparison and discussion (Chapter 5) are used to form a conclusion and answer the main research question.

Sustainable Drainage Systems are multifunctional solutions which combat the effects of climate change and increased extreme precipitation events, in particular. Examples of multifunctionality are water squares, which combine water storage with sports facilities, and green roofs, which accomplish water storage and cooling. Amsterdam and Rotterdam are front runners when it comes to implementing these types of solutions, and major initiatives fostering SuDS are present in the two cities: Amsterdam Rainproof and Water Sensitive Rotterdam.

When considering the theory and the framework for transition to a Water Sensitive City, both initiatives clearly are making progress in the right direction. They foster the use of SuDS which alleviates pressure on the conventional system in the Water Cycle City. When examining the two initiatives using the Restemeyer et al. framework, the transformability attribute stands out as most important for the two initiatives. Each initiative attempts to foster societal change by raising awareness among the private and public stakeholders using various forms of communication, campaigns, and projects. Also, both initiatives feel the necessity to view rainwater as an asset that should be re-used locally.

Social capital plays a large role for both initiatives. Amsterdam Rainproof aspires to be viewed by inhabitants as an independent, apolitical organization and utilizes a strong community network approach. In contrast, Water Sensitive Rotterdam works more at the municipality level and implements larger projects, with the involvement of inhabitants and neighborhood initiative groups; which enhances the social capital. Both initiatives are advancing the implementation of SuDS in their respective cities, albeit with different approaches. Amsterdam Rainproof's social network influences other groups, who are encouraged to make financial investments. Water Sensitive Rotterdam more directly finances SuDS projects. Irrespective of their approach, both cities are making progress in transitioning toward more Water Sensitive Cities.

The main research question is: *"What is the role of initiatives in Amsterdam and Rotterdam fostering Sustainable Drainage Systems as a measure to combat urban flooding caused by extreme precipitation?"*

In short it can be answered as following: The initiatives Amsterdam Rainproof and Water Sensitive Rotterdam use their programs to promote societal change to help advance the adoption of SuDS. They excel in transformability, and contribute toward increased robustness and adaptability in the cities, three of concepts in the Restemeyer et al. framework. Above all, a focus on social capital stood out in the interviews. The role of the initiatives is fostering societal change.

To conclude, the following two policy suggestions are advised:

- The multifunctional solutions that many SuDS projects offer should receive greater consideration and be encouraged. Use of a holistic resilience approach can solve urban drainage problems, while also helping with social issues in the community. Two examples: the case of the neighborhood Spangen shows how implementing SuDS together with a neighborhood initiative can both increase the water resilience of an area and the feeling of safety within a community. And the urban heat island effect can be reduced, at the same time that the urban environment is made more green and attractive, through implementation of SuDS measures.

- Use both top-down and bottom-up measures. Both cities and initiatives currently use a rather bottom-up social approach when implementing SuDS in the city. To speed up the transition toward a more Water Sensitive City, it could be beneficial for the government to take more of a leadership role by adopting additional policy embracing SuDS. One example might be to enact more attractive green roof subsidies. New construction and some remodeled buildings of a certain roof area, might be encouraged or possibly required to implement a green roof installation, or at least more water storage capacity.

Chapter 7: Reflection

In this chapter, the results of the conducted research are reflected upon, the research process is commented upon, and recommendations are made for further study.

7.1 Recommendations for further research

The term SuDS originated in a UK context and is rarely used in the Netherlands. Terms such as green-blue infrastructure or climate adaptive measures are more in favor, according to Joris Voeten (Appendix C6). SuDS is a broad concept and research can be facilitated by narrowing the scope and focusing on a single component of SuDS, such as green roofs or water squares.

This research focuses primarily on work done by initiative programs, experts, and municipalities, and documents the methods Amsterdam Rainproof and Water Sensitive Rotterdam are taking to foster Sustainable Drainage Systems.

Additional research needs to be conducted to further investigate public awareness, knowledge, opinions, of the issues and initiatives and their participation in the solutions, as it is still unclear to what extent the Rainproof and Water Sensitive messages have come across to inhabitants of the cities. To study this, surveys could be conducted in the neighborhoods near multiple SuDS projects in both Amsterdam and Rotterdam. Survey questions might include: Do you think increased precipitation resulting from climate change is a threat? Have you heard of Amsterdam Rainproof/Water Sensitive Rotterdam? Have you ever attended one of their events? Have you implemented rainproof measures in your garden?

Surveys could also be undertaken within the municipal governments of Amsterdam and Rotterdam, to measure the penetration of the initiative messages within the organizations and discover to what extent they are implementing recommendations in future policy and design.

Furthermore, a case study could be conducted, perhaps in an international context. The activities in Amsterdam and Rotterdam could be compared with those in Australian, British, and Danish cities active in enhancing flood resilience. For example, the approach of Denmark is quite technical, in contrast to a more social approach at Amsterdam Rainproof and Water Sensitive Rotterdam, according to Irene Poortinga of Rainproof (Appendix C3).

The problem of the urban heat island will become more of an issue in the future and requires further study, according to Wijten and Bals (appendices C7 and C8, respectively). Additional implementation of SuDS in a city can solve multiple problems, for example, measures that increase green space, can decrease the effects of the urban heat island, and research into the multifunctionality of SuDS is needed.

7.2 Process

During the writing this thesis, the author fine-tuned the focus of the research. Initially the research was focused on initiatives fostering SuDS in general. After discovering the existence of two very large initiatives in the two big cities, Water Sensitive Rotterdam and Amsterdam Rainproof, the choice was made to focus on and compare only these two programs.

After the interviews, the researcher decided to concentrate primarily on transformability, because the goal of both initiatives is to foster societal change. Unfortunately, the last interview with Tjerron Boxem was accidentally not recorded. His work at a water board near Rotterdam and past work for

Amsterdam Rainproof could have made him a very useful source. However, enough similar data had already been collected, so the decision was made to leave this interview out of the research. In addition, the interview with Sacha Stolp was not used.

After the first interview, the researcher thought it might be necessary to modify the research question to focus more on Water Sensitive Urban Design (WSUD), instead of Sustainable Drainage Systems (SuDS), because WSUD seemed to be more relevant to the Netherlands. However, a literature review helped to conclude that SuDS is similar to both WSUD and Low Impact Design (LID), with the latter two terms used mostly in the theoretical framework. In practice, however, these terms are never mentioned on the websites of Amsterdam Rainproof, Water Sensitive Rotterdam, the municipalities, or the water boards. Instead, these organizations refer to climate adaptive solutions, water sensitive or rainproof solutions. In the end, the author chose to keep the research focus on SuDS, in part to minimize confusion in the terminology.

Chapter 8: References

Scientific literature

Barbosa, A., Fernandes, J., David, L., (2012). Key issues for sustainable urban stormwater management. *Water Research,* 46, 6787-6798

Brown, R., Keath, N., Wong, T., (2008). Transitioning to Water Sensitive Cities: Historical, Current and Future Transition States. *International Conference on Urban Drainage*, Edinburgh, 1–10.

Charlesworth, S.M. (2010). A review of the adaptation and mitigation of global climate change using sustainable drainage in cities*. Journal of Water and Climate Change*, volume 1 (3): 165-180.

Clifford, N., French, S. & Valentine, G. (Red.) (2010). *Key methods in Geography.* Second edition. London: SAGE Publications Ltd.

Evans, E.P., Simm, J.D., Thorne, C.R., Arnell, N.W., Ashley, R.M., Hess, T.M., Lane, S.N., Morris, J., Nicholls, R.J., Penning-Rowsell, E.C., Reynard, N.S., Saul, A.J., Tapsell, S.M., Watkinson, A.R. & Wheater, H.S. (2008). *An update of the Foresight Future Flooding 2004 qualitative risk analysis*. Cabinet Office, London.

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Throwsdale, S., Barraud, S., Semandi-Davies A., Bertrand-Krajewski, J., Mikkelsen, P.S., Rivard, G., Uhl, M., Dagenais, D. & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more - The evolution and application of terminology surrounding urban drainage. *Urban Water Journal*, 12(7), 525-542.

Garofalo, G., Giordanoa, A., Piro, P., Spezzanoa, G. & Vincia, A. (2017), A distributed real-time approach for mitigating CSO and flooding in urban drainage systems, *Journal of network and computer applications,* Vol. 78, 30-42.

Goontilleke, A., Thomas, E., Ginnc, S. & Gilbert, D. (2005). Understanding the role of land use in urban stormwater quality management. *Journal of Environmental Management*, 74, 31-42.

Jha, A., Bloch, R. & Lamond, J. (2012). *Cities and flooding: A guide to integrated urban flood risk management for the 21st century.* Washington, DC: GFDRR/World Bank.

Jones, P. & Macdonald, N. (2006). Making space for unruly water: Sustainable drainage systems and the disciplining of surface runoff. *Geoforum 38,* 534-544.

Longhurst, R. (2010). Semi-structured interviews and focus groups. In N. Clifford, S. French, G. Valentine (Red.), *Key Methods in Geography,* 103-115.

Lu, P., & Stead, D. (2013). Understanding the notion of resilience in spatial planning: A case study of Rotterdam, The Netherlands. *Cities*, 35, 200–212.

Ma, A., & Norwich, B. (2007). Triangulation and Theoretical understanding, *International Journal of Social Research Methodology,* 10:3, 211-22.

Macdonald, S. and Headlam, N. (2009). *Research methods handbook: Introductory guide to research methods for social research*, Centre for Local Economic Strategies, Manchester.

Van Nes F., Abma T., Jonsson H. & Deeg D. (2010). Language differences in qualitative research: is meaning lost in translation? *Eur. J. Ageing,* 7, 313–316.

O'Leary, Z. (2010). *The essential guide to doing your research project.* Sage Publications Ltd, London.

Olsen, A., Zhou, Q., Linde, J. & Arnbjerg-Nielsen, K. (2015). Comparing Methods of Calculating Expected Annual Damage in Urban Pluvial Flood Risk Assessments. *Water.* 7, 255-270.

Perales-Momparler, S., Andres-Domenech, I., Hernandez-Crespo, C., Valles-Moran, F., Martin, M., Escuder-Bueno, I. & Andreu, J. (2016). The role of monitoring sustainable drainage systems for promoting transition toward regenerative urban built environments: a case study in the Valencian region, Spain, *Journal of Cleaner Production*, 1-12.

Perales-Momparler, S., Andres-Domenech, I., Andreu & J., Escuder-Bueno, I. (2015). A regenerative urban stormwater management methodology: the journey of a Meditteranean city, *Journal of Cleaner Production,* 109, 174-189.

Restemeyer, B., Woltjer, J. & van den Brink, M. (2015). A strategy-based framework for assessing the flood resilience of cities – A Hamburg case study, *Planning Theory & Practice*, Vol. 16 No. 1, 45–62.

Semadeni-Davies, A., Hernebring, C., Svensson, G. & Gustafsson, L. (2007). The impacts of climate change and urbanization on drainage in Helsingborg, Sweden: combined sewer system, *Journal of Hydrology,* 350, 100-113.

Yin, R. K. (2003). Case study research: Design and methods (3rd ed.). Thousand Oaks, CA: Sage

Documents and Reports

CIRIA (2010). *Planning for SuDS – making it happen*, C687. London: Construction Industry Research and Information Association (CIRIA)

Gemeente Rotterdam (2016). *Rotterdam Resilience Strategy.* Rotterdam: Gemeente Rotterdam

EEA (2012). *Urban adaptation to climate change in Europe — challenges and opportunities for cities together with supportive national and European policies.* EEA Report No 2/2012. Copenhagen: European Environment Agency

Gemeente Amsterdam (2015). *Agenda Groen, 2015-2018.* Amsterdam: Ruimte en Duurzaamheid Gemeente Amsterdam.

IPCC. (2014). *Climate Change 2014 Impacts, Adaptation, and Vulnerability Part B: Regional Aspects.* Fifth Assessment Report. United Kingdom: Intergovernmental Panel on Climate Change.

KNMI (2014). *Klimaatscenario's 2014 voor Nederland*. Herziene uitgave 2015. De Bilt: Koninklijk Nederlands Meteorologisch Instituut.

KNMI & PBL (2015), *Klimaatverandering. Samenvatting van het vijfde IPCC assessment en een vertaling naar Nederland,* Den Haag / De Bilt: PBL / KNMI.

Rotterdam Climate Initiative (2013). *Rotterdamse Adaptatiestrategie.* Rotterdam: Rotterdam Climate Initiative - Climate Proof.

Waternet (2016). *Gemeentelijk rioleringsplan 2016-2020.* Amsterdam: Waternet

Magazine articles

Ernst, L. (2016). Case study Water Sensitive Rotterdam. *Watergovernance*, 2016/04, 32-34.

Naafs, S. (2016). Case study Amsterdam Rainproof. *Watergovernance*, 2016/04, 29-31.

Websites

CBS (2017). *Bevolking; ontwikkeling in gemeenten met 100 000 of meer inwoners.* Retrieved on 04-03-2017 via www.cbs.nl

C40 Cities (n.d.). *Benthemplein Water Square: An innovative way to prevent urban flooding in Rotterdam.* retrieved April 25, 2017, from http://www.c40.org/case_studies/benthemplein-water-square-an-innovative-way-to-prevent-urban-flooding-in-rotterdam

De Urbanisten (n.d.). *Water Square Benthemplein*. Retrieved May 5, 2017, from http://www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein

Initiative [Def. 1]. (n.d.). In *Online Cambridge Dictionary*, retrieved May 1, 2017, from http://dictionary.cambridge.org/dictionary/english/initiative

Fostering [Def. 2]. (n.d.). In *Online Cambridge Dictionary*, retrieved May 1, 2017, from http://dictionary.cambridge.org/dictionary/english/foster?q=fostering

KNMI (2014) *Hoe vaak komt extreme neerslag voor zoals op 28 juli tegenwoordig voor, en is dat anders dan vroeger?* Retrieved on 30-03-2017 via https://www.knmi.nl/kennis-en-datacentrum/achtergrond/hoe-vaak-komt-extreme-neerslag-zoals-op-28-juli-tegenwoordig-voor-en-is-dat-anders-dan-vroeger

KNMI (n.d.) *Uitleg over zware neerslag.* Retrieved on 10-05-2017 via https://www.knmi.nl/kennis-en-datacentrum/uitleg/zware-neerslag

Rainproof (2014). *Wolkbreuk 28 juli.* Retrieved on 30-03-2017 via https://www.rainproof.nl/wolkbreuk-28-juli

Rainproof (2016). *Watervertragende groenstrook Kop Zuidas.* Retrieved on 07-05-2017 via https://www.rainproof.nl/node/239

Rainproof (2017). *Campagne maart: "Natuurlijk de Watervriendelijke Tuin".* Retrieved on 01-06-2017 via https://www.rainproof.nl/nieuws/campagne-maart-natuurlijk-de-watervriendelijke-tuin

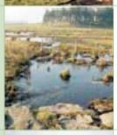
Stichting de luchtsingel (n.d.). *The Dakakker.* Retrieved on 03-06-2017 via http://www.luchtsingel.org/en/locaties/roofgarden/

Water Sensitive Rotterdam (n.d.). *Water Sensitive plekken.* Retrieved on 10-06-2017 via http://www.water sensitiverotterdam.nl/plekken/

Appendix A: Figures

Appendix A1 Different types of SuDS techniques

		What	Why	Where	Flood risk management benefits	Water quality management benefits	Amenity and biodiversity benefits
Green roofs		The roof of a building that is partially or completely covered with vegetation or another growing medium.	To control runoff as close to source. Store water and filter out pollutants. Can provide other benefits.	Private in curtilage (source control).	☆☆☆	☆☆	☆☆☆
Soakaways		Excavation or trench that can be filled with filter material. Can be made of pre-cast concrete or polyethylene rings/ perforated storage structures that are then backfilled with granular material. Allows water to soak away into the ground.	To store runoff, filter out pollutants and recharge groundwater.	Private in curtilage (source control). Also next to roads. Can be easily retrofitted.	☆☆☆	☆☆☆	☆
Rainwater harvesting		System to collect water from impermeable surfaces for use in non-potable water situations.	Reduce the amount of potable water use.	Private in curtilage (source control).	☆☆☆	☆☆	☆
Permeable pavements		Surfaces that allow water to soak into the ground or a gravel-filled base. Porous surface replaces traditional hard (impermeable) surfaces.	Water is stored in the base and released gradually. Also, it can treat runoff and remove pollutants. Can be used in permeable and impermeable ground conditions (it incorporates some form of outflow and overflow component).	Private in curtilage (source control), car parks and some roads.	☆☆☆	☆☆☆	☆
Geocellular /modular systems		Modular plastic systems that can be used to create below ground infiltration or storage.	Can both store and allow infiltration of water. Flexible systems that can be used on most sites.	Driveways, car parks, next to roads.	☆☆☆	☆	☆
Channels and rills		Open landscaped channels which can be vegetated, used to convey water from one SuDS component to another.	Used to convey water and can provide some storage.	In curtilage, in open space.	☆☆	☆☆☆	☆☆☆
Bioretention		Depressions backfilled with a sand/soil mixture and planted with vegetation. Water enters through a vegetated surface and then trickles via a filter layer entering a perforated pipe at the bottom before being carefully transported downstream.	To store water and release it gradually. Some water quality improvement is provided by a filter layer.	Private in curtilage SuDS (source control), in open space, next to roads and car parking.	☆☆☆	☆☆☆	☆☆☆
Infiltration trench		Stone-filled trenches that allow water to soak into the ground, as close to where the rain lands as possible.	To control the amount of runoff and provide storage. Needs permeable ground conditions.	Open space next to roads (if preceded by filter strip) and car parks.	☆☆☆	☆☆	☆☆☆
Filter strips		A vegetated area of gently sloping ground designed to drain water evenly off impermeable areas and filter out silt and other material.	To filter out pollutants, especially sediment, before runoff entering another SuDS component or watercourse.	Open space, next to roads and car parks.	☆☆	☆☆☆	☆☆
Rain garden		Vegetated area into which runoff is drained, attenuated and stored. Water infiltrates into the ground or is taken up by plants.	To store runoff, filter out pollutants and recharge groundwater.	Next to roads, in residential developments and throughout urban areas.	☆☆☆	☆☆☆	☆☆☆

		What	Why	Where	Flood risk management benefits	Water quality management benefits	Amenity and biodiversity benefits
Filter drain		They are gravel filled trenches with a pipe with small holes installed in the bottom.	The gravel slows the flow by storing water and releasing it gradually. Can be used in permeable or impermeable conditions. May need periodic maintenance to prevent siltation.	In open space, next to roads and car parks.	☆☆☆	☆☆	☆
Swales		Shallow vegetated swales that can run parallel to hard surfaces, allowing runoff to trickle down the side slopes and into the base of the component. Water is then transported in a controlled manner to another SuDS component or to a stream or river downstream.	To treat and attenuate runoff. Can be used in permeable or impermeable ground conditions (if under-drained).	In open space, next to roads and car parks.	☆☆☆	☆☆☆	☆☆
Trench troughs		Open landscaped channels which can be vegetated, over filter medium and under-drained. Used to convey, attenuate and improve water quality.	Used to convey water. Will provide some storage and attenuation.	In open space.	☆☆☆	☆☆☆	☆☆☆
Detention basin		Shallow vegetated depressions to control the amount and rate of runoff and some water quality improvement.	To store water during large storms, and release it gradually.	In open space.	☆☆	☆☆☆	☆☆
Wetland		Retention ponds with more emergent aquatic vegetation and a smaller open water area.	The wetlands store water and release it slowly. Sediment removal also takes place through settlement and biological treatment occurs due to the vegetation.	In open space, next to roads and car parks.	☆☆☆	☆☆☆	☆☆☆
Retention ponds		Artificial ponds with an open water area and marginal wetland around the edge. Also, should incorporate a stilling/settlement area at the inlet to allow for some treatment and calming of storm flows to prevent shock loading of the main water body.	Ponds store water and release it slowly, allowing sediment to settle in the pond in a designated basin at the inlet, while the vegetation provides biological treatment. Can be hard engineered.	In open space.	☆☆☆	☆☆☆	☆☆☆

Key

Good contribution ☆☆☆
Medium contribution ☆☆
Low contribution ☆

Figure 2: SuDS components, CIRIA Planning for SuDS, making it happen 2010, p. 27-29

Appendix A2: Enlarged Figure 1, natural catchment

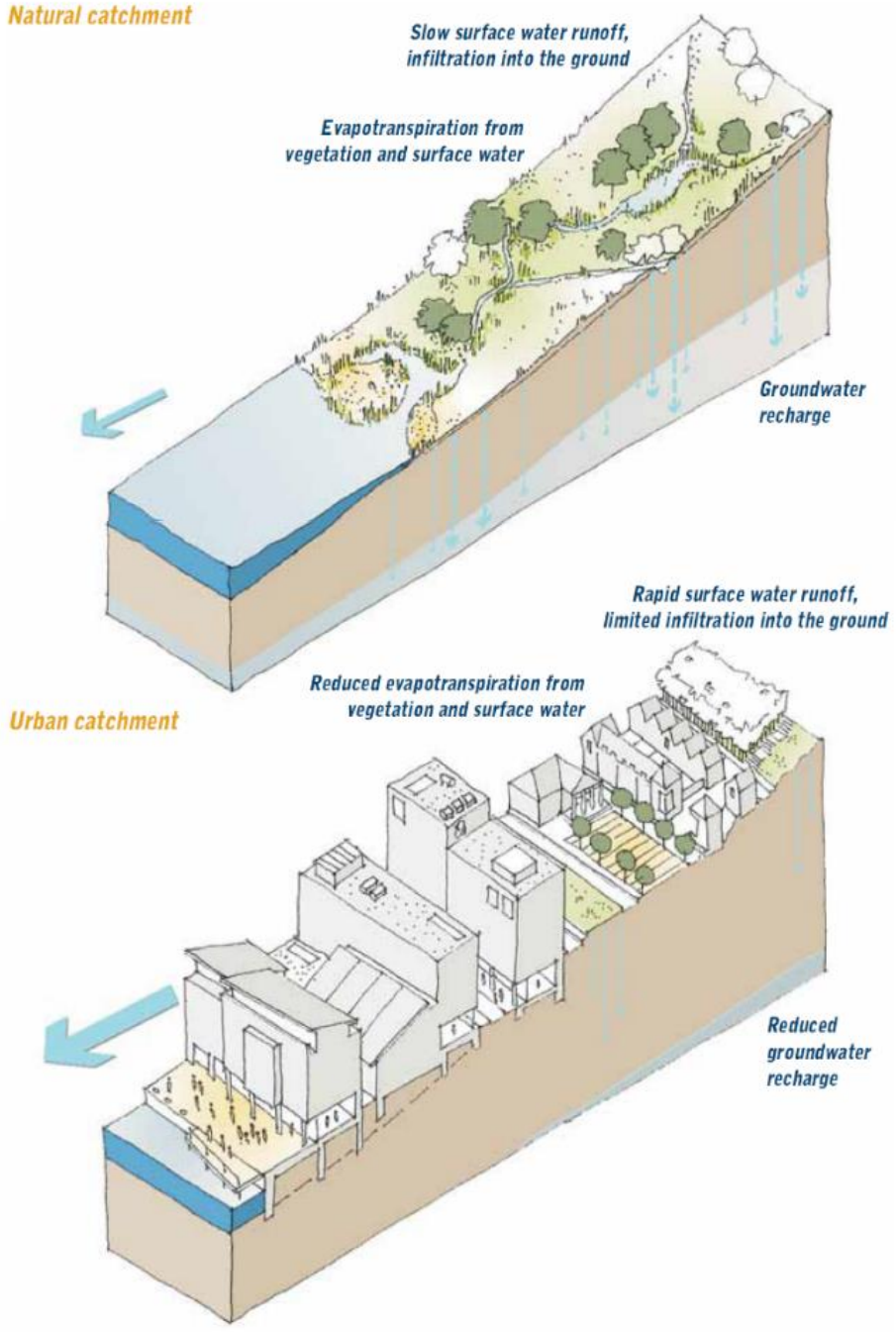


Figure 1: enlarged version (CIRIA)

Appendix A3: Rainproof measures for gardens

Figure 3: Rainproof measures for gardens (Rainproof)

Measure
1. Disconnect the rain pipe
2. Water permeable paving
3. Relief in your garden
4. Open gutter
5. Rainwater detention ponds
6. Replace tiles with green
7. Gravel strokes
8. Infiltration crates
9. Green roof
10. Rain barrel
11. Rainwater fence
12. Rainwater usage system

Appendix B: Example semi-structured interview guide

Introduction

- Welcome, ask permission to record, confidentiality
- Introduction interviewer and research topic
- Introduction and (professional) background interviewee

A. Municipality

- What are the biggest risk considering increased rainfall in your city?
- Where in the city are the biggest problems regarding urban stormwater management?
- What are the current policies regarding urban stormwater management?
- What are the cities strategies regarding urban stormwater management?
    - Top down? Bottom up?
    - Are there certain important policy documents I need to know about?

Sustainable Drainage Systems (SuDS)

- Is your municipality using SuDS? If yes, what kind, why and where. If no, why not?
- Who is financing SuDS?
- Are there other organizations/initiatives you are aware of that are fostering SuDS?
- Who should be in charge in fostering SuDS?
    - Local level, municipal? Collaborations?
    - In which ways are stakeholders and local citizens involved in SuDS?
- Is you municipality collaborating with initiatives when fostering SuDS?
    - If yes, which ones?
    - How is your collaboration?
    - Is the collaboration useful? Would you recommend other cities working together with such an initiative? Why?

B. Initiative

- What are the biggest problems regarding urban stormwater management in this city?
- What is the role the municipality plays in this city in combatting urban stormwater?
- When was this initiative founded? And why?
- What strategy does your initiative have to combat urban stormwater?
- What is its goal/aim? Transformability? Sustainability
- What types of SuDS does your initiative promote/foster?
- Who is financing SuDS?
- With which other initiatives, companies, governmental organizations etc. are you working together?
    - If yes, is this collaboration useful?
- Who should be in charge of fostering SuDS?
    - In which ways are stakeholders and local citizens involved in SuDS?

C. Organization, company involved in SuDS

- What are the biggest problems regarding urban stormwater management in this city?
- What is the role the municipality plays in this city in combatting urban stormwater?
- What SuDS does you company use?

- Who pays you when implementing SuDS?
- Do you collaborate with any initiatives? (e.g., Amsterdam Rainproof?)
    - If yes, how do you experience this collaboration?

Rounding off

- Do you have any further questions?
- Do you want the research results to be sent to you afterwards?
- Thank you for your time!

Appendix C: Interview transcripts

Due to their large size the interview transcripts can be found in a separate file. For questions about the transcripts please contact the researcher.