# RAINDROP FOR RANDERS

SYNERGIES OF STORMWATER MANAGEMENT AND PUBLIC SPACE DESIGN

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**Synergies of stormwater management and public space design**
ill. 1: Cover photo

## MASTER THESIS

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# MOTIVATION

The topic of climate change is the most discussed subject in recent years, by not only urban designers and environmentalists but the whole population. It is a crucial issue that must be further investigated, and the solutions should be promoted everywhere to make a change.

We feel it is our role to propose interventions that would help to not only adapt but also mitigate the effects of climate change. The inspiration for this thesis came from the recent events aiming to increase awareness of climate change and promoting people and governments to act in the matter. Though there is extensive literature on the topic, we think there is a need to continuously adjust our approaches and find innovative solutions that help to identify future actions.

By writing about this topic we want to contribute our knowledge to making cities resilient for the future conditions and creating urban environments that support both the ecosystem and the people.

# ACKNOWLEDGMENT

We express our sincere gratitude to Lea Holst Laursen for the support and guidance through our thesis project, which helped us to thoroughly investigate and critically analyse the challenges of climate change and urban design to create a resilient and responsive design proposal.

We would like to thank Jes Vollertsen for the advice on the technical aspects of our project which provided us with knowledge to make this design proposal realistic and adaptable to the future challenges.

A special mention goes to the anonymous interviewee from Randers municipality, who has given us insight into current and future projects, plans and challenges the city is facing.

Lastly, we thank our family and friends who supported us through the intense period of research and design.

# ABSTRACT

Climate change is a challenge we cannot escape, therefore planning and urban design must consider its consequences and ensure the resilience and sustainability of current and future cities. Urbanisation and human activity have increased greenhouse gas emissions and pressure on our ecosystem, causing increasing temperatures that result in raising sea levels, drought and heavy rainfalls.

Northern cities such as Randers, Denmark face increase in heavy rainfalls and flooding, therefore water management is a key element in sustaining quality of life and protecting the city from extreme weather events. With the point of departure in academic literature and case studies, followed by site analysis, topics of resilience strategies, nature-based solutions and livability will be investigated to identify strategies for climate change adaptation and design for people.

This thesis will explore the synergies between stormwater management and urban design that can enhance public spaces and contribute to city growth while transforming water from a threat into an asset and new identity of Randers. The design proposal suggests a water management strategy for the inner city and harbour area and presents a transformation of the boulevard into an attractive and lively public space with unique characters, stitched by a green and blue thread.

# READING GUIDE

The master thesis project presented in this report is distributed into the main reading material and the appendix with supporting material for water management calculations and site analysis. All illustrations in the report have been produced by the group members, unless referenced otherwise.

The texts are set to guide the reader from more general climate problems to site specific challenges and solutions. Hence, to gain the best understanding of the situation, it is advised to read through all the chapters in the given order.

The report is divided into 6 chapters counting the Opening as Chapter 1, which formally introduces the project, research question and applied methods. Following, Chapter 2 discusses the overall global issues related to climate change and more specifically water management in Northern regions and Denmark. Chapter 3 further investigates the topic and the future of cities through the approaches of urban resilience and livability. Urban resilience consists of principles in planning and adaptation strategies, which are supported by an investigation of case studies from Northern Europe to exemplify some of the existing strategies. The livability concept presents the methods and parameters used for socially oriented design and improvement of public space. Additionally, the design principles are introduced in this section in order to give a better insight into the following Chapter 4 about Randers city challenges and development. In this chapter, the previous research is applied and shown graphically through analysis of Randers city and project site. Chapter 5 presents the project vision and concept, which then are explained with strategies and design proposal developed through diagrams and visualizations. It also shortly summarizes the design proposal, functions and discusses its effect on the central area of Randers. In the final Chapter 6, the proposal is concluded in the perspective of future development and contribution to city growth and the project is reflected upon. It is followed by reference and figure lists, which end the main part of the report and unfold the appendix.

# CONTENTS

# 1

# OPENING

This chapter contains a short introduction to the master thesis topic and research question related to climate change and how it affects urban development. Furthermore, it explores the main aim and objectives of the project and discusses the methodology used both in the research and fieldwork, which form the basis for the project work.

# INTRODUCTION

Urbanisation and population growth are increasingly putting pressure on our ecosystem resulting in extreme weather conditions, such as drought, rising sea levels and increased precipitation. Urban development has disrupted the water cycle (Liptan and Santen, 2017) causing insufficient processes for excess water, resulting in the need of better water management strategies, known as Sustainable Urban Drainage Systems.

These water management strategies have been widely discussed in terms of planning and governance of water resources and providing frameworks for implementation (Koop and van Leeuwen, 2017; Jabareen, 2013). However, many planning support systems do not aid in the design and selection of best solutions (Voskamp and Van de Ven, 2015), and often strategies are reactive, expensive and ineffective (Koop and van Leeuwen, 2017). Reactive solutions do not foresee future conditions making them lack adaptability in design.



Recently academic focus has shifted to appropriate selection and design of water management systems, exploring both 'grey' and 'blue and green' adaptation measures to stormwater impacts (Voskamp and Van de Ven, 2015). Grey solutions focus on man-made infrastructure, such as sewer systems that aid in redirecting water, while green and blue solutions and nature-based interventions that support the natural processes of the ecosystem. Research suggests to consider different scales, local and context-based solutions, multidisciplinary approach and long-term adaptation strategies (Palazzo, 2018; Kuller et al., 2017) as well as blue and green measures which connect them to form an effective strategy (Voskamp and Van de Ven, 2015). What requires further investigation is looking at the problem as a potential for recreational reuse that would not only restore the ecosystem but also improve public spaces. The concepts of livabilty and people-focused design are crucial to understanding the workings of the public space and provision of appropriate interventions. Urban design literature has emphasised the use of greenery, promoting walkability, encouraging participation and provision of social gathering opportunities.

The focus of this thesis is rethinking the solutions for more frequent and heavy precipitation to manage fluvial and pluvial flooding and at the same time making public spaces that remain functional and attractive for present and future users. It will explore ways in which interactive urban design strategies can aid in water management while giving the runoff water a recreational and aesthetic value before it returns to the ecological cycle. The challenges of water management and current strategies are explored through a review of recent literature and case studies (Cook et al., 2018; Ellis, 2013; Conte et al., 2012) to provide an understanding of the approaches taken in water management and best practice solutions to illustrate the different problems and types of urban areas that require integrated water resource management.

Randers, one of the 6 most flood vulnerable cities in Denmark (Miljoministeriet Naturstyrelsen, 2011) is facing water challenges of heavy rainfalls and flooding. The city has focused on flood protection, however the central boulevard Østervold has a major risk of pluvial flooding as it is the leading channel for water runoff from surrounding areas, Furthermore this area in Randers not only has challenges with water but is also an unused by the locals due to traffic, wind and lack of activities. Therefore, the aim of the thesis is to create a design proposal for the transformation of Østervold that would achieve climate adaptation and improved public space. Through fieldwork and literature review, the design proposal is made to improve the water flow through the city as well as its social and economic aspects. The proposal will improve walkability in the area creating better connections through the city as well as provide attractive public spaces to make the area a destination with different characters for everyone all year round. It combines technical, functional and aesthetic solutions in an integrated water management strategy that stiches the city centre and the fjord into a resilient and livable urban centre strengthening Randers transforming identity.

How can urban design of inner-city areas aid in the distribution of stormwater while making the public space more attractive and functional in different weather conditions?

# OBJECTIVES

The thesis aims to identify and synthesize water management strategies and public space design that help to adapt cities to climate change and contribute to livability and spaces for people. It will examine ways in which these strategies can be used as an asset to create attractive and functional spaces in different weather conditions. The aim of the thesis is to create a strategic plan for the main boulevard that will improve the public space and manage runoff water. The following objectives are set to provide guidance through the process of research and design during the 4 months of the project:

1. Review academic literature on climate change and water management to gain understanding of the climate challenges and their implication on urban design and livability.

2. Collate and assess existing water management strategies using best practice examples in Northern countries to gain understanding of their contribution and application in different public spaces.

3. Critically analyse Randers development plans and strategies for city growth and climate adaptation.

4. Synthesise the findings with livability concepts to determine design principles for a resilient and attractive city of Randers, Denmark.

5. Identify and apply best water management solutions and public space designs to Østervold to achieve a functional and attractive space in all weather conditions.

# INTEGRATED DESIGN PROCESS

Problem Based Learning is a method incorporated during the studies at Aalborg University, where the main principle is that either the theoretical or practical problem is the starting point for the student's learning process.

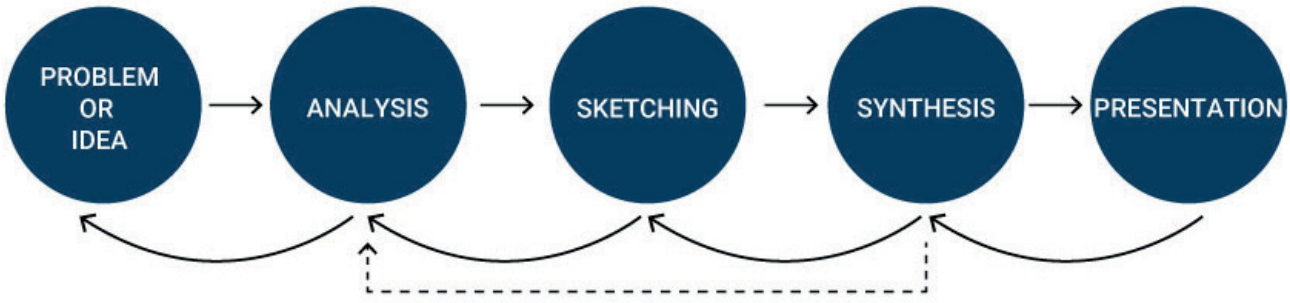
This pedagogical method has been adapted into the field of engineering, architecture and design by Mary-Ann Knudstrup, which resulted in a model called the Integrated Design Process. Knudstrup refers to it as a "synthesis of Problem Based Learning, the students' personal learning efforts, and the professional learning components from architecture and selected components from engineering" (Knudstrup, 2004).

The design is perceived as a process with multiple stages. The stages of the Integrated Design Process shown below in ill. 2, indicate how the process starts from problem statement to final design proposal, and loops in between the different phases. These loops, which are understood as looking back into the previous stages of the process, are a necessary measure in order to examine the previously taken decisions and their relevance in regard to the chosen design approach (Knudstrup, 2004).

The method should be looked at in a holistic way, where every piece is interacting with each other and at the end creating this fulfilled project. The method allows the students to reflect, analyse and go back, to test and try different solutions. And then, when the design succeeds in the synthesis, it is possible to work on the presentation. In the presentation, all the solutions are shown in a report, drawings, visualizations and models.

The essential task at the end of the process, is reflecting upon the undertaken methods and solutions and confronting them with the problem stated at the beginning of the project.






ill. 2: IDP diagram

# PROCESS

## Literature review

Climate change is not a recent phenomenon but remains one of the main focuses of academic discourse in the environmental and urban design fields providing direction to more sustainable and resilient city planning with consideration of future risks. The literature review consists of theoretical papers from peer reviewed academic journals in the fields of urban design, water management and environmental studies, as well as grey literature from Danish database and Randers municipality documents. The theoretical papers for the topic of climate change were limited to the past 10 years to review the most recent literature and identify the shift in practice and theory with the rising awareness of the issue. Articles on livability and design for people were reviewed to determine the guidelines and principles for city improvement and public space design.

## Analysis

The analysis consisted of mapping and research of the current challenges and potentials of Randers on different scales. This included regional analysis found in Appendix, to frame Randers in the context. Followed by city scale analysis found in Chapter 3 that present the local challenges. The information was gathered through secondary research and fieldwork, which consisted of 2 visits to the site where we gathered qualitative data on the use and perception of the site, see Appendix for site photos. This was recorded through photographs, time-lapse videos and personal experience.

## Interview

The primary research included an interview with the municipality employee and fieldwork. The interview was conducted on April 5th with an employee in the climate adaptation department. This interview gave insight into the municipality perception and possible projects in Randers that could help in flood protection and increasing resilience. The proposed projects include works and competitions along the waterfront as well as future developments in the city centre that include more greenery and strategies for cloudbursts.. However, the information gained at the interview cannot be treated as final municipality plans, but only possible solutions that are still under discussion. Therefore, any information used as the basis of the design project is a decision made by the group members from a critical analysis and municipality visions.

## IDP tools

Some of the tools of the sketching process are drawings on manifold paper, models or computer 3D models. Many of them are used during the sketching process, but also for calculations to solve the different complex problems attached to the project. The sketches are the tool for the students to maintain the ideas and thoughts and it serves as an internal creative dialogue during the process (Knudstrup, 2004).

In the sketching process hand drawings are often the most common among students as it makes it easy to show and compare the ideas. This phase is also important since the group is able to openly communicate proposals to discuss and reflect before taking the final decisions to further development.

The computer gives the possibility to create more than the classic geometric forms,It allows to add the technical detail as well aesthetic in the presentation phase. The computer is an important tool for handling the increasingly complex problems attached to optimizing the different elements simultaneously. Not only in the presentation phase but also during the Integrated Design Process (Knudstrup, 2004). It is a useful tool to show possible solutions and test them easily.

# 2

# THE CHANGING CLIMATE

Global climate challenge phenomena is used to emphasize the importance of water management in cities. By introducing the general climate challenges and their consequences, the reader is made aware of the greater scale of the issue and is then directed to the key challenge that is the focus of the thesis and the design proposal. The possibilities and limitations of water in a city are discussed in regard to urban design. This chapter scopes down to the Denmark specific challenges and implication on city scale, which will help to set the reader's focus on the project site in the following chapters.

# THE CHANGING CLIMATE

Climate change is a global issue affecting countries in different ways and impacting many dimensions (NASA, 2019a). There can be catastrophic consequences of our actions and global warming, posing threat to human life, economy and the environment (European Commission, 2019a, 2016a, 2014).

## CLIMATE CHANGE

Climate change can already be seen in today's global average temperature of 0,85ºC higher than in the late 19th century (European Commission, 2014) which is predicted to increase in the next century from 1.4 to 5.5°C (NASA, 2019b). This means that the weather conditions will intensify with more extreme events occurring. Northern Europe will experience increasing wetter climate conditions, river flows and flooding, while central and southern Europe and the Mediterranean region will have decreased river flow and be exposed to hot temperatures causing drought, heatwaves and fires, resulting in casualties and high damage costs (European Commission, 2019a, 2016a, 2004). The environmental consequences include destruction of habitats, biodiversity, reduced land coverage, extinction of certain species and many more. With climatic conditions changing, human life is also in danger not only due to natural disasters but due to inability to quickly adapt to changing conditions leaving us exposed and prone to spreading diseases. Furthermore, apart from costs incurred due to natural disasters, there are also impacts on the economy; influencing trade, businesses, production and city growth. Climate change causes economic problems for sectors that depend on climate stability, such as agriculture, forestry and tourism, and significantly for developing countries which rely on the natural recourses and do not have the capacity to cope with the changes (European Commission, 2019a). The effects of climate change might seem invisible on the global scale as they have not touched everyone directly.



This causes a political debate on a global scale which adds to the difficulty of reaching consensus on policies and guidelines, and common efforts to reduce our impact. Urban development and our way of life has been the main contributor of CO2 emissions, which is one of the greenhouse gasses that cause increased temperature.

In 2013, we have reached the peak of carbon dioxide emissions, and they have not stopped rising, despite increasing debates and awareness (NASA, 2019a). The consequences of climate change depend on our actions and even if we stop emitting greenhouse gasses, the effects of the past actions will still remain and we will be exposed to some degree of climate change (NASA, 2019a). However, if no action to mitigate the effects is taken, we continue to increase the dangers for the environment. Our actions have influenced climate change and as we try to restore the ecosystem, many dimensions will also be impacted, some for the better some for the worst. This becomes an obstruction to achieving the common goal, as the perception remains that we would need to give up certain ways of life. However, the consequences are more than visible locally, causing damage and resulting in independent reactive solutions by local authorities and organisations (NASA, 2019a). Not enough action is taken to mitigate the effects and mainly adaptation strategies are used with short term vision, which is ineffective; as the faster our climate changes, the bigger the challenges will become and adaptation will become even more difficult (NASA, 2019a).

Jabareen (2013) noticed that often mitigation and adaptation strategies have been focused on one at a time, but in order to restore the ecosystem to a balanced state they must complement each other. We cannot afford to use reactive strategies only in the affected areas, instead we must protect the whole city from all consequences, both the extreme and the common events (European Commission, 2004). What is truly needed are long-term strategies, risk management and adaptation to climate conditions rather than "defensive action against hazards" (European Commission, 2004, p.4).

## WATER AS A THREAT

The effects of global warming can be seen through temperature change and extreme weather conditions leading to rising sea levels, rainfall and drought, which are becoming more frequent and more intensive (European Environment Agency, 2018a). The largest impact of climate change can be seen through water; its excess, abundance and quality. It is both a recourse and threat to human existence. Flooding occurs due to rising sea levels and heavy rainfall, which are predicted to increase in frequency and severity in the coming years (European Environment Agency, 2018a; European Union, 2007). Flooding is the most common and costly natural disaster due to climate change (European Commission, 2016b). Within 4 years from 1998, there were over 100 flood events and until 2004 the total damage resulted in 700 fatalities, displacement of around half a million people and costs of more than 25 billion euros (European Commission, 2016a). With the increasing air, earth and water temperatures, the glaciers and ice covers are melting and water levels are increasing, leaving low lying and coastal areas in risk of flooding and erosion (European Environment Agency, 2018a; European Commission, 2019a). The sea level rise is expected

ill. 3: Flood threat

to be between 9cm to 88cm by 2100 (European Commission, 2004). Precipitation patterns are also changing and becoming shorter but more frequent and intensive (European Environment Agency, 2018a). These extreme weather events are predicted to happen once every 10 years by 2050 (Koop and van Leeuwen, 2017).

Denmark has been experiencing increasing temperatures, rising 1.5°C since 1870 (Olesen et al., 2014). As forecasted by IPCC, in the worst scenario of increasing emissions the temperature will rise by 3.7°C and if the emissions are lowered by only 1°C by 2100 (Olesen et al., 2014). In either case the raising temperatures will put Denmark at risk of flooding due to more winter precipitation and rising sea levels (Olesen et al., 2014). There are increasing risks of pluvial flooding due to cloudbursts. Rainfall mean intensity is predicted to reach 5.6mm/day, with about 15 days /year of rainfall over 20mm and about 78 days/year of rainfall over 10mm (Olesen et al., 2014). The sea levels have been recorded to rise 1,7-2,2 (± 0,3) mm/year (Olesen et al., 2014) which puts low lying areas at risk. There are 10 water endangered areas in Denmark as stated by the EU directive, out of which 6 are major cities located by coasts and fjords that face challenges of fluvial and coastal flooding (Miljoministeriet Naturstyrelsen, 2011), see ill. 3. Cities located by water bodies are particularly prone to flooding due to their structure and lacking capacity to manage excess water.

The excess of water is unavoidable; therefore, managing water in cities will be the focus of this thesis project, specifically Randers which is one of the most endangered cities in Denmark. These water challenges put pressure on the ecosystem and cause it to become unbalanced. Increasing flood events lead to human casualties, displacement of people and damage the environment which then impacts economic development and activity (European Union, 2007; European Commission, 2004). These occurrences have caused cities to view water as a risk rather than an asset (Illman, 2013). However, to protect cities from the damages, we need to find innovative solutions that would allow us to live with water in the long term, instead of fighting it.



## WATER AND THE CITY

Urban development and climate change are intertwined forming a cycle, therefore our lifestyle and progress will also have to change in order to sustain the quality of life we reached and prevent further harm to the environment (NASA, 2019a). Cities are in most danger due to the built environment and inability to handle the consequences of climate change.

The European Environmental Agency (EEA) (2018b) estimates that already 20% of Europe's urban areas are at risk of flooding due to increased urbanization, while two thirds of the world's largest cities will be in danger of rising sea levels (Koop and van Leeuwen, 2017). To allocate the increasing number of people in cities, they will have to expand, but already the demands for services exceed the supply. Cities take up 2% of land but produce 75% of CO2 emissions and consume 60-80% of energy, sometimes exceeding their environmental footprint by a factor of 10-150 (Koop and van Leeuwen, 2017). This puts pressure on the natural and built environment to sustain the soil, air and water quality, sufficient supply of water, recycle waste and wastewater treatment (Koop and van Leeuwen, 2017). The emission of greenhouse gases also takes place from developing infrastructure, increased transportation possibilities and socio-economic conditions that increase the number of car users, therefore increasing CO2 production. Other reasons include industrialisation, mass production which grows with demand and agriculture which contributes to 92% of the water footprint (Koop and van Leeuwen, 2017). These actions will have to be reduced in areas prone to flooding and "as far as possible, human interference into the processes of nature should be reversed, compensated and, in the future prevented" (European Commission, 2004).

The water cycle in an uninterrupted environment can distribute water from oceans, rivers and land through a cycle of rain, infiltration and evapotranspiration, however with the changing climatic and geomorphologic conditions the distribution is no longer balanced, resulting in unpredictable abundance and excess of water at different times (European Environment Agency, 2018a; Voskamp and Van de Ven, 2015). The problem is "'the intensification of the hydrological cycle — due to changes in temperature, precipitation, glaciers and snow cover'" (European Commission, 2016a).

This in turn is further impacted by the built environment as seen in ill. 4-5. Solar radiation, high temperature and decreasing vegetation have impacted the evapotranspiration and cooling systems, while infiltration, detention and retention are impacted by the soil type and the lack of permeability of concrete city surfaces (Voskamp and Van de Ven, 2015).

The city surfaces have also alternated water runoff and increased risks of fluvial flooding as all water is directed to larger water bodies. Furthermore, water quality has been decreased due to polluted runoff water and lowered treatment capacity of the ecosystem.

The development of cites has a great impact on the waterflow. Both sprawl and compact cities have their positive and negative impacts on the environment. Urban sprawl and river basin alterations will lead to increased flooding and damage from reduced capacity to absorb excess water (European Environment Agency, 2018b; European Commission, 2016a). Sprawl cities put pressure on land use and increase infrastructure needs, but allow for nature-based solutions for water management, while compact cities may require less infrastructure and lower costs of grey solutions, but struggle to provide SUDS (Fenner, 2017). Increasing number of buildings, expanding infrastructure and transformation of natural areas, lead to reduced infiltration and inability to absorb excess water (European Environment Agency, 2018b). When developing new areas it is necessary to understand and incorporate all levels of the water cycle in order for the area to be functional (Illman, 2013).

The challenge of climate change is not only concerned with the environment but the whole ecosystem and its processes. Most of our services are dependent on water as its source, therefore it is necessary to keep a balance and ensure enough water to maintain natural ecosystem services (Fenner, 2017). Urbanization and ineffective water systems lead to increased management and maintenance cost of urban infrastructure and human health impact (European Environment Agency, 2018a; Koop and van Leeuwen, 2017; Jabareen, 2013; European Commission, 2019a).

Due to the excess water from more frequent cloudbursts and flooding, the functionality of the city is limited extending past the occurrence of the actual events. Wetlands can be destroyed reducing biodiversity (European Commission, 2016a), green spaces become unusable due to saturated ground, city centres become flooded and dirty due to water pollution and overflown sewage systems, flooded streets impact the transportation possibilities and safety, while the built environment is exposed to erosion causing need of maintenance. There are huge costs of damages from extreme events as well as huge costs of implementing water infrastructure. The average cost of flooding in Europe between 2000 to 2012 was 4.9billion/year which is estimated to increase to 23.5 billion in 2050 (Jongman et al., 2014 in (Koop and van Leeuwen, 2017). Therefore it is essential to balance economic development and urbanisation with the required space for water flow and retention areas (European Commission, 2004).



## PLANNING WITH WATER

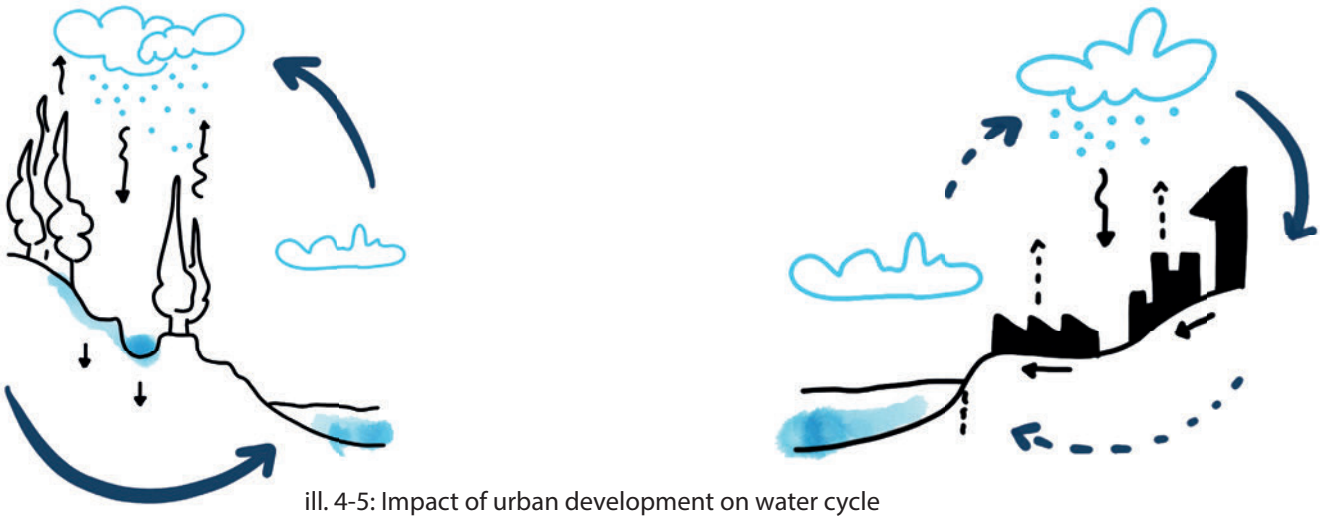
Many cities in the past have chosen to lead the water away from the public spaces in central locations. However, recent studies show the importance of water in our everyday lives and hereby suggest working with it by including it in the urban design and distributing it evenly over the whole city, rather than trying to remove it completely. Though having too much water can cause severe consequences to the surrounding environment and our lives, it is crucial to study the water in order to be able to control it.

This has stimulated the planning and policy around the world to include new approaches such as water sensitive urban design (WSUD), low impact development (LID) and sustainable urban drainage systems (SUDS). They focus on incorporating water management in urban design by using nature-based adaptation measures that reflect natural processes and bring many economic and social benefits (Ahammed, 2017). SUDS is the European approach that integrates water quality and quantity with amenity aspects through green alternatives that reflect the traditional drainage systems (Fryd et al., 2012 in (Ahammed, 2017). The goal is to create SUDS and integrate it with the approaches for livable cities to make attractive places to live in (Illman, 2013).

Many European cities have been worked towards become water-efficient and adaptable, but have not reached the cohesion of all the water aspects in the city as explained by Koop and van Leeuwen (2017). Denmark is one of the leading countries in climate adaptation and water management. Cities like Copenhagen, Aarhus and Odense have already adopted some of the strategies to manage excess water and become resilient in the future.

Following these examples, many cities implement new strategies to minimise damage from extreme event, help restore the environment and at the same time improve the quality of life for people (European Environment Agency, 2018a) One of the cities that is working towards this change is Randers, aiming for not only climate adaptation but also city development to enhance public space. These are further explored in Chapter 4, along with city analysis and facing challenges. It will look closely into approaches and strategies for water management of the city centre and harbour area.





ill. 4-5: Impact of urban development on water cycle

ill. 6-9: Copenhagen strategic flood plan

Copenhagen due to its location and urbanisation experiences the challenge of excess water. Copenhagen recently suffered four severe rainfalls, with the biggest in 2011 causing damages of 5-6 million DKK (European Environment Agency, 2018b; European Commission, 2018). With 150mm of rain within 2 hours, the city was flooded as the sewer system did not have enough capacity and overflown into houses and streets (Koop and van Leeuwen, 2017). After this event, in 2012 Copenhagen has made the "Cloudburst for Copenhagen Management Plan" (Climate-ADAPT, 2016). Copenhagen like many Danish cities will experience less rain events but with more frequent intense precipitation (Climate-ADAPT, 2016). Projections show that in 2100 the intensity of 10—year event will increase by 30% overflowing the current drainage system, and the 2110 100-year event projections show 742ha will be flooded if no action is taken comparing to only 235ha if solutions are implemented (Climate-ADAPT, 2016). The assessment showed that traditional drainage systems alone would not be sufficient and the costs would be too high while the city would still be flooded, whereas the combination of nature-based and grey infrastructure would be cost effective and provide more social and economic benefits (Climate-ADAPT, 2016). The result was the decision to extend the sewer network and implement 300 projects for surface water runoff, which would improve retention and drainage systems, until 2033 (European Environment Agency, 2018b). The report outlined 4 main solutions; stormwater roads and pipes to distribute water, detention roads; detention areas such as parks and green roads (Climate-ADAPT, 2016). Other solutions include reopening and constructing streams and canals, lakes and permeable pavements (Climate-ADAPT, 2016). The water management plans and solutions used in Copenhagen serve as examples of best practice from which other cities can learn of adaptation strategies and resilient development plans (European Environment Agency, 2018b).

# 3

# CITIES OF THE FUTURE

This chapter discusses urban resilience strategies through planning and adaptation for long-term and uncertainty. Moreover, it elaborates upon grey contra nature-based solutions for urban design, which are then summarized in a water management table. The strategies are supported by a collection of case studies from Northern Europe to provide and examine the success of such strategies. The livability topic is used to both explore the vision of this project and also introduce design parameters, which will be used in developing design proposals and finally creating a strategic plan.

# CITIES OF THE FUTURE

The concept of resilience has two elements; to ensure functioning of the ecosystem which means handling and recovering from extreme unexpected events, and adaptation which improves the capacity to handle future events at reasonable costs and timeframe (Voskamp and Van de Ven, 2015).

## URBAN RESILIENCE

These are the goals that need to be met on the technical side to protect cities from climate challenges and can be achieved through future oriented planning and implementing nature-based solutions that have capacity to handle extreme events in a natural process. There is a need for active adaptation processes in policy making and implementation strategies due to the constantly changing climate (Koop and van Leeuwen, 2017). Current strategies and policies need to be constantly reviewed and adapted to create a future resilient state. The ideas discussed by many academic papers revolve around resilient city frameworks (Jabareen, 2013) and planning policies for climate adaptable cities, such as EU directives. The frameworks and policies, however, only guide the planning process and assessments of risks without suggesting design solutions for water management, which only appear in more technical literature. The lack of interdisciplinary approach and synthesised knowledge is a clear barrier to implementation of resilient strategies and is further separated by contextual differences. Therefore, there is a need to compile and analyse best practice examples to be able to suggest appropriate strategies for specific vulnerable sites.



## Planning

Water management is affected by multiple sectors and decision-making bodies. Its planning must incorporate the changes and processes of other areas of city planning and collaboration with different stakeholders. Interdisciplinary approach and sharing knowledge are key to improving water management systems. In planning for climate change it is important to first assess the current conditions and risks, to be able to set objectives and approaches for further action. The actions taken need to place focus on planning with uncertainty of the future. Policies need to put forth mitigation strategies, as well as adaptation strategies in the long term even though it is uncertain of what the climate conditions will be. Adaptation strategies should not only be based on the current conditions but predict into the future (Jabareen, 2013), in order to maintain the environmental, social and economic system, therefore retain the current quality of life.

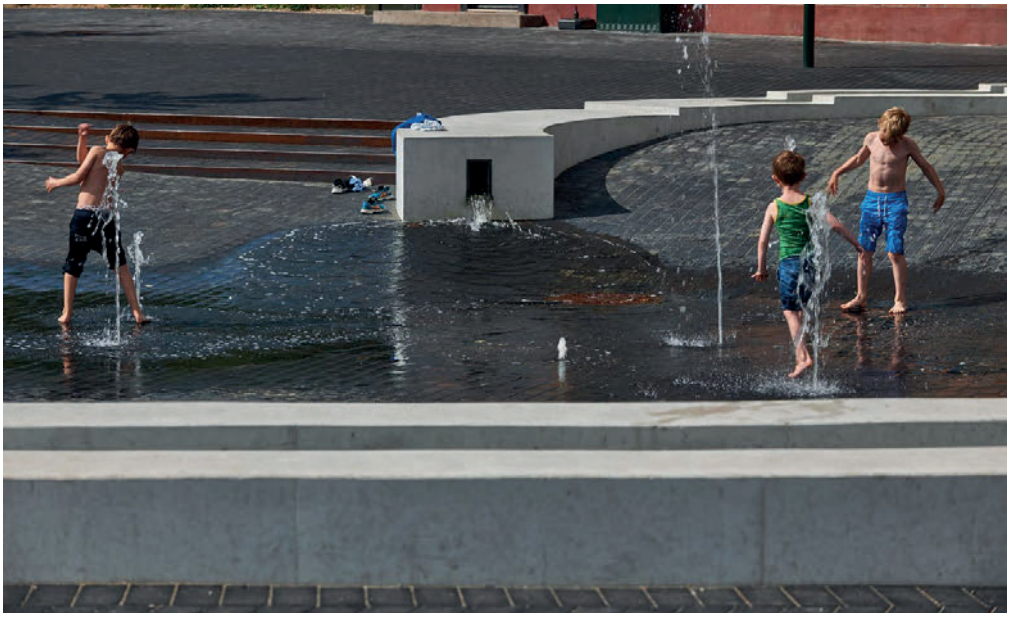
## Collaboration

Participation, collaboration and integration in decision making and sharing knowledge has been discussed to be an important element in planning effective solutions. There is a need to include all the stakeholders in the process to create the best resilient solutions and more importantly to give resources and spread knowledge to the local communities for them to be able to act independently (Jabareen, 2013; European Commission, 2004). Managing flood at community level and coordinated actions can improve flood protection, especially in more populated areas with economic assets and ecological value (European Union, 2007; European Commission, 2016a).

Exchange of information and knowledge with communities and different stakeholders through participation and education is the key to ensuring effective and innovative solutions to the given area (Palazzo, 2018; European Commission, 2004; Fenner, 2017). This can be seen in Lindevangs Park by Marianne Levinsen Landskab, ill. 10-12, where the public is involved and is able to interact and learn of the water management strategies in the area. The Adaptation Preparedness Scoreboard for Denmark (European Commission, 2018) shows that most municipalities have adopted the strategies from the NAP at the local level but have not done so in the subnational level which suggests there can be improvements in the collaboration between different levels of governance (European Commission, 2019b).



There needs to be clear communication and collaboration at different levels of governance, from international to local scale and in different departments, that also consider different levels of the water cycle to provide a holistic approach with guidelines and policies to tackle the challenges together (Ahammed, 2017; European Commission, 2004; Fenner, 2017). To achieve resilience, it is necessary not to relocate the problem to another area but to; first retain the water, secondly store it locally and then release and distribute it further (European Commission, 2004).



**Lindevangs Park / Marianne Levinsen Landskab**

The project includes a grass field, communal city garden and square with a reservoir for water collection underneath. The public square is sloped and surrounded by a water wall to be a detention area and a recreational feature. The park contains detention areas, swales and natural playgrounds that all serve as a recreational and educational purpose (Landezine, 2017).

ill. 10-12: Lindevangs Park

**Hans Tavsens park / SLA**

This climate adaptation proposal is integrated with urban design on all scales and levels of the process. The team has incorporated the input of the community in their approach to find best solutions not only for water management but also benefits for the public. The rainwater is collected and used locally, and the excess water is directed to a lake. This shows connectivity of the solutions on many scales and the importance of collaboration with different stakeholders (SLA, 2019).

ill. 13-15: Hans Tavsens park

Collaboration with different cities on a bigger scale to share knowledge and best practice methods is necessary to improve current strategies (Koop and van Leeuwen, 2017). Hans Tavsens Park by SLA, ill. 13-15, is an example of this practice where expertise on water management is shared and different stakeholders have played part in the creation of the proposal. Planning support systems are interactive and participatory methods used to gain multidisciplinary perspective and share knowledge in the planning process, but they do not help in selecting and designing best strategies (Voskamp and Van de Ven, 2015).



In Denmark there is ongoing progress for improvement of collaboration in the vertical and horizonal level of the involved sectors of governance and there have been expert teams involved in helping municipalities in adaptation procedures through workshops, seminars and training (European Commission, 2018). There was an analysis done for the 14 different departments which provided information on the impacts of climate change on each planning body; division of tasks, possibilities and constraints for adaptation, future action, and ongoing and planned projects (European Commission, 2018). The involvement and clear communication with other stakeholders are also visible in planning procedures. Major public policies are accessible and open to public opinion while the relevant stakeholders are contacted directly (European Commission, 2018). There are strong efforts made to expand national knowledge base and provide multidisciplinary perspective for adaptation solutions (European Commission, 2018). International collaboration also plays a key role in Danish planning for adaptation. Denmark has participated in multiple climate adaptation design and research projects around the Nordic and Baltic Sea region, as well as EU projects and overseas collaborations (European Commission, 2018).

**Risk assessment**

There needs to be a better understanding of the climatological, hydrological and ecological contexts for effective prevention and management measures (European Commission, 2004). Urban design solutions for water management have to originate from analysis of the context and risks, through surveying, mapping, data collection and pre- and post-implementation monitoring (Palazzo, 2018). In recent years, countries took action towards assessment and management of risks and effects of climate change, through better consideration in development plans such as coastal protection, response to extreme weather events, impact of land management, water scarcity, energy use and resource management (NASA, 2019a).

Jabareen (2013) suggests the vulnerability matrix as a tool that can be used for mapping the demography, intensity, scope and distribution of the future challenges of our environment and risks, to then show how these can affect the city. The demography, informality, uncertainty and spatiality components ensure that in the planning process there is consideration of the economically disadvantaged areas and the distribution of risks that can identify these areas as more prone and having lower capacity to cope with the challenges (Jabareen, 2013).

The EU directive (2007, p.29) sets out a framework for "the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community," however, it

does not consider future events and climate change nor does it provide guidelines for reducing the effects. Each EU country was required to make a risk assessment by 2011 which included maps, historical analysis of events and their impact and flood risk areas which later should be used to support the strategies for prevention, protection and preparedness that include forecasts, warning and control systems for flooding, sustainable land use and water retention measures (European Union, 2007). Cities should make action plans of different measures, their costs and effects to mark the importance and priority in implementation (European Commission, 2004) as a way to set objectives and focus areas. Further, they should invest in warning systems and relay on real-time data collected for forecasting and reliable information especially in the flood risk areas (European Commission, 2004).

## Uncertainty

One of the key concepts in planning for climate change is long-term strategies and planning with uncertainty. The uncertainty of climate change has put pressure on the current planning approach (Jabareen, 2013) proving it is unable to anticipate and resolve future conditions. Traditional planning for flood prevention has been reactive, arising only after the fact, making them ineffective and expensive, therefore the main challenge is to transform these strategies to long term proactive measures (Koop and van Leeuwen, 2017), which will be able to respond to the uncertainty of events. Hence, the current approaches have to be assessed in the perspective of how policies and planning contribute to the resilience strategies and shaping the different dimensions of a city (Jabareen, 2013). The decisions and strategies implemented today have to be adaptable and affordable, so that the future generation does not suffer from today's choices (Koop and van Leeuwen, 2017).

In 2012, Denmark enforced the National Adaptation Strategy (NAS) that not only identified most vulnerable areas and the facing challenges but also ensured policies were made that addressed long term strategies and current actions to be taken with contributions of the whole society (European Commission, 2018). The NAP covers 5 areas of concern: "more consultation and a new knowledge base; strengthened collaboration and coordination; green transition; and international climate adaptation," and suggests total of 64 initiatives (European Commission, 2018, pp.6–7). All municipalities in Denmark have incorporated the adaptation plans, however not all have manged to implement the strategies and none of the plans have defined time frames to set clear goals (European Commission, 2018, 2019b).



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## Adaption

Adaptation is changing our actions and environment to the consequences of the already existing problem. '"The goal is to reduce our vulnerability to the harmful effects of climate change. It also encompasses making the most of any potential beneficial opportunities associated with climate change" (NASA, 2019a). Adaptation, in contrast to behaviour-oriented macro-scale mitigation, is a tangible micro-level strategy focusing on the design of the urban environment that impacts the actions and processes within to deal with climate change effects (Jabareen, 2013). This means that the focus needs to be placed on how physical design of cities can help to improve functionality of spaces during those events.



The provision of infrastructure to handle flooding events is more than combined cost of energy, road, rail, air and sea ports, but it is still lower than the cost of renewal after such events (Koop and van Leeuwen, 2017). Technologies for water management should be more affordable and better integrated in urban planning (Koop and van Leeuwen, 2017). Implementation of new strategies is expensive; however, it is cost effective to implement them additionally to already planned works for regeneration, development or maintenance (Voskamp and Van de Ven, 2015; Koop and van Leeuwen, 2017). Additionally due to smaller budgets and increasing risks, many cities have turned to nature-based solutions, which are shown to be more effective, reducing costs of prevention and damage by achieving the same level of protection in a more sustainable way while enhancing public spaces (European Environment Agency, 2018a; Illman, 2013; European Commission, 2016b).

## Grey adaption

In extreme cloudburst events, the traditional systems that cities have been relying on are human-built drainage systems, known as grey adaptation (European Environment Agency, 2018a). These measures are mainly concrete structures, drainage pipes or pumping stations, which tend to have single purpose and are typically very rigid in their use (Voskamp and Van de Ven, 2015). More over traditional dams can sometimes have a negative impact on biodiversity and natural processes, causing increased drought or reduced quality of water (European Commission, 2016b). The European Commission (2004) suggests that floodplains should be designated by law as retention sites or restored waterways, which are not interrupted by any protective construction that would interfere with natural water flow unless it surrounds a densely populated area. As learnt from flooding events, grey adaptation is often not sufficient capacity for the amount of water and can cause more damage by pipe bursts and flooding downstream (European Environment Agency, 2018b). It is a 19th century solution that is not sufficient for today's problems, instead we ought to look towards natural drainage which is more efficient, costs less and enhances spaces at the same time (Illman, 2013). An example of such transformation is the Zollhallen Plaza by Ramboll Studio Dreiseitl, ill. 16-18, where the plaza has its own water management system and takes pressure off the local grey infrastructure.

**Zollhallen Plaza / Ramboll Studio Dreiseitl**

This square has been disconnected from the combined sewer system which is overflown during storm events. The square becomes a SUDS that builds on heritage of the area while being also being a low maintenance and cost-effective strategy. Permeable pavement and incorporated greenery offer evapotranspiration and infiltration possibility that reduces the heat island effect and pressure on the local sewage system (Grau, Nielsen and Hoeijmakers, 2011).

ill. 16-18: Zollhallen Plaza

## Nature based adaptation

Green-blue solutions are adaptation measures that use natural landscapes to imitate and regain natural waterflow in our ecosystem (European Environment Agency, 2018b). They reduce the impact of severe rainfalls in cities while being more environmentally friendly and easier to maintain than grey infrastructure (Illman, 2013). These strategies include detention and retention basins, swales, bio-filtration systems, vegetated swales and strips, permeable and porous pavements, wet lands, ponds, green facades and roofs, rain gardens, redirected roof leaders, rainwater harvesting, treatment and re-use systems (Ahammed, 2017). With green strategies we can reduce the "costs of damage to society, human health, economic activities, infrastructure, cultural heritage and the environment" and contribute to natural and social resilience, by protection and restoration of the natural habitat and ecology (European Commission, 2016b). Green and blue measures are adaptable and offer multipurpose value for the environment, economy and society (Voskamp and Van de Ven, 2015; Ahammed, 2017).



Blue and green areas have multiple environmental benefits which improve the thermal comfort, reduce damage and improve quality of life. Green surfaces and vegetation in cities helps with excess water storage and infiltration, and additionally provides pollution and noise reduction, slower traffic and increased safety (Fenner, 2017). Furthermore, green spaces can increase biodiversity and recharge underground aquifers and clean water (European Commission, 2004). This improves habitats for wildlife and supports the natural processes. Water bodies and trees provide cooling effect through evapotranspiration and shadow, especially needed in cities suffering from heat islands (European Environment Agency, 2018a). The most effective method for flood prevention is through river basins and floodplains, focusing on restoring the ecological and chemical state that would mitigate the effects of climate change. (European Union, 2007). Queen Elizabeth Olympic Park by Hargreaves Associate, ill. 19-21, has been developed to restore the natural riverside and gain environmental benefits along with a new recreational purpose. Implementing greenery through the city will help to distribute water and return it to the natural cycle, while improving the aesthetics and quality of life for the citizens.

There are also multiple benefits for the society including physical and mental wellbeing, recreation, social integration, connectedness to nature, as well as urban comfort, aesthetics, property and amenity value, which support livability and economy (Palazzo, 2018; Fenner, 2017; Soga and Gaston, 2016; Virtudes, 2016). Natural landscapes can not only provide protection from flooding but can create recreational spaces (European Commission, 2016b, 2004). Taasinge Square by GHB, Figure X, shows how water management can be incorporated in a dense city and provide attractive and fun structures for public spaces. A green space can become a gathering space, play area or an escape from the city. It creates a different atmosphere providing many people with relief and necessary change of setting. This benefits the mind, soul and health contributing to better lifestyles. In children, exposure to green space additionally increases awareness and connection to nature therefore promoting pro-environmental conservation behaviour in the future (Cheng and Monroe, 2012; Vanaken and Danckaerts, 2018). Green spaces have environmental and social impacts that aid in protecting the future and creating sustainable environments.

**Queen Elizabeth Olympic Park / Hargreaves Associates**

This area was an industrial channel which has been transformed as part of the Olympic Games park. The natural riverbed and meadows have formed wetlands surrounded by a park which provide a flood protection area, filtration and improved biodiversity. The area offers a place for gathering, play and many viewpoints. The North part is a more natural landscape, while the South part is a terraced landscape with variety of planting reflecting the theme of the Olympic Games and participating teams (Landezine, 2016).

ill. 19-21: Queen Elizabeth Olympic Park

**Taasinge Square / GHB**

This project adds educational and recreation value using sculptural features such as parasols and tanks, as water collectors. The tanks store water from roofs and become interactive furniture imitating water drops reflecting the sky. Water can be released to irrigate the vegetation in the square which provides detention ponds and infiltration possibility. Parasols collect rainwater and lead it to the ground to be infiltrated, this way providing cover during rain and shadow on sunny days (GHB Landskabsarkitekter, 2019).

ill. 22-24: Taasinge Square



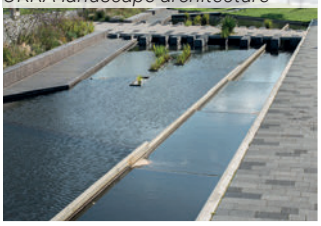

## Implementation

There is an urgency for compiling and evaluating current adaptation measures (Voskamp and Van de Ven, 2015) to the challenges of the Northern climate in such a way that it can be a tool for decision-making and design solutions. This table presents the challenges relating to excess water and different area typologies, providing solutions from the best-practice projects. The chosen projects integrate many solutions in one proposal proving the benefits of hydrologic and ecologic connectivity. This tool is used to narrow down and inspire possible solutions that can be used at Randers to tackle the same challenges.

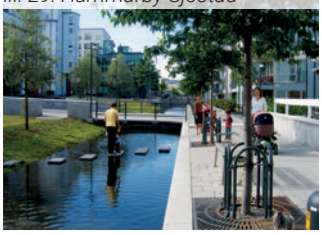
ill. 25: Water design principles

*ill. 26: Westergasfabriek Park / Gustafson Porter+Bowman*

*ill. 27: Laasby Sea Park / LABLAND architects*



*ill. 28: Catharina Amalia Park / OKRA landscape architecture*



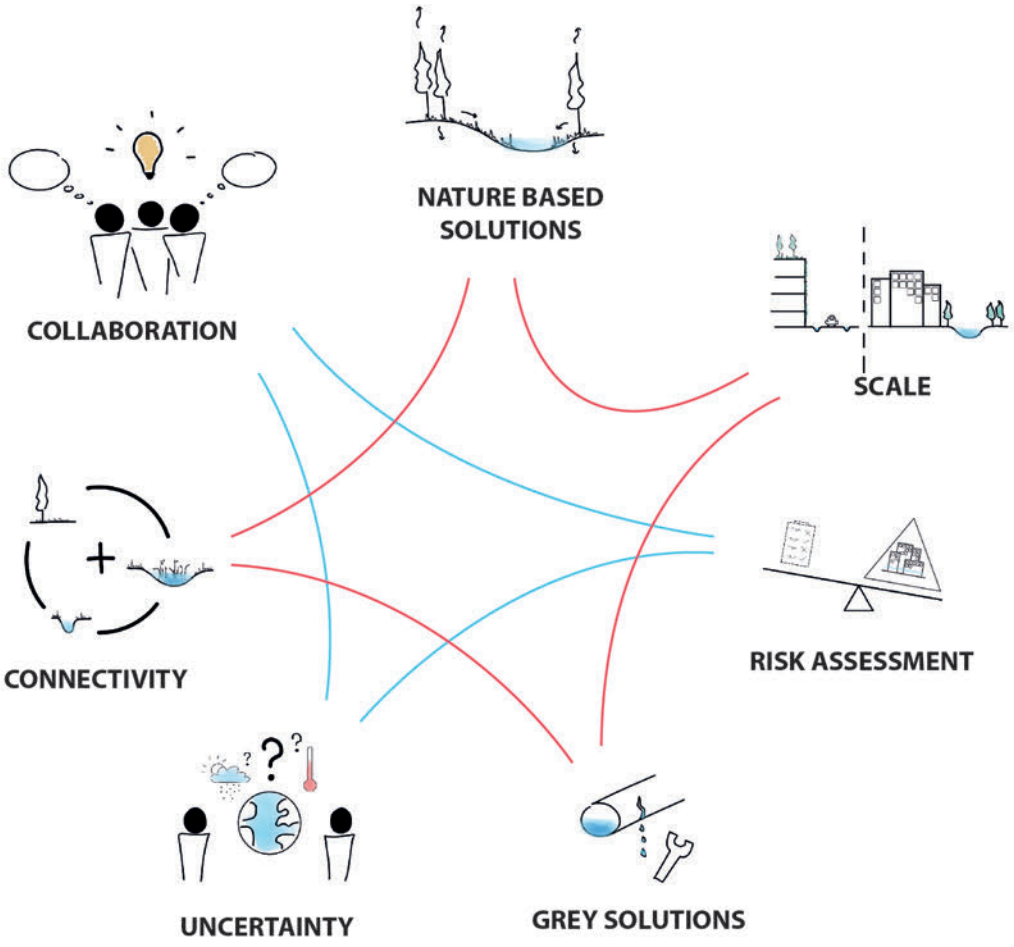
*ill. 29: Hammarby Sjöstad*

*ill. 30: Arkadien Winnenden / Ramboll Studio Dreiseitl*

## Connectivity and scale

Conventional centralized drainage systems are becoming vulnerable due to the fact that they are optimized for certain areas, while with the changing climate decentralised solutions are beneficial to locally deal with the problems and preventing failures and overflooding of a single system (Palazzo, 2018).

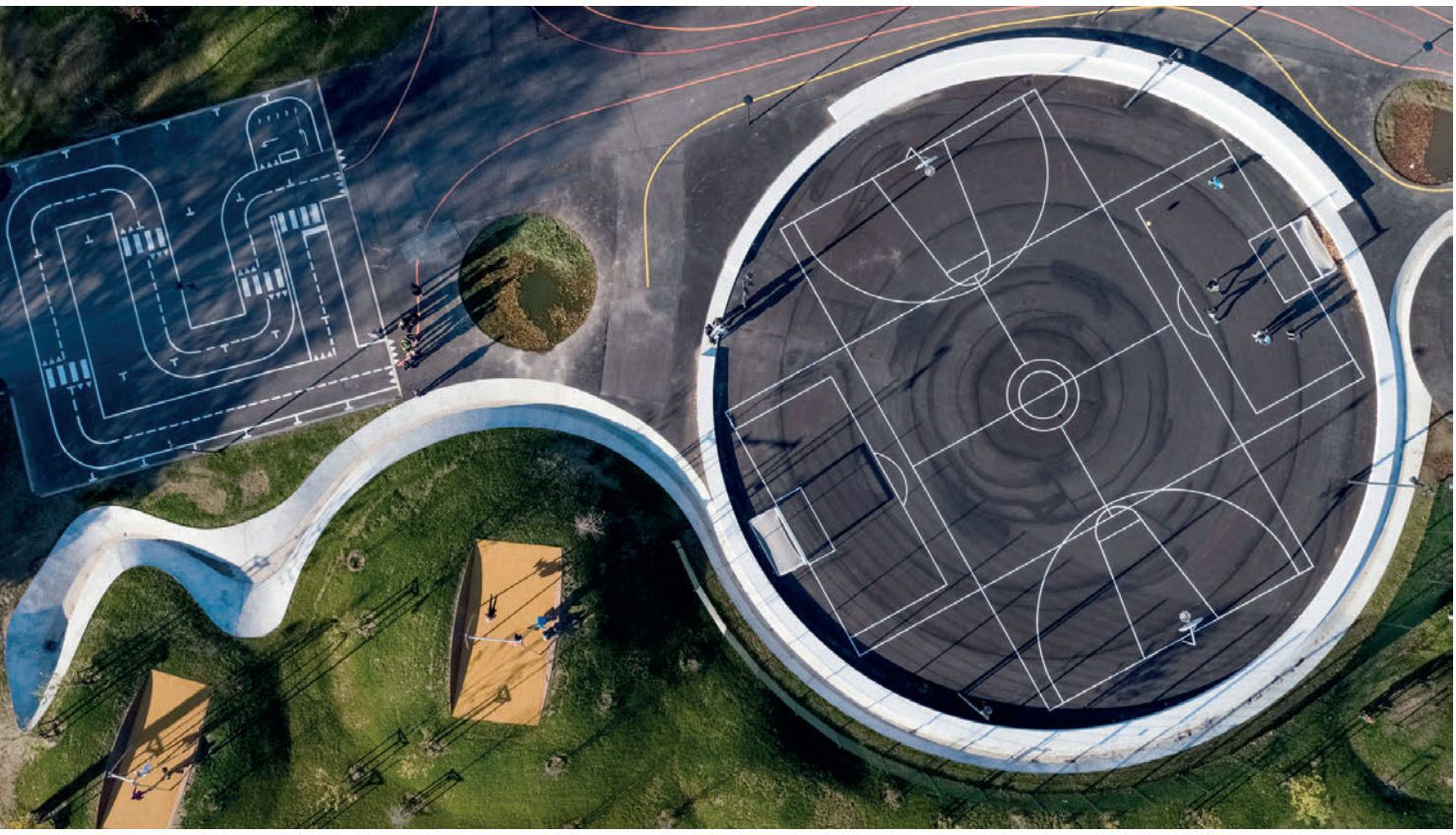
Regenerative urban design (Palazzo, 2018) suggests the use of multi-dimensional and flexible strategies capable of responding to the causes of climate change and at the same time retaining the basic function and state of the space. This becomes a safe-to-fail approach that does not harm the basic process of the ecosystem by providing back-up solutions to support basic functions (Palazzo, 2018; Fenner, 2017). Kokkedal Climate Adaption Project by Schønherr, ill. 31-33, is developed as a series of different water management strategies on different scales that are well combined to support the natural processes. For appropriate and effective adaptation measures, it is crucial that the context and characteristics of the flood are taken into account (European Union, 2007).






The key concept and most effective strategy for nature-based solutions is combining blue and green measures to achieve solutions on all scales, for all weather conditions and connectivity between them, therefore reflecting and supporting the natural ecosystem process (Voskamp and Van de Ven, 2015; Palazzo, 2018). Water management cannot be seen as a single discipline and should be combined with green infrastructure as these processes are interdependent and provide support to make cities resilient, for example, storing and releasing excess water in times of need or ease the pressure off from grey infrastructure (Voskamp and Van de Ven, 2015; Illman, 2013; Fenner, 2017). Fenner (2017) believes in the modular system of smaller connected interventions that is a more effective than single large solution.

It is important to consider the spatial scale of the individual solutions, from individual houses to whole cities, to find locations and scale where strategies are most effective and ensure their connectivity with other elements of the ecosystem (Voskamp and Van de Ven, 2015; Illman, 2013; European Commission, 2016b, 2004). The small-scale solutions have little impact on the large-scale catastrophic rain events such as river flooding, seaside flooding or very intense cloud bursts that produce the greatest danger to urban infrastructure and communities. Thus, there is a necessity to work on multiple spatial scales to adapt to changing precipitation, focusing on the installation of local solutions, developing regulations for developments, and proactively planning flooding areas, forming an integrated and multifunctional urban drainage system (Emilsson and Ode Sang, 2017). However, more research is required to fully understand and combine strategies for all weather events to achieve complementary solutions and sustainability (Voskamp and Van de Ven, 2015).



**Kokkedal Climate Adaption / Schønherr**

This area has been disconnected from the drainage system and replaced with 35 individual strategies for climate adaptation. The projects use nature-based solutions and make water a visible and an interactive element. Areas such as gardens, activity and exercise places and playgrounds offer safe public areas for recreation and educational purposes. These projects connect the areas and people, offering recreational spaces such as gardens, playgrounds and wetlands. The area can handle a 5-year event through the connectivity of the different scale solutions and more extreme events can be managed without extensive damage. Streams and trenches connect detention basins of different sizes and lead water into the river cleansing it on the way (Landezine, 2018).

ill. 31-33: Kokkedal Climate Adaption

## LIVABLE CITIES

Livability has become an important concept and it is widely used in the field of planning. However, the concept of livability has several definitions and often describes a range of goals (SCI, 2019). Perkins (2008, p.178) argues that "'Livability thus touches on sustainability, quality of life, and place, giving special attention to people and their location. 'Place,' in turn, reflects the 'particular environmental features and socially constructed settings in which people interact with each other and with nature.'"

Livability is an ideal condition whereby a city can adapt to create an enjoyable life, to maintain and even improve the quality of life (Setijanti et al., 2015). However, over the years cities started to lose their livability, when vehicles became prior to pedestrians who lost their sense of place, as many negative impacts came along (Yassin, 2019). Nowadays modern cities have created a social deficit; many of our needs can be covered without gathering in public. Technology and prosperity have largely privatised the realms of exchange in malls, living rooms and on the screens of computers or smartphones (Montgomery, 2013).

On the other hand, green urban spaces foment transformations in the sense of place and sense of belonging of communities. Frantzeskaki, van Steenbergen and Stedman (2018) found that nature-based solutions positively transform the sense of place of local communities when these communities are actively engaged in co-creating green spaces. Nature-based solutions rebuild natural flows in cities and generate new green urban spaces. This in turn creates space for new relations between people and nature, as well as between people in their communities (Frantzeskaki, van Steenbergen and Stedman, 2018).

Nature-based solutions have a key role to play in achieving a future compact city that is livable and sustainable. Vegetation in different forms can contribute to various degrees to climate adaptation, as well as climatic and socio-ecological contexts (Emilsson and Ode Sang, 2017). Montgomery (2013) in his book "'Happy City'" mentions that green spaces in cities should not be considered an optional luxury and it is a crucial part of a healthy human habitat. Proximity and frequent exposure are also essential. In other words, there is the need to create space for nature in the city on all scales. All sizes of nature-based solutions can contribute to more livable and resilient cities. The scale and design of the solutions are critical factors to the viability of the solutions to be replicable in other locations in the city (Frantzeskaki, van Steenbergen and Stedman, 2018).

Walkability is a component of livability that promotes a livable space and sustainable environment. Its purpose is promoting sustainable access and linkage for all its citizens within a neighbourhood. Thus, pedestrianisation is an effective tool for increasing the city's livability, by improving accessibility, mobility, safety and environment. This makes to the city a good quality place for all its citizens. Furthermore, the pedestrian street works not only for movement, but also as a public space where social activities take place (Yassin, 2019).

Pedestrianisation of an area of the city brings a lot of benefits to every section of community. It is low cost, high benefit, easy and fast to implement, sustainable and long-lasting solution to contemporary urban issues. It also brings economic benefits, since it increases retail turnover, shop occupancy rates and attracts buyers. As a result, more pedestrian traffic will lead to decreasing car traffic in the long term (Soni and Soni, 2016).

As can be seen in ill. 34, the physical features, urban design qualities and individual reactions determine the walkability of a street. In other words, those are the main aspects that influence the way that individuals perceive the street as a place to walk. Hence, it is a fact that features mentioned before affect walking behaviour (Ewing et al., 2006).

This thesis focuses on bringing life in the city through implementing green spaces, water management solutions and pedestrianising the city, which will increase the users' visit frequency and encourage social interactions to improve livability. With this purpose, the following chapters will show how urban design is a tool to achieve a successful relationship between site and design, to respond to social and physical local conditions.




ill. 34: Walkability diagram


Randers Blomsterfor
VINSPECIALISTEN RANDERS
VINSPECIALISTEN RANDERS
mates
20%
THE GUIGGS


SPECIAL Smørrebrød
Special Smørrebrød
Special Smørrebrød
Coffee to go


TrygFonden
respektforvand.dk

# 4

# RANDERS UNDER WATER

Analysis of challenges and aims regarding Randers' development, population and economy are described in this chapter to get a better understanding of the city. The value of water in connection to Randers' development has changed throughout time, and therefore, this section further explores the future water adaptation and how it can be used as an asset to bring citizens together and encourage positive change. Ultimately, the research and analysis will ensure that the following design proposal is based on an integrated design solution, which considers the city as a whole.

# RANDERS UNDER WATER

Randers is the sixth largest city in Denmark. It is located in a hilly area in the Eastern Jutland and has a direct connection to nearly 70km coastline towards Mariager Fjord, Kattegat and Randers Fjord. Furthermore, the surrounding environment - Gudenå river, lakes and ripples, wide meadows and forests,- helps to increase the recreational possibilities and attract more visitors to the municipality (Fakta om Randers Kommune, 2019).

## DEMOGRAPHY AND ECONOMY

Having all the assets and opportunities of a modern city, Randers might struggle with adjusting the new identity, however, it welcomes visitors and continues providing more residential space for citizens. Despite the decrease in population by 356 (01.2019) since January 1st 2018 (COWI, 2019b), the Denmark's Statistics predict that the number of citizens will increase from 98'261 (2018) to 100'000 citizens by year 2021. Currently most of the people are in age between 40 to 64 years, and it is predicted that until 2027 the biggest age group will be population in the working age (Randers Kommune, 2015b). The statistics also foresee an increased number of elderly people within the upcoming years. Hence the city has to become even more aware of the different generations and be attractive for both youth and families (Randers Kommune, 2017). Since Randers is located between other larger cities, such as Aalborg and Aarhus, it also increases the possibility of increased migration or a permanent emigration. These predictions are based upon historical migration patterns. From urban design perspective, these numbers can change if Randers becomes a more responsive city and applies the needs and wishes of its citizens.



The change in population leaves a great mark on the Municipality's economy. Such sectors as housing, requires new development strategies in order to accommodate all citizens. In the same time there is visible evidence of urbanisation in the last decades - in 2017, there were built 162 new residential units in Randers Municipality (COWI, 2019a). Due to the growth of the city and the fact that it becomes more attractive to live in, the housing costs per square meter are increasing, proportionally (COWI, 2019b). However, this also makes one question if the raising prices might become too high for what the residents get back from the city, and therefore actually cause in population decline as people would prefer to live in more attractive areas for the same budget.

This suggests that the more the city gives to its citizens, the more it expects in return. Randers has begun its development becoming a larger and more active city in central Denmark. Therefore, it is crucial to have successful and well analysed local and municipal plans that include future development strategies and urban design criterion. And even more importantly - climate change and its effect on both environment and society in terms of future development.

## WATER IN RANDERS

Randers is a city by the water. However, the ways in which the city has used water, has changed throughout the time and it is still in the search for new adaptation possibilities.

Since the 11th century, when Randers city name was first mentioned, the proximity to water was used as an asset for agriculture and water transport. It had a clear advantage in terms of growth due to the possibilities of water usage. Through the centuries Randers developed into a more sophisticated and in 1801 was considered as Jutland's largest city thanks to economic increase, grain exports and shipping. Great changes could be seen in the city landscape in the second half of the 19th century, when such large factories as Strømmen and Skandia were founded. It also shifted the use of water for industrial purposes. Although it opened up for city development South from Gudenå river, the new water purpose in the city development remained and Randers waterfront slowly transformed into an industrial harbour (Lykke-Andersen, Degn and Kjær, 2017). In the beginning of the 20th century, waterways were once again realized and Randers was promoting ferry services to Copenhagen with a new motto "The city where the sea meets the 13 roads" (Helge Buch Rasmussen, 2019). However, the idea was not a success. Nowadays, the city waterfront is still seen as an industrial harbour and water is on the merge of being forgotten as a part of city's identity.

It is therefore the municipality is currently looking forward to again integrate the water in the city design. Since Randers city has developed around both a river and a fjord, it is directly forced to adapt to water and its characteristic nature. Though it is not only the rising sea levels, that are a threat, but also the increasing and severe precipitation events. Due to the hilly terrain , the city centre is the most vulnerable area in case of flooding, as it not only is being affected by the rising water level, but also collects the excess water from the rest of the city located at the higher areas, look Waterflow and Blue Spots analyses. Historically, the highest water level measured in Randers was 1,8m above the normal sea level, leaving Østervold, Dytmærsken, Tørvebryggen, Tøjhushaven, Hospitalsgade and many other streets in the old town under water (Randers Kommune, 2015a). This causes high maintenance costs and rethinking of water management strategies for the city.



Randers, among other challenges, is more recently dealing with the consequences of excess rainwater. Though, Randers mayor Claus Oman Jensen, expresses that on the contrary to other cities, Randers has a great advantage – nature. Using nature as an asset could be a way to increase recreative functions and create attractive public spaces. Due to the climate change, the weather in Denmark is becoming warmer and severe rainfall events start to happen more often. It is predicted that water level in Randers fjord will rise 1cm per year, reaching 30cm higher water level by year 2060 (Miljoministeriet Naturstyrelsen, 2011; Randers Kommune, 2015b). It is hereby vital to work on climate resilience solutions related to water management, as it would both benefit the safety of the city and allow it to transform into a more attractive place to the citizens and visitors.

For the first time in history, over half of the world's population is living in cities. By 2050, roughly 6.4 billion people will live in a city. These people will be living in an increasingly water scarce world at a time when demand for water is projected to increase by 55 per cent by 2050 (Cities of the Future, 2016).

However, if nothing will be done, then according to Randers Municipality Climate Resilience in a case of 100-year flooding, the water level would rise by 2,4m and flood nearly half of the city. One can only guess what impact it would leave on the city's economy and the lives of the citizens.

Water can also be a potential, when talking about the city life. For instance, once the current industry has moved out from Randers centre, there will be an area of 55ha available next to the waterfront, which can be used for innovative water management solutions and additionally include recreational aspects related to water (Randers Kommune, 2018). Thanks to the hilly topography, it is also possible to create open channels in streets of Randers that would help to redirect water in the city centre. More importantly, it would work as a tie to link different parts of cities and could become a part of the new vision "City by the Water".



## CITY TRANSFORMATION

Randers Municipality has their own strategies and development plans, which cover different topics and are based on the city needs. The vision takes its departure in such topics as green and sustainable development, attractive area both for residential and business purposes as well as using water as an asset (Randers Byråd, 2018). These factors are considered as sublayers in the thesis design process in order to create an attractive city area.

The regional and local development plans are strategies created as guidelines for long-term development in the city and its surroundings. Additionally, 'Byen til Vandet' or in English "City by the Water" is a strategy created by Randers Municipality in collaboration with Realdania in order to provide best conditions for future livability in terms of nature access, infrastructure, residential and recreational purposes, and most importantly, climate resilience and sustainability. The greatest focus of this vision is to restore the connection between city and water. The idea is that different companies may come up with proposals for the city development, considering the existing requirements. In total there were 18 local and international companies applying for the design project, however, only 3 were chosen to work on further proposals: C.F.Møller, Effekt Arkitekter and Vandkunsten. After the forum and evaluation processes of the proposals, and decision making, the building process could start already in 2020. In order to support the livability, such topics as recreation and culture have to become one of the most important factors to make the city even more attractive. It is also stated that in order to create long lasting solutions, they are additionally needed to be climate adaptive. Seeing the city and nature as one, will allow for best social, economic and environmental results (Randers Byråd, 2018). Hence it is essential to focus on water in all its forms, including precipitation, and become an example for other cities.

The development plans and strategies are made in order to improve and make the city more responsive to the society's and environmental needs. Atthe same time, as the city grows, so does the society and vice versa. Currently one of the layers, where Randers experiences this the most, is infrastructure and movement through the city. It is registered that daily there are nearly 40'000 cars passing over Randers bridge (KomSe, 2019).

Although these plans and strategies include various elements, the combination of them is what emphasizes Randers' identity. For instance, the Randers bridge's primary function is connection and allowance for movement. However, currently, it starts to become a barrier between the different city parts and the waterfront. Moreover, the area is not designed to handle so much traffic on a daily basis. And on a busy day, Randers centre feels like any other city, which is not necessarily located by the water. It is therefore the municipality has decided that changes have to be made and the new city vision conceits an additional bridge which would have a double function – traffic and climate bridge called "Klimabroen" (Randers Kommune, 2018). According to an anonymous interview from Randers Municipality, it is expected that the new Klimabroen will be able to take off around 50% of the traffic from the Randers bridge and Havnegade.

There are more proposals to be created by the chosen architectural and landscaping companies until the middle of May 2019, which would specifically consider the infrastructure, public spaces and water management at the waterfront areas in Randers.

"Nature in Randers is unique. It must create a framework of the overall city development and for the future urban space in the centre of Randers. The objective is to keep the spatial context along the water in order to ensure and strengthen the link in the city and community." / L.V.Palm, C.F.Møller



## CITY FOR PEOPLE

As described in "Urban design in the planning system: towards better practice," "Urban design is the art of making places for people. It includes the way places work and matters such as community safety, as well as how they look. It concerns the connections between people and places, movement and urban form, nature and the built fabric, and the processes for ensuring successful villages, towns and cities" (DETR and CABE, 2000, p.8).

Until now, the citizens of Randers have had the chance to participate in municipality's organised events and some of them are divided by specific age groups. Where on the one hand it might allow for a more strategic evaluation of the results, on the other hand it splits the community and reduces the possibility for citizen interaction and idea exchange between the different generations, hence, it impacts co-creation. From the urban design perspective, it could be questioned if this is the right way to communicate with the society or other actions should be taken. Though it also depends on the purpose of the meetings – if it is purely informative or to collect ideas and data, and if so, then – to what extent.

Nonetheless, the interview results, look Appendix, show a rather interesting tendency – the overall population seem to be more concerned about traffic congestion than climate changes and their impact on the environment (Randers Kommune, 2015a). In order for the city to evolve and become future resilient, it is important that not only the current needs are taken care of but also the possible future scenarios are addressed. Furthermore, it should be brought up to the citizens as they are the main users of the city and have the greatest impact on the development of Randers.

"A city's environment is shaped not only by people who have an important influence, but by everyone who lives and works there." / Robert Cowan, urbanist

Judging from the input provided from citizens so far, it is the nature and the recreational possibilities that will tie the different parts of Randers together. Infrastructure plays an important role, however, it has to be laid out carefully in order to avoid seeing it as a barrier. The feedback from citizen involvement and the further described analyses of the city, will lead to conclusions about the current situation and highlight the most challenging areas in the city.

**"It is important that there is a place where to sit down and enjoy the view and the atmosphere, and maybe a cafe and small oases, where one can sit or sit next to in peace and quietness with possibilities for both walking, running and cycling without being irritated by the ones, who are sitting there."**

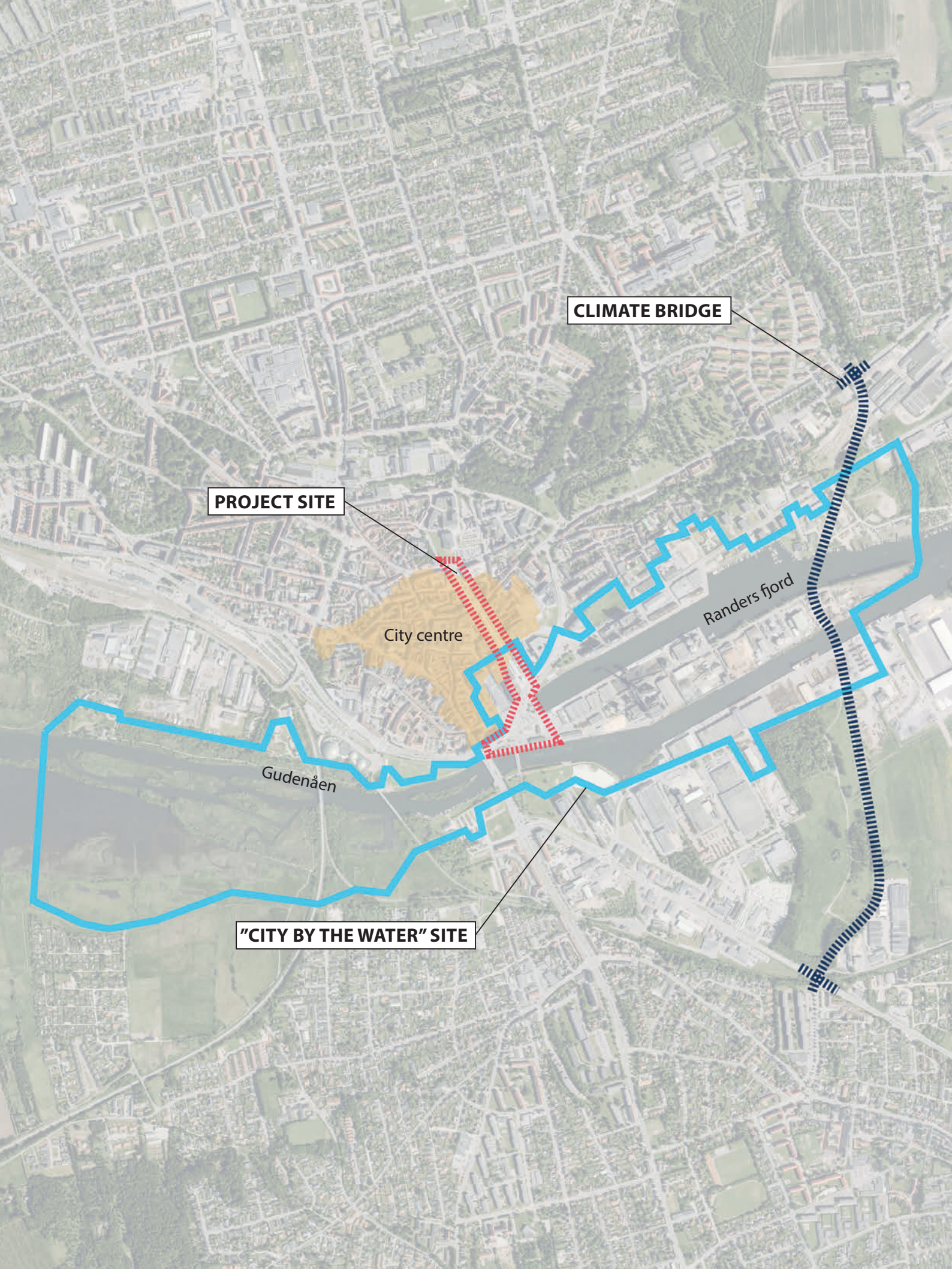
**/ S.Andersen, facebook "City by the Water" comment**

*ill. 35: Forum "City by the water"*

**"There are so many, who are dissatisfied with Østervold - it would be fantastic if instead we could get more water and life."**

**/anonymous from "City by the Water" debate at Træløberen, Østervold**




CLIMATE BRIDGE
PROJECT SITE
City centre
Randers fjord
Gudenåen
"CITY BY THE WATER" SITE

*ill. 36: Randers bird-view*



## SITE CHOICE AND ANALYSES

Randers is in the process of doing a development strategy "City by the Water", which contains the area around the Randers fjord and the Gudenåen river. This strategy focuses on climate change, nature adaptation and the new built area. However, it does not include Randers centre and the weather adaptation of the inner city, apart from protection from rising sea levels.

In Raindrop for Randers, we have chosen to work on Østervold since it works as a connection between the harbourfront, new development area and the city centre. Additionally, this area is threatened and analysed as a critical point for water flows in the inner city, look Appendix. From the environmental point of view, the site also allows for opportunities to link the water, the city and the nature. Though it also joins the historically and culturally important points throughout on and around Østervold.

A precondition is set for the project, assuming that the Climate bridge is built and protects the city centre from fluvial flooding due to rising sea levels. In case of Climate bridge not being realized, it is advised to build a sluice at another location at Randers fjord or a dyke along the city waterfront.

In the following sections of the report, analyses of the city and the site will be shown in order to introduce the reader to the project site. Furthermore, it will help to point the potentials and challenges of the area, which then will be translated into design parameters for the vision of the new Østervold.


WATERFLOW

scale 1:10 000
@ A4

- 0 - 1m
- 1.1 - 2m
- 2.1 - 3m
- 3.1 - 4m
- 4.1 - 5m
- + 5m
- topography (every 2.5m)
- 3 m.a.s.l. line



scale 1:5 000

- water flow
- topography
- flood area for 2.4m sea level raise

## WATER CHALLENGE

The hilly topography of Randers and the location between the fjord and Guenåen river, shapes lower areas around the city centre and the waterfront. In case of rain events, the rainwater flows through the main streets in the city centre and the ring road. Those areas will be the most impacted and lead most of the water towards the fjord. The central boulevard requires a capacity for the rainwater coming down from the hilly landscape in the North.

Additionally, Randers centre is prone to fluvial flooding, if there are no adaptation measures considered at the waterfront.


PAVED AREA
scale 1:5 000

scale 1:50 000
@ A4

- green rural areas
- significant ecological areas
- recreational green areas
- urban zone




## GREEN AND PAVED AREAS

Randers is surrounded by natural areas, such as forest, meadows and beaches. Randers fjord and Gudenåen river flows through the city. The waterfront and Vorup Enge meadows offer countless possibilities of different activities along the way. Furthermore, Randers Regnskov (Rainforest) works locally on wildlife conservation and restoration through the involvement in the surrounding Vorup Enge.

On the contrary to the natural areas, the city centre is fully paved increasing runoff water and potential flooding. Most streets lack vegetation and swales, which means higher levels of noise, pollution and excess water. The city centre relies on grey infrastructure for capacity to handle extreme weather events, which increases the risks of damage and overflow of the single system. Most public spaces in the city are paved, hence, not many public areas remain functioning during flooding. Due to the industry, the East side of the waterfront is paved and is also vulnerable to flooding and damage.


3.786
41
11.727
40
16.617
46
1.356
25
18.243
44
165
28
463
18.540
43
23.714
18.679
45
102
19.425
36.251
1140
36.603
14.171
35.152
47
1.122
24.160

# TRAFFIC

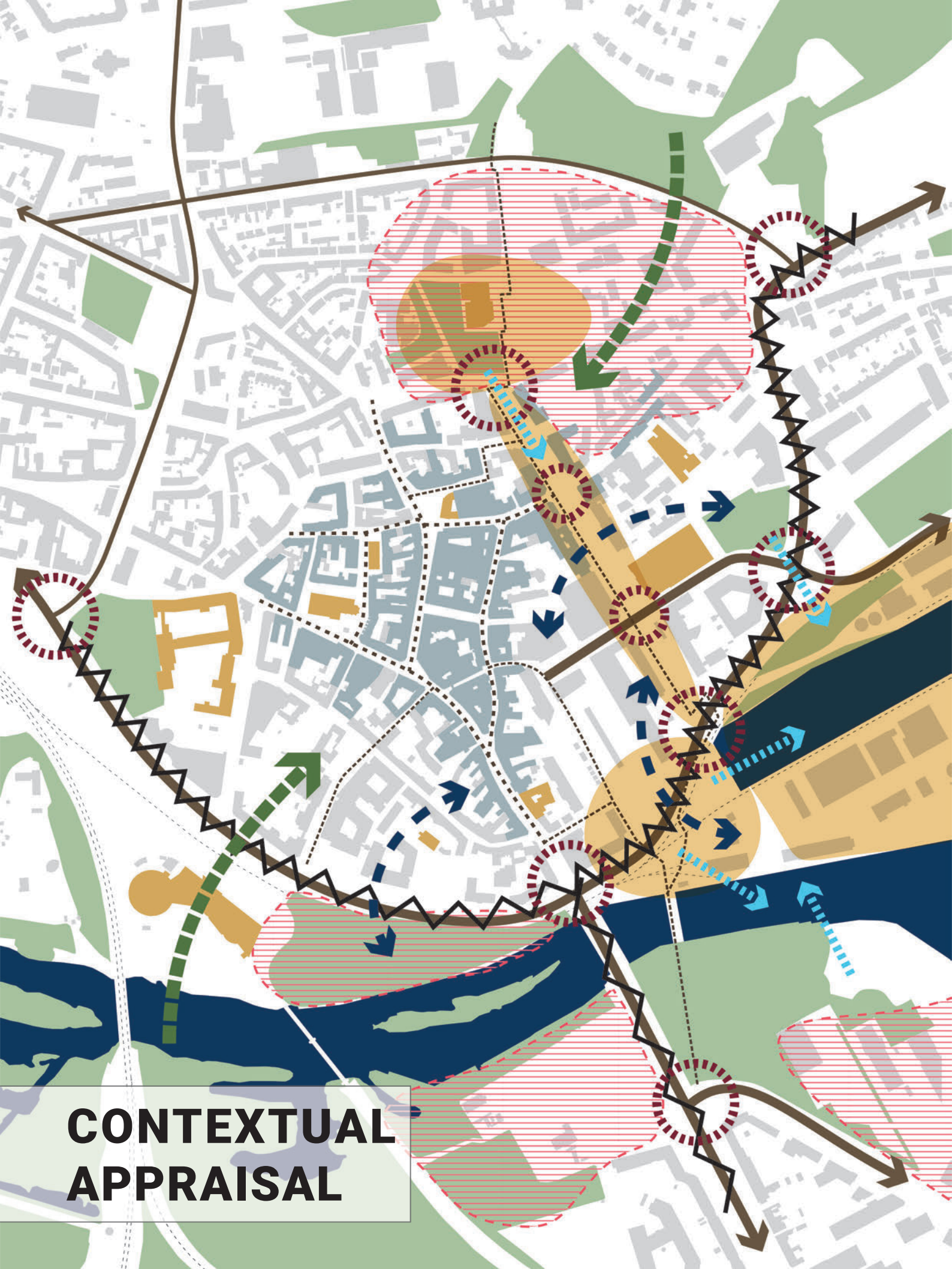




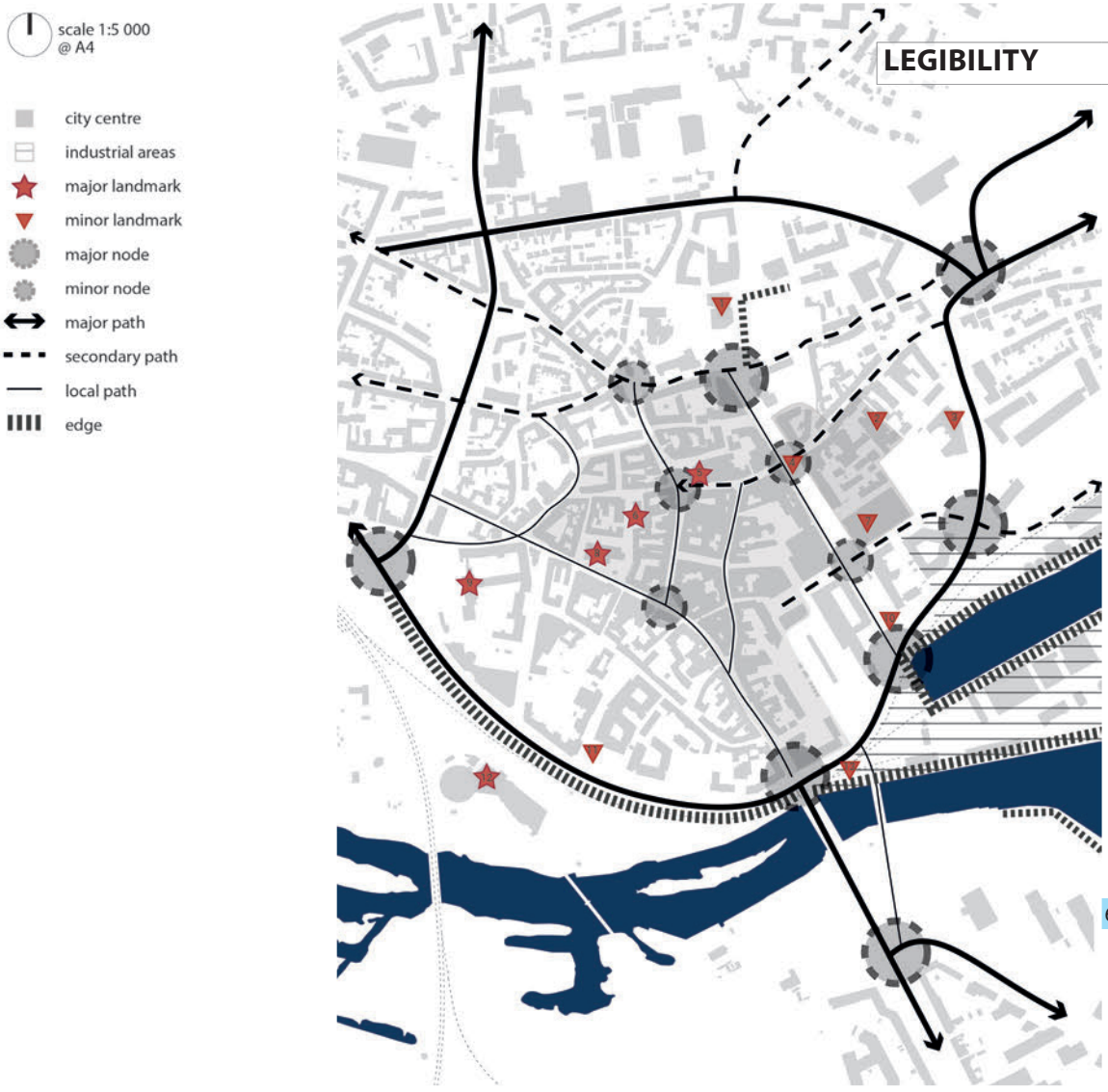
## WALKABILITY AND TRAFFIC

There are large green and recreational areas outskirts of Randers, though they are not well connected and remain isolated from the city centre. Moreover, there is a limited number of significant public spaces in the centre, and mainly offer shopping and eating opportunities. Despite the good pedestrian connections and limited car access, and public transport being directed away from the city centre, the main boulevard keeps the traffic and remains a barrier to East-West flow. Sustainable transport options (e.g., biking, car sharing, public transport) is not sufficiently encouraged, making only a limited number of city bikes and bike stands available. Despite that pedestrian-bike bridge offering a safe crossing over the fjord, the ease of access is impaired by multiple crossings on the North end. Meanwhile, the designated bike lanes along the ring road increase safety.

Most traffic is recorded on the South end of the ring road, especially, on the bridge, which holds ca. 36.000 cars daily. This creates an enormous pressure on the infrastructure and transportation options, as well as increases pollution in the centre.



# CONTEXTUAL APPRAISAL

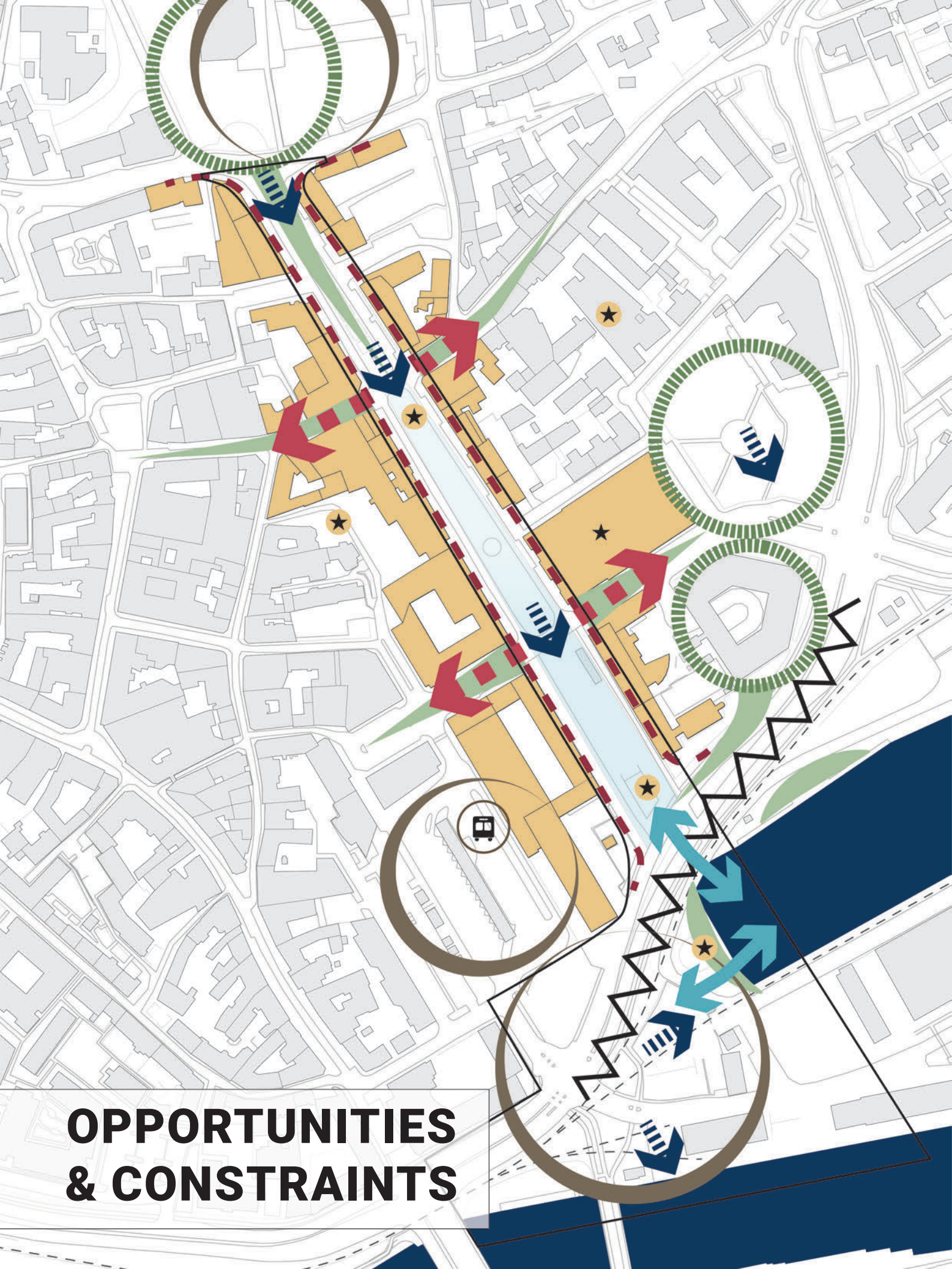





## CONTEXTUAL APPRAISAL AND LEGIBILITY


The analysis shows the main roads and traffic as an edge of the city centre, dividing it from the rest of the area both visually and physically. It also reveals that there is an opportunity to bring greenery into Randers centre to improve connection of the green areas and provide SUDS. The major nodes are more active as pedestrians and traffic cross, and become unsafe and in need of improvement. The minor nodes create possible interaction and social meeting points. There is a potential to regain pedestrian priority and encourage activity on the main boulevard to transform it into a public space and connector between the East-West cultural buildings. It offers both key views, access and landmarks. Multiple historical and cultural landmarks are distributed around the centre and are well connected by pedestrian paths.

There is a poor connection between North and South in terms of paths, visibility and interaction. Due to industry, there is a limited accessibility to waterfront, as well as limited crossing opportunities. However, multiple areas have the potential to become public spaces since they offer key views of the fjord and accessibility to water.



# OPPORTUNITIES & CONSTRAINTS

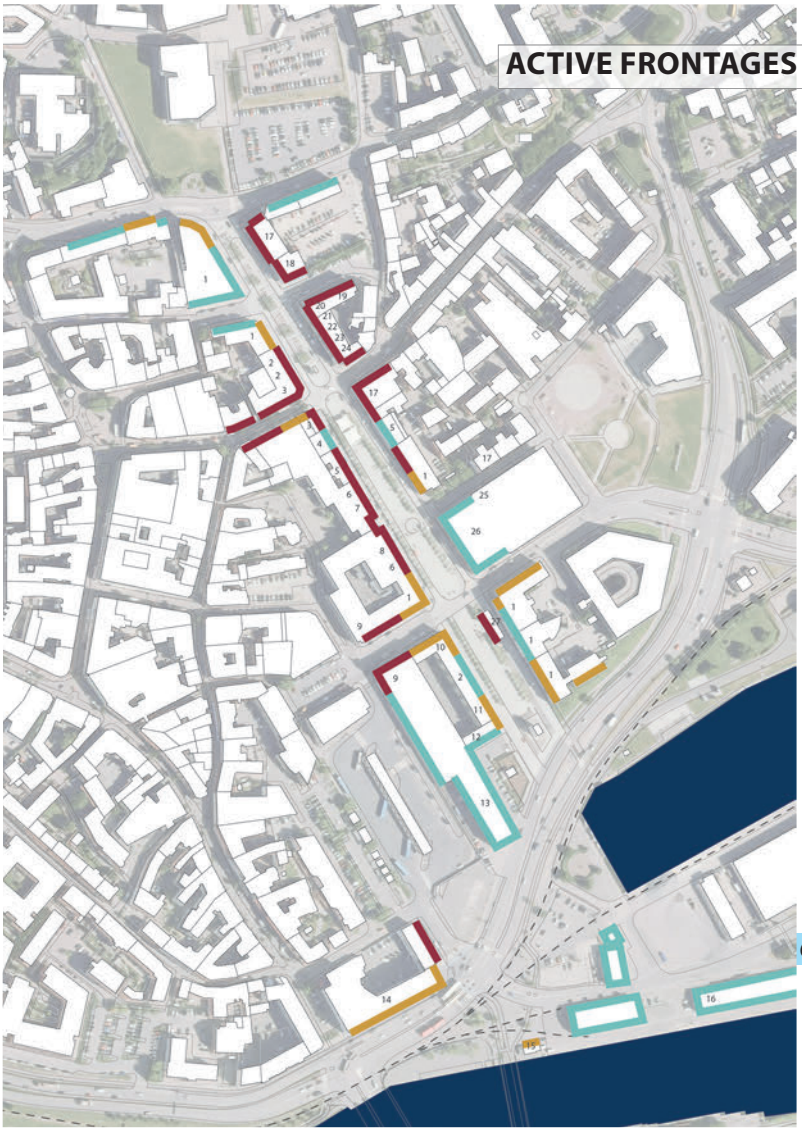
scale 1:2 500
@ A4

intense activity
moderate activity
low activity

building function

1 bank
2 doctor
3 clothing store
4 pharmacy
5 groceries
6 Pizzeria
7 butcher store
8 gym
9 supermarket
10 real estate
11 medical store
12 insurance
13 B&B
14 offices
15 seafood cafe
16 fish store

17 hair saloon
18 optician
19 asian store
20 candy store
21 market
22 laywer
23 cafe Toscana
24 pub
25 library
26 cuture hosue
27 fresh habits





scale 1:2 500

site outline
activate frontages
traffic barrier
enhance existing structure
green space
area of improvement
landmark
gateway to the city - bus station
optimize waterfront access
key view
restore historical links
new green link

## SITE OPPORTUNITIES AND CONSTRAINTS

The analysis emphasizes the green areas and elements that can work as a nature link towards the rest of the city. It would help to reduce noise, absorb water and bring nature in the city centre. There is a clear opportunity for an improved accessibility to the waterfront. Additionally, possible water channels could be a connection between the city centre and harbourfront.
There are several areas of improvements identified around the project site, and with the help of enhancing the existing built structure and opening for diverse social activities, the current pedestrian activity could be spread equally over Østervold. Currently, the highest activity level is in the middle part of the boulevard - close to shopping streets, cafes and pizzerias.
Activating ground floor frontages, using landmarks for the cultural possibilities and enhancing key views from and to Østervold, would be the steps towards transforming the site to a more responsive public space.

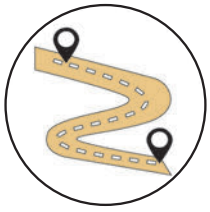
## POTENTIALS

The site has a favourable location. It is close to the water (river and harbour) and the city centre. Moreover, it has good infrastructure and is well connected both locally and regionally.

**Location**

There are two important landmarks located along the street, which could be used as meeting points, while additionally improving legibility of the city.

**Landmarks**



Other factor is the topography. It gives the possibility to adapt water management solutions. Additionally, it could create different key viewpoints along the street, both to and from the water.

**Topography**

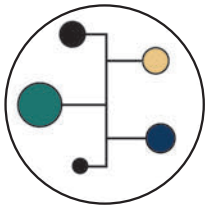


The street could be transformed into a gateway to the city due to the proximity to the bus terminal, train station and a future light rail.

**Gateway**

Østervold is a lengthy corridor capable of connecting different areas within the city. Moreover, it can create diverse public spaces along the street and bring more life into the city.

**Connection**



There are located some important green areas in the northern part of the site. It also provides the possibility to convert the boulevard into the link between the nature, water and the city centre.

**Nature**

## CHALLENGES

**Waterfront**

Restricted accessibility to the water due the industrial area and water pollution.

**Barrier**

Havnegade is a visual and physical barrier to the city's connection with the water.

**Traffic**

High traffic congestion on the Randers bridge. Main boulevard has fast traffic which impacts pedestrian movement.

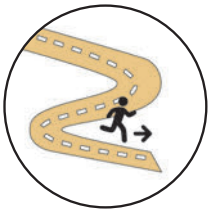


**Identity**

Deficiency of a clear identity of the city, especially in relation to water.

**Flooding**

Lack of protection against extreme rainfall events. Østervold is covered with only one type of impervious pavement, which increases the risk of flooding.



**Pass-through**

The boulevard works as a pass through space and is not attractive enough for making people to stay. There is a lack of activities on Østervold.

# 5

# RANDERS WITH WATER

This section presents the design approach. It begins with a concept description based on previous research and analyses, which is then further translated into site specific design guidelines. This is followed by a strategic design proposal and visualizations for the previously set vision.

## VISION

### Rainwater Adaptable Natural Development Enhancing Resilient Strategy

Østervold will be an attractive and robust pedestrian boulevard capable of connecting Randers with water. The boulevard will create places for people to interact with water, nature and culture. These elements will become a part of Randers daily life.

Social interactions and variety of activities will encourage people to spend more time outdoors and explore the city and its features. Water, nature, art, history and culture are important elements to boost along the boulevard and they will aid in building up a strong local community.

The site location will be the link to connect both the residential and new development areas with the city centre and the waterfront when the industrial area has moved out. Consequently, both visitors and citizens will be attracted to a pleasant walk and activities throughout the area.

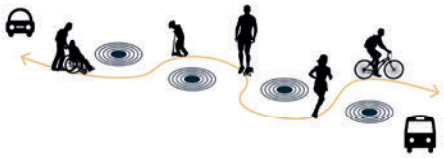


Nonetheless, the city is in a constant transformation and the boulevard will be able to adapt to the city needs in terms of modernisation, social togetherness/ interaction and climate change.

Water management solutions will be merged with attractive public spaces with the aim of coping with such risks as stormwater, flooding and rising sea levels. Moreover, these spaces are functional both, during normal and rainy conditions.

Østervold will support creating a livable city where water is a part of Randers identity.

## DESIGN PARAMETERS



### Ease of movement

Create a well-designed and integrated circulation system, that encourages diverse modes of movement throughout the street and access for everyone. Additionally, the street conduits more than movement, it provides open spaces and activities along.


### Character

The aim is to generate a place capable of capturing attention and creating a long-lasting impression by reinforcing the existing site potentials. Furthermore, the project site would aid in strengthening Randers identity.

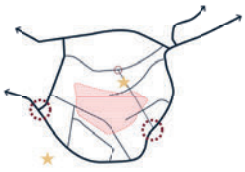
### Quality of the public realm



Transforming the street into a place with attractive and successful outdoor areas, urban furniture, appropriate selection of vegetation, lighting and public space uses.

### Adaptability

Generate a place that can change easily, suitable for modernisation and climate change or conversion to other uses depending on the city's needs. Moreover, a place that is capable to bridge past and future.



### Legibility

To improve legibility, it is necessary to design a place that is easy to understand and locate its parts. Using landmarks, routes, intersections and main features of the site will help people travel and find the places easily.

### Diversity

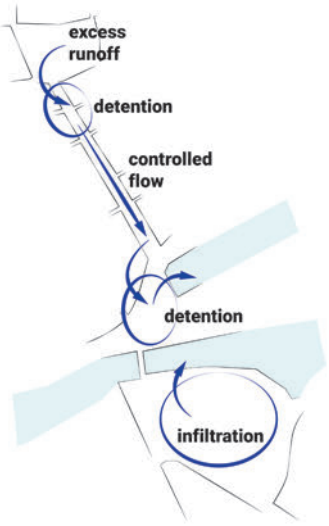
It is important to incorporate a variety of uses and activities to encourage people to explore and discover what the place offers.

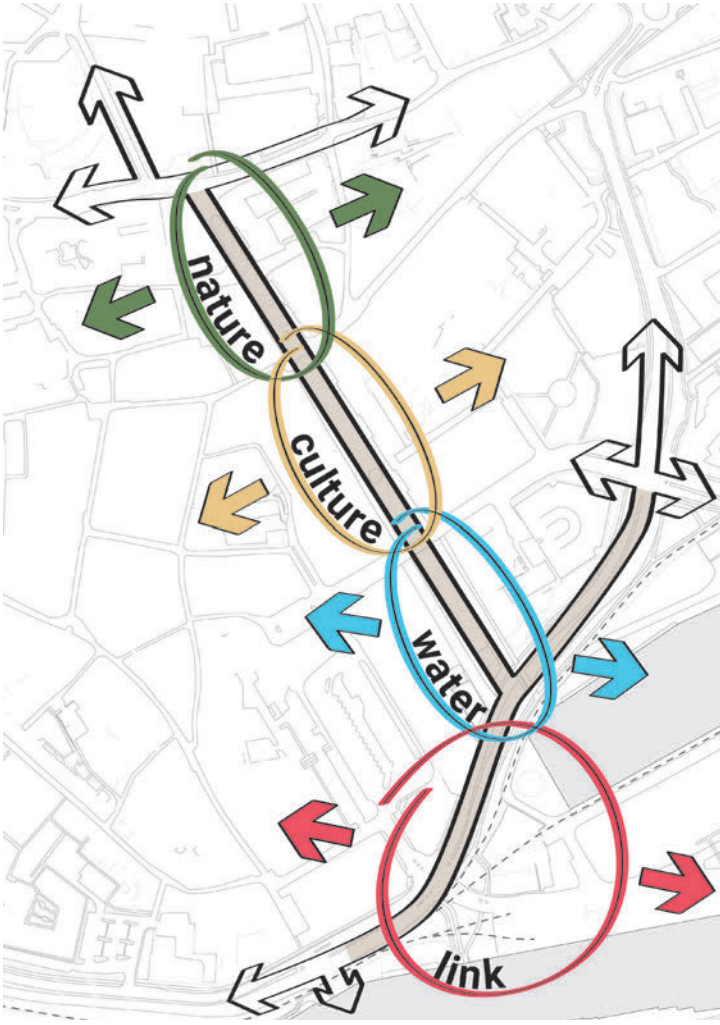
## RAINDROP FOR RANDERS

In order to be able to design with water, water management strategies must be part of urban design practice. This means that the same way urban design relates spaces, people and form, water must interact and connect to these elements as well. Water should be seen as an opportunity rather than a threat (Palazzo, 2018) and should enhance spaces to be more enjoyable and attractive, adding to the sense of place and promoting social interactions. Therefore, the concept of the Raindrop for Randers is used for the redesign of Østervold.

The concept divides the site into 4 areas with a unique character that creates the identity of Randers. The different stretches will emphasise nature, culture, water and connectivity to enhance public spaces and provide a wide range of activities and atmospheres. At the same time the boulevard will become a connection, both through movement and activities, between the city centre and the new development. The different parts of the street, although emphasized with a unique character, will be stitched together with the use of nature-based solutions and materiality, especially under heavy rain conditions, providing attractive space at all times.

The water management strategy will control the waterflow and ensures that rainwater from severe cloudbursts will not flood the streets and cause damage. The strategy aims to delay the rainwater flow from the higher situated surrounding in a detention pond at the top of the street and release it through a series of public spaces which will distribute and reuse the runoff water before it is evacuated into the fjord. The aim for water management is to disconnect the street from the main drainage system and use nature-based solutions to create hydrologic and ecologic connectivity. Specific methods will be described in each part of the street as they play a different role in the solution.



**Nature Drop**

The first drop incorporates greenery from the surrounding into the city centre. This stretch will provide areas with increased connection to nature and an escape from the grey city centre. Spaces will vary from the quiet relaxation areas in nature to more active playgrounds and outdoor activities.

**Cultural Drop**

The cultural drop will spread and emphasising culture and history of Randers to improve its identity. In this area there will be multifunctional public spaces that can be used for all sorts of cultural activities and exhibitions. The proximity to the culture house allows for its activities to expand into the stretch. The public spaces will showcase the transformation of Randers into a livable city by the water and provide educational and cultural uses. This stretch will have a lively character created by temporary activities.

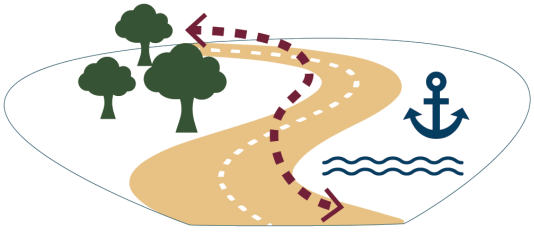


**Water Drop**

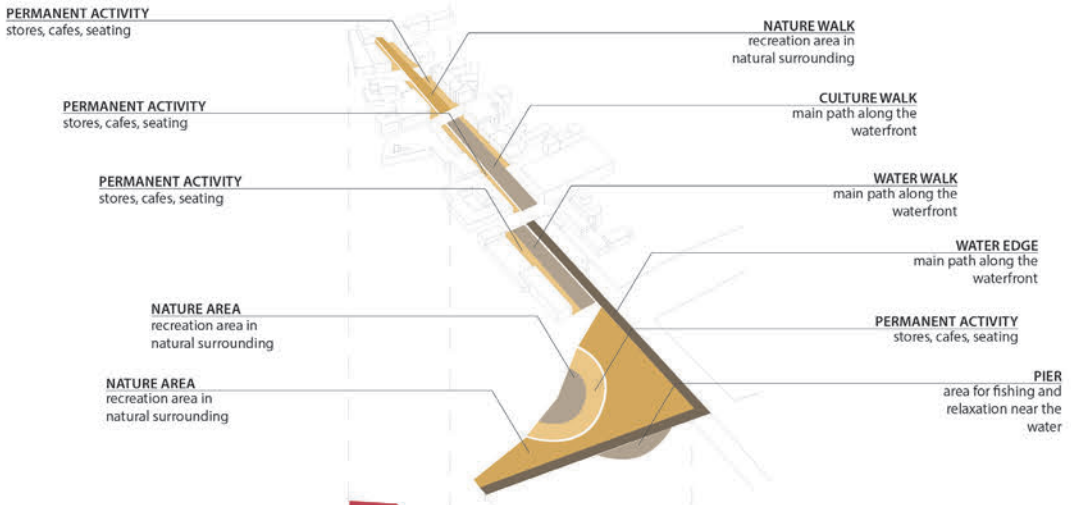
This drop focuses on incorporating interactive water features transform the perspective of water to an asset. This space will connect the city centre to the fjord and the people with water. Through multiple types of water activities, this stretch will have fun atmosphere that enforces the new identity of city by the water.

**Rain Drop (link)**

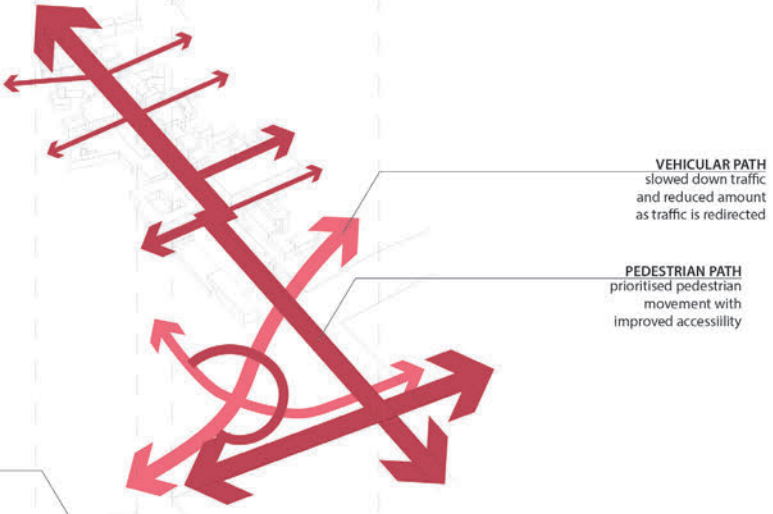
This public space at the waterfront incorporate the different characters and activities from the street as well as infrastructure and public transport. It is the connection of all the layers of the city and its identity and a connection to the new development, as a point of transition to livable and resilient cities.



## Public space




## Movement




## Nature

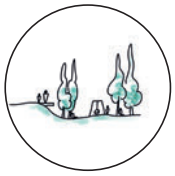

## Water


STRATEGIC PLAN
scale 1:2500
Deep water
Shallow water
Green area
Trees
Bridge
Stepping stones
Green bench
Path
Building
1 Detention pond
2 Green pocket
3 Natural Playground
4 Horse statue
5 Channel
6 Cultural pocket
7 Exhibition area
8 Water Feature - Rain forest
9 Water spiral
10 Ground fountain
11 Water playground
12 Amphitheater
13 Viewing tower
14 Water tunnel
15 Randers anchor
16 Waterfront boulevard
17 Natural playground
18 Harbour activities
19 Water playground
20 Pavillions area
21 Orchard
22 Dyke
23 Fishing deck


SWINGS
PICNIC AREA
QUIET RESTING AREA
CAFE AREA
NATURAL PLAYGROUND
STATUE AND MEETING POINT
N
0
5
10
25m

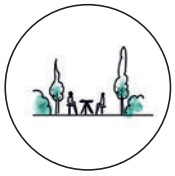
**Wetlands**

Natural water management strategy with focus on a diverse greenery implemented in the central boulevard to activate human senses and open up the area for a diversity of natural activities throughout the seasons..



**Playground**

Wetlands used as a natural hilly outdoor excercise areas on a daily basis to attract children and families and bring more nature in the city centre.



**Green pockets**

Green cafe and picnic areas to create enclousures and bring people closer to nature and enrich positive experiences and social togetherness.

**NATURE DROP**

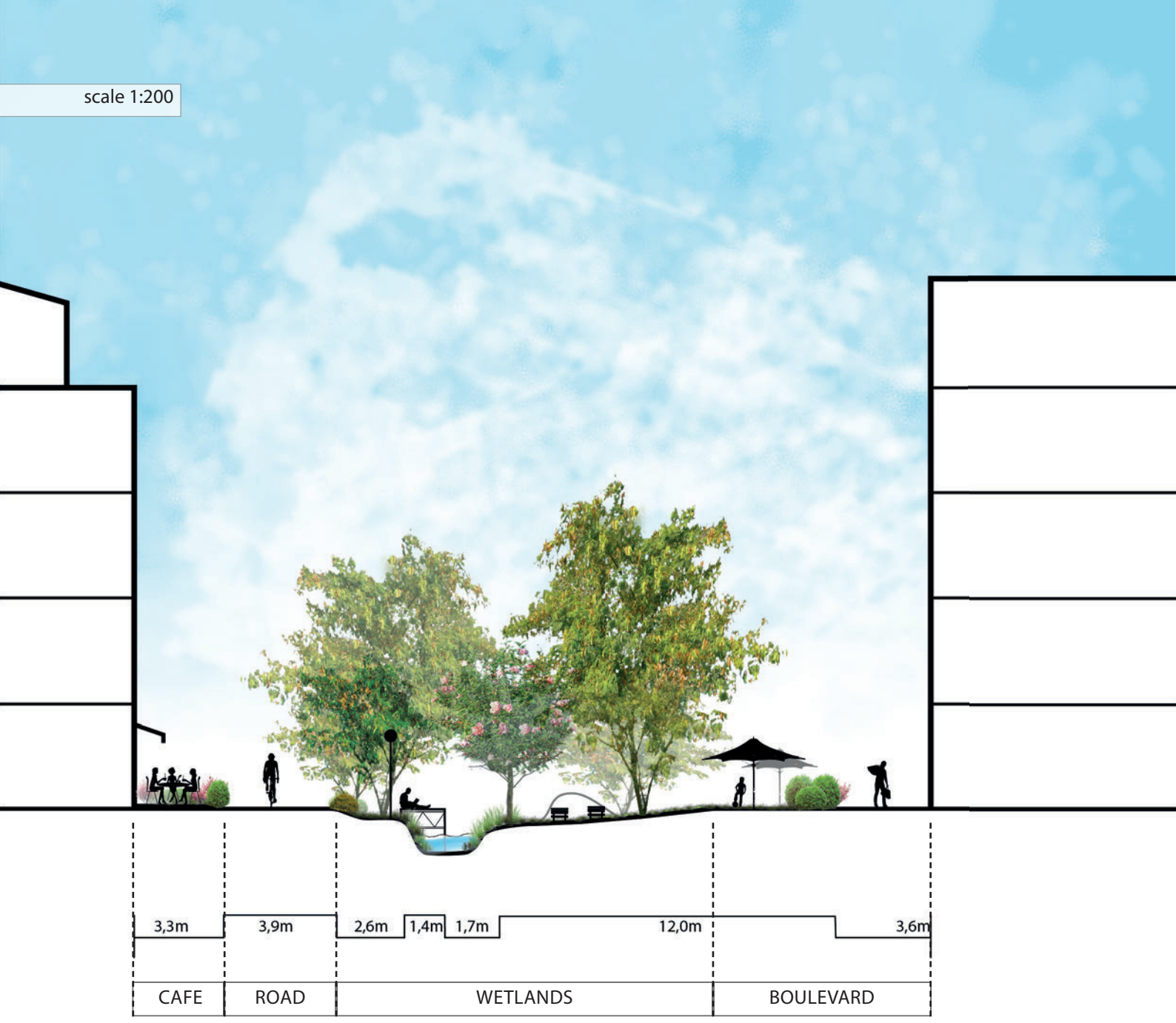
*ill. 37: Active water management*

*ill. 38: Public park*

*ill. 39: Luminescent ark swings*

*ill. 40: Natural playground*

scale 1:200






Green pocket cafe area

Boulevard

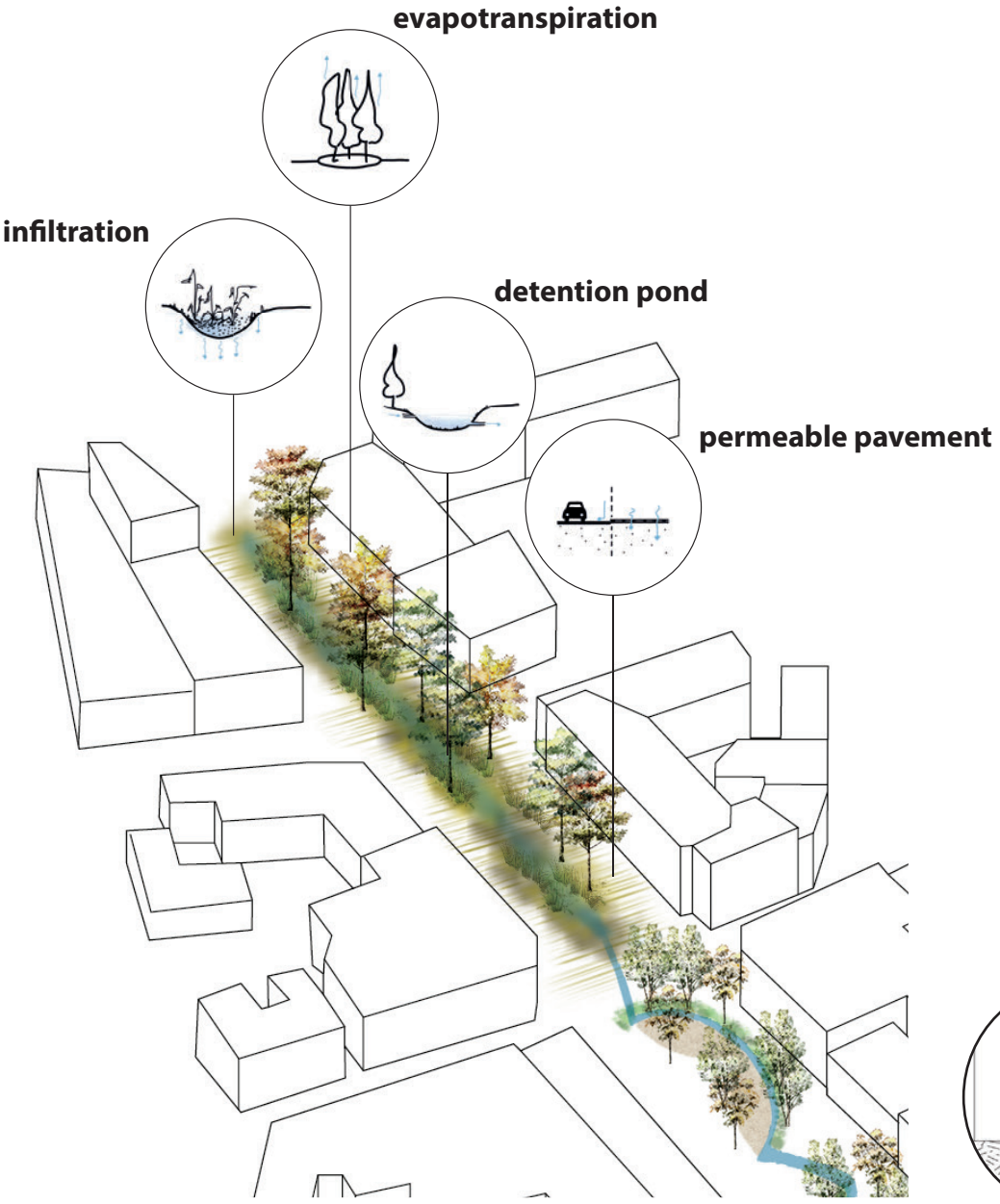
Boardwalking in wetlands

Natural playground and flood protection

Picnic and resting area

Boulevard

scale 1:200

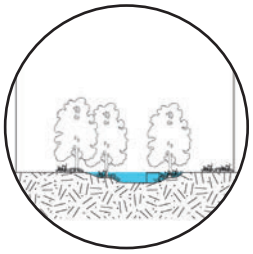





DRY

DAILY RAIN

HEAVY RAIN



**Water management**

The water management of this stretch focuses on retaining the water to prevent flooding on the street below. This is done using a natural detention pond with a capacity of 1749m3, which equals to a 10-year event with a safety factor, look Appendix for calculations. Further strategies include increasing infiltration which is achieved by increasing surfaces of green. The design optimises the surface area of the park as well as uses a semi permeable pavement for the main paths. Vegetation and greenery are used to increase evapotranspiration and filter the runoff water as well as the air quality, noise and thermal comfort. Greenery in this stretch plays an important role in reducing the excess water that will need to be distributed through the city.

When there is no rain the nature stretch becomes a park for recreation with playful topography. On a daily event of rain, the park has a narrow channel formed by the topography to collect water and because an interactive water feature. This natural channel will lead it to channel in the following stretch. In a heavy rain event, the pond will be able to store the water to full capacity and still allow people to cross over the wooden path.

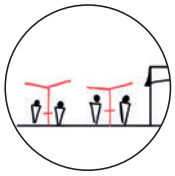
DRY


ESPRESSO HOUSE


ART EXHIBITION
SCULPTURE GARDEN
CAFE AREA
CULTURE AND HISTORY EXHIBITION
RANDERS IDENTITY EXPLAINED
PERFORMANCE SPACE
PHOTOGRAPHY MEDIA EXHIBITION
N
0
5
10
25m

**Meetings**

**Exhibitions**



**Cafe area**

**CULTURE DROP**

Culture stretch allows for such social interactions as public gatherings, speeches, combined with pocket areas that offer quietness and enclousure.

Culture pockets are designed to set focus on cultural and historical values. Temporary art and media exhibitions take place to link the cultural objects throughout the city, while educating the visitors and enhancing the city's identity.

Additionally, to create a variety of functions, the culture pockets are used for cafe seating to create a closer connection between the culture and public on a daily basis. Furthermore, they offer protection from both heat and wind.

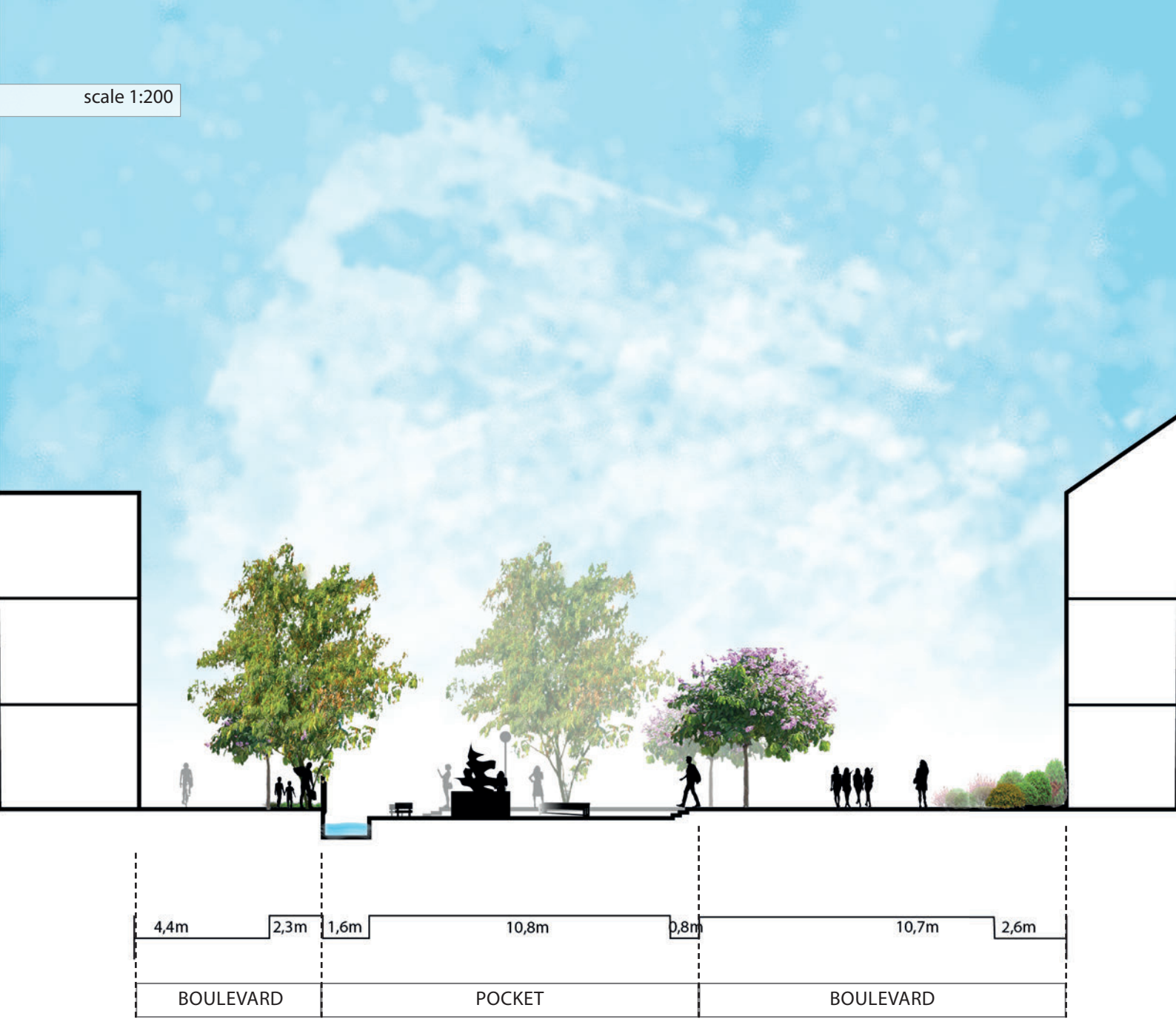
*ill. 41: Sculpture park*

*ill. 42: Media exhibition*

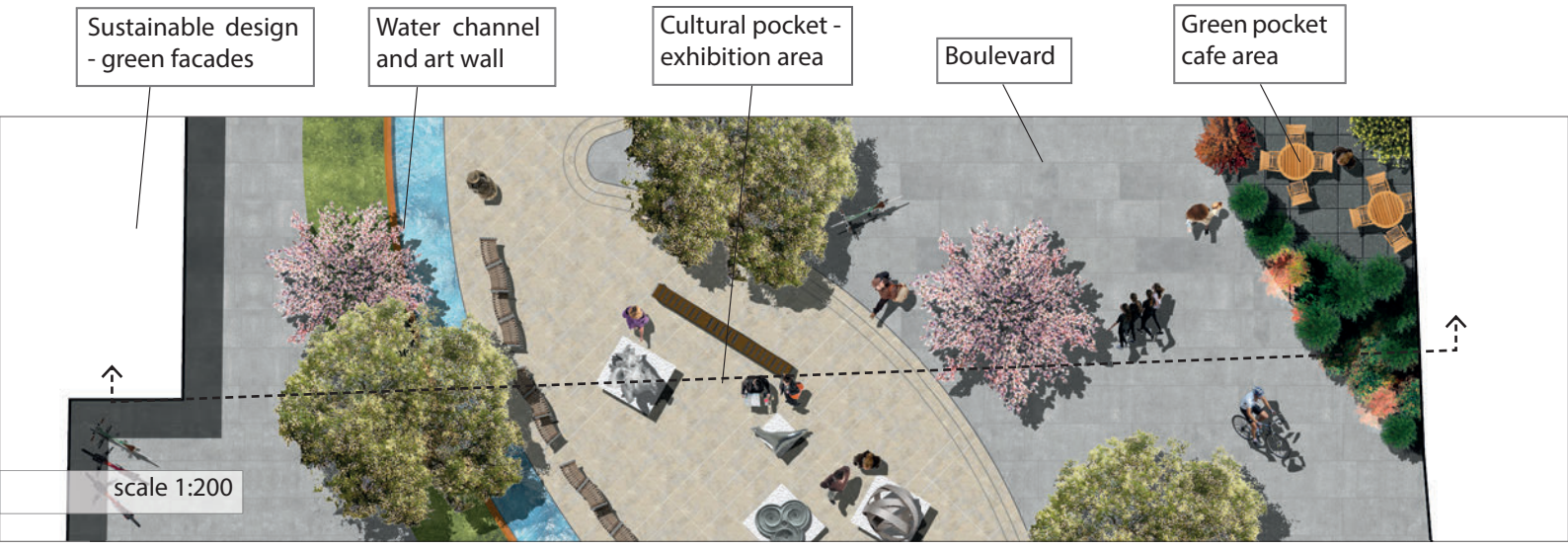
*ill. 43: Green cafe*

*ill. 44: Stepping stones*

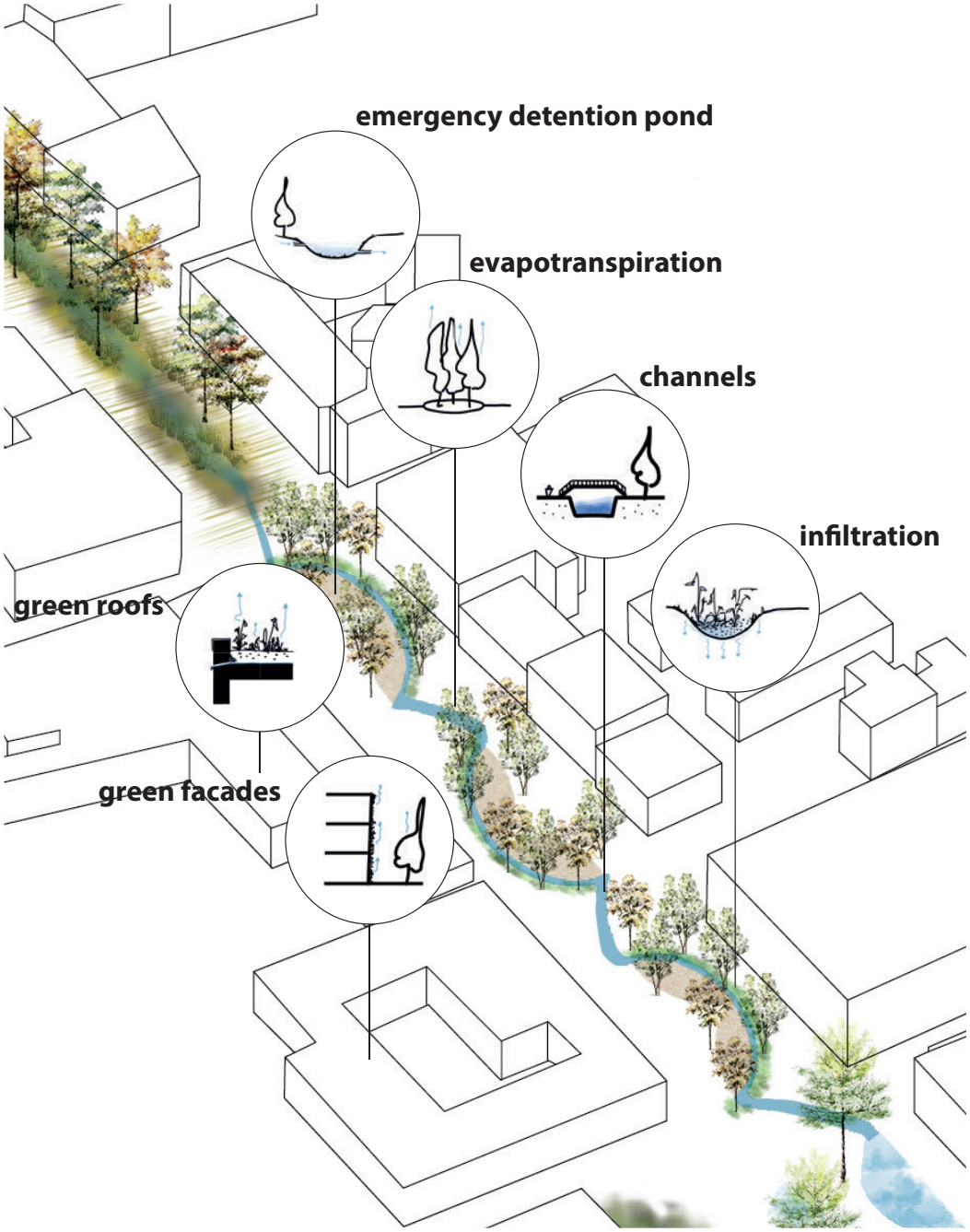
scale 1:200






scale 1:200

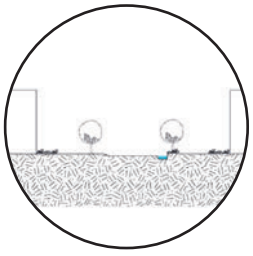





DRY

DAILY RAIN

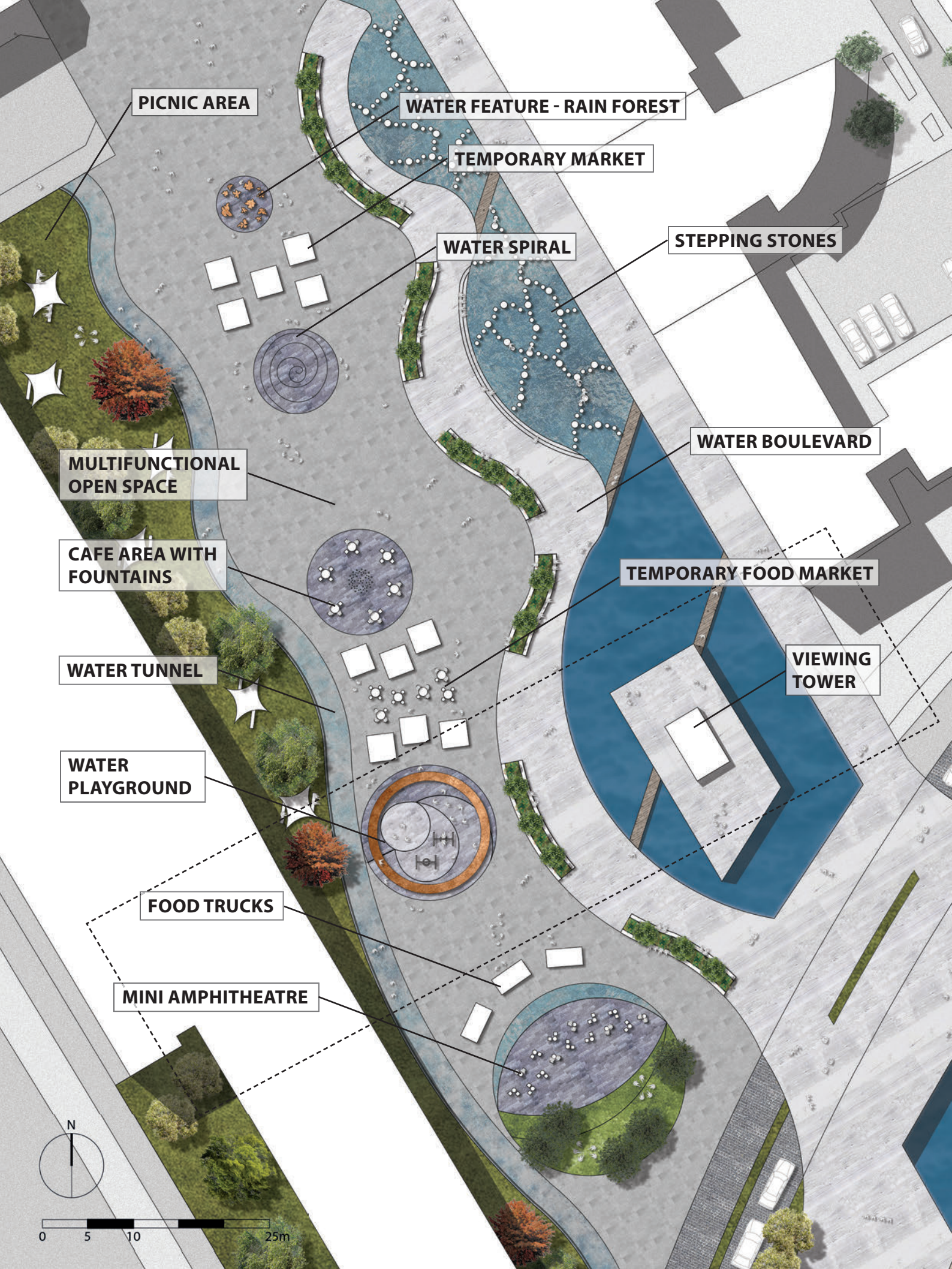
HEAVY RAIN



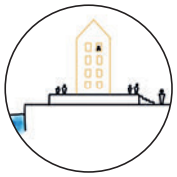
**Water management**

In this stretch the water management strategy relays on the detention pond above for collecting and controlling the waterflow and focuses on providing enough capacity for the waterflow from incoming side streets. The channels used in this part will be 1.5m wide and 0.7m deep, which is enough to distribute the capacity of a 10-year event with a safety factor. In case of heavier rain, the public space can be allowed to flood as it is created as a detention pond therefore protecting surrounding public spaces. There is greenery incorporated throughout for evapotranspiration and infiltration, however with the channels and controlled waterflow, the surrounding area can be allowed to have more impervious pavement to provide better functionality.

This area on daily basis when there is no rain will have a pumping system to bring the water from the fjord to the channels, to create aesthetic public spaces. During daily and heavy rain events the pump will be stopped and the channels will fill up with runoff water to protect the public space from flooding.


PICNIC AREA
WATER FEATURE - RAIN FOREST
TEMPORARY MARKET
WATER SPIRAL
STEPPING STONES
WATER BOULEVARD
MULTIFUNCTIONAL OPEN SPACE
CAFE AREA WITH FOUNTAINS
TEMPORARY FOOD MARKET
WATER TUNNEL
VIEWING TOWER
WATER PLAYGROUND
FOOD TRUCKS
MINI AMPHITHEATRE
N
0
5
10
25m

**WATER DROP**

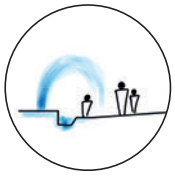


**Viewing tower**

Interactive cultural element transformed into a viewing tower offering a changed perception of art monuments and a beautiful view over the city and fjord.

**Public speeches**

The multifunctional open spaces by the waterfront allow for variety of activities - public speeches, concerts, temporary markets and other temporary and seasonal social gatherings.



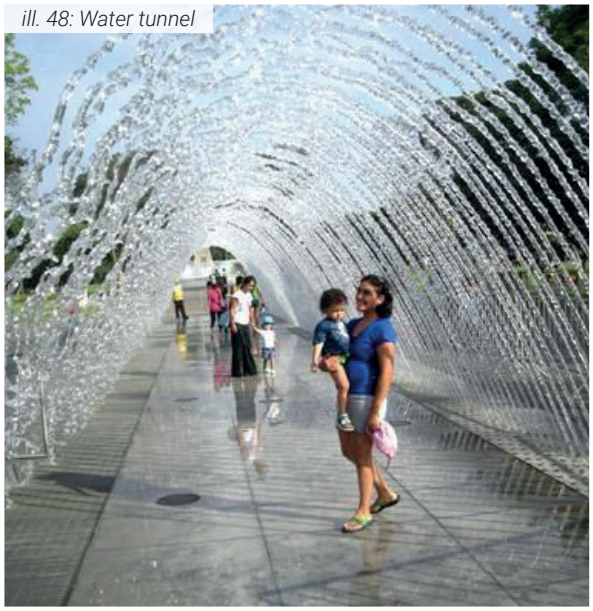
**Water tunnel**

Interactive water elements and water playgrounds provide recreational uses such as water tunnels to enhance the main function of the water stretch. An attractive public space for all generations.

*ill. 45: Water playground*


*ill. 46: Water tree*

*ill. 47: Water feature*

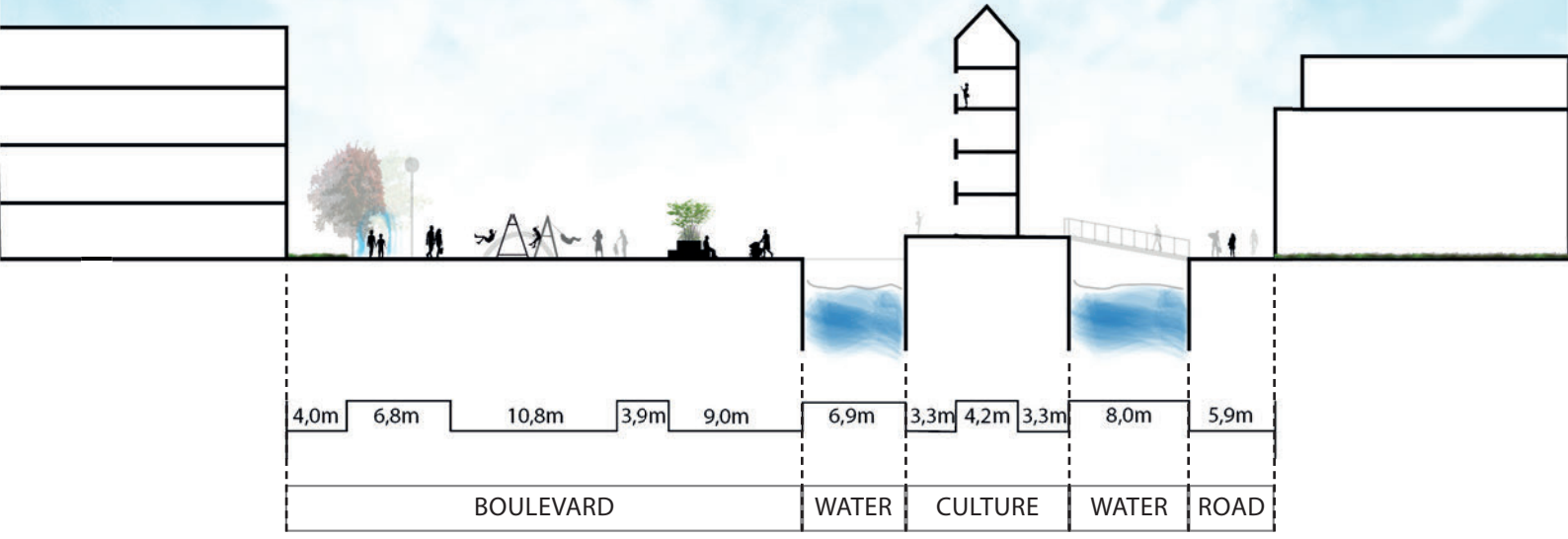


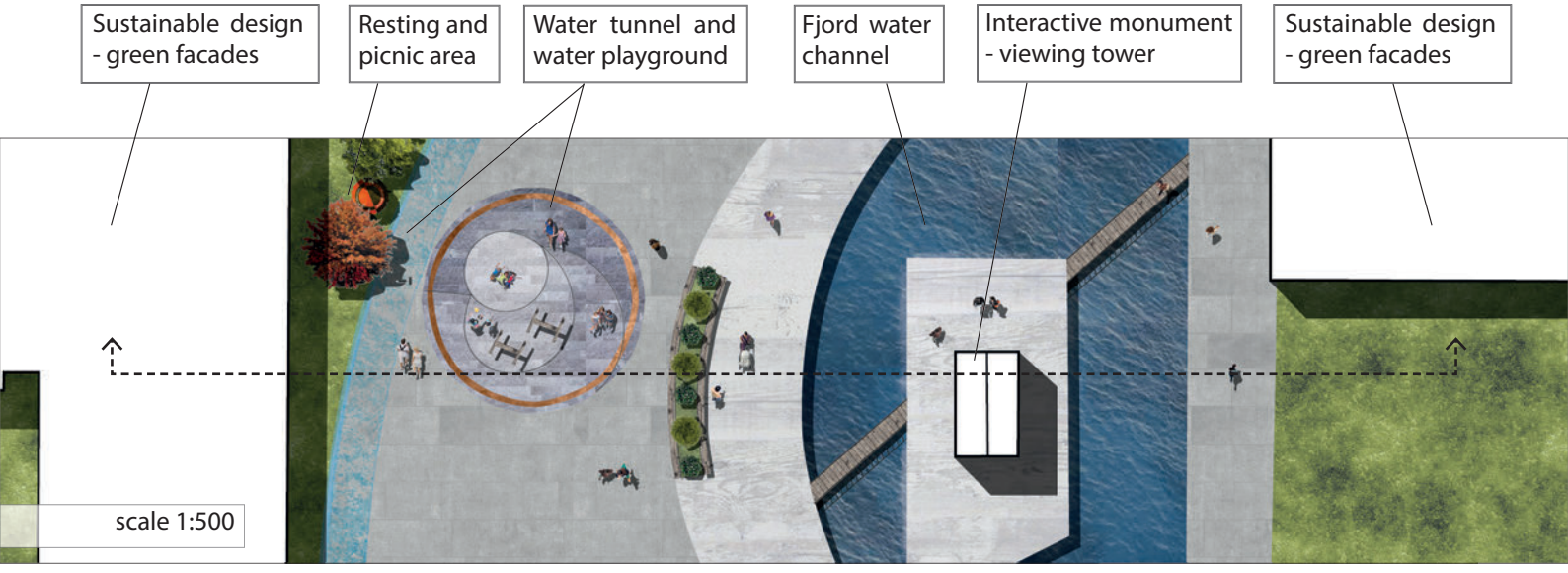
*ill. 48: Water tunnel*

*ill. 49: Water boulevard*

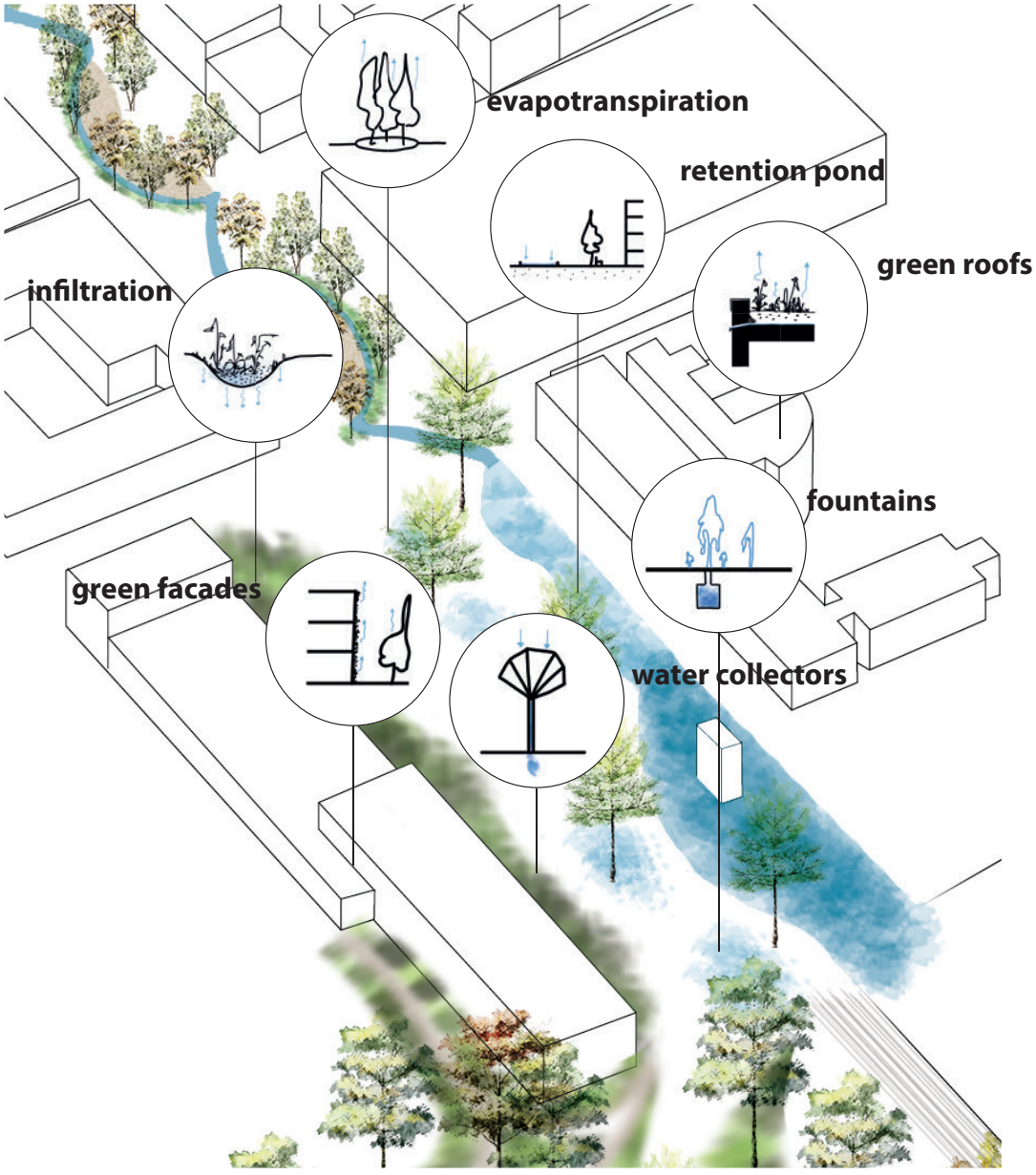
*ill. 50: Stepping stones - winter*

scale 1:500



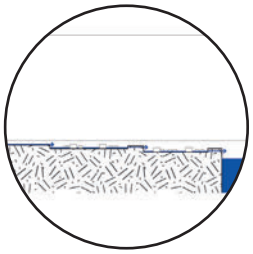




scale 1:500

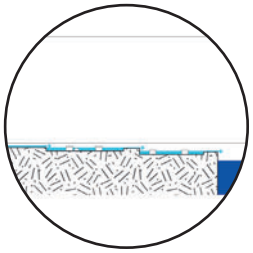




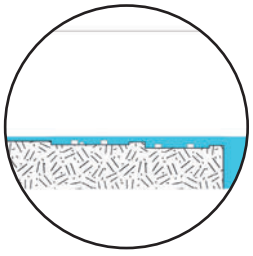

DRY



DAILY RAIN



HEAVY RAIN



**Water management**

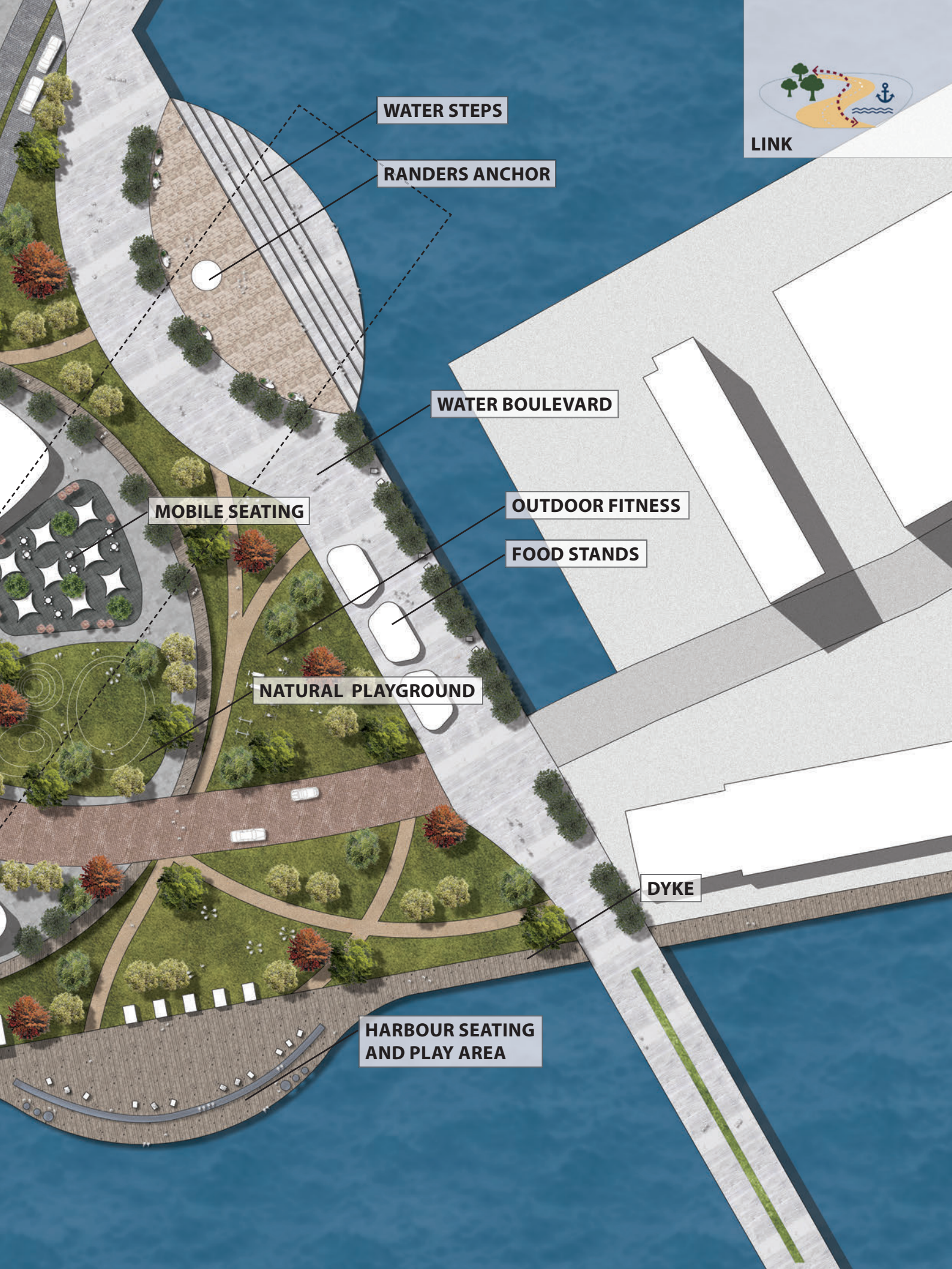
The strategy of this part is to extend the fjord into a channel to incorporate it in the public space as well as provide the outlet for the runoff water into the fjord basin. The new channel will be in the form of water steps allowing the water to flow through retention ponds into the basin. Additionally rainwater is collected and stored in water collectors that have a recreation purpose. The collected water through interactive structures will be reused for water features such as fountains, water tunnels and playgrounds. Greenery is used to provide infiltration areas especially around the west side where excess water runoff might flow from side streets. The greenery will improve evapotranspiration and thermal comfort while also cleaning the air that can be more polluted from the adjacent bus station. This will take the form of ornamental trees, small park with trees and other vegetation as well as a new green façade of the transformed building.

In dry weather conditions the stepped retention ponds will be filled with water pumped from the fjord and through the channel in the culture stretch. It will create a water cascade in a cycle to maintain constant water flow through public space and in the water features. During rain events the cascade will direct the water from the culture stretch above to the basin, and during heavy rain the basin and retention ponds will be flooded to full capacity before the water is pumped out into the fjord.

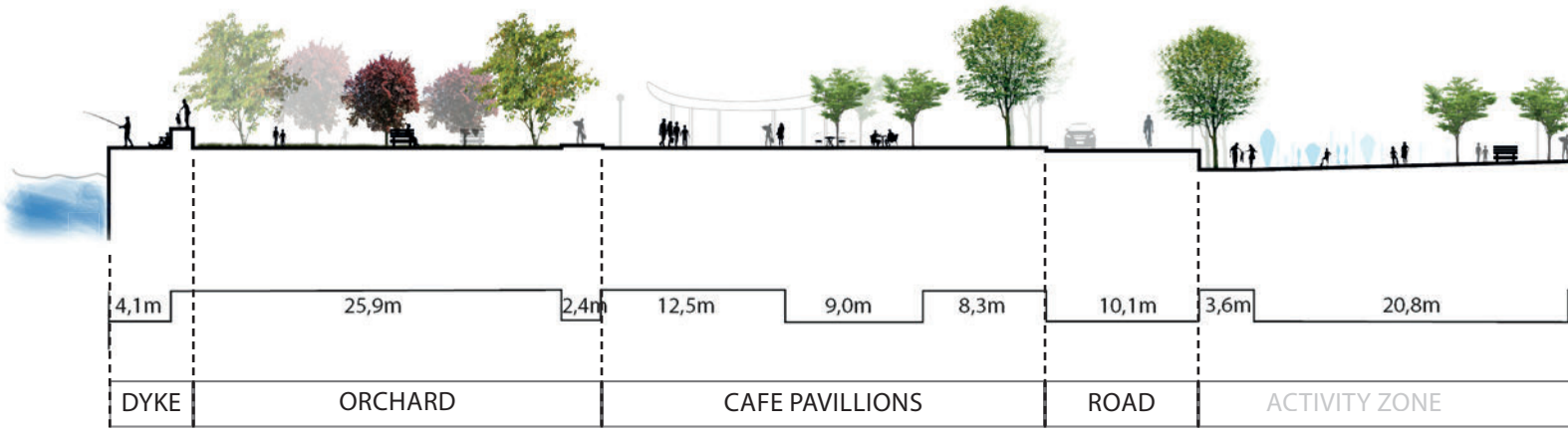
BEFORE

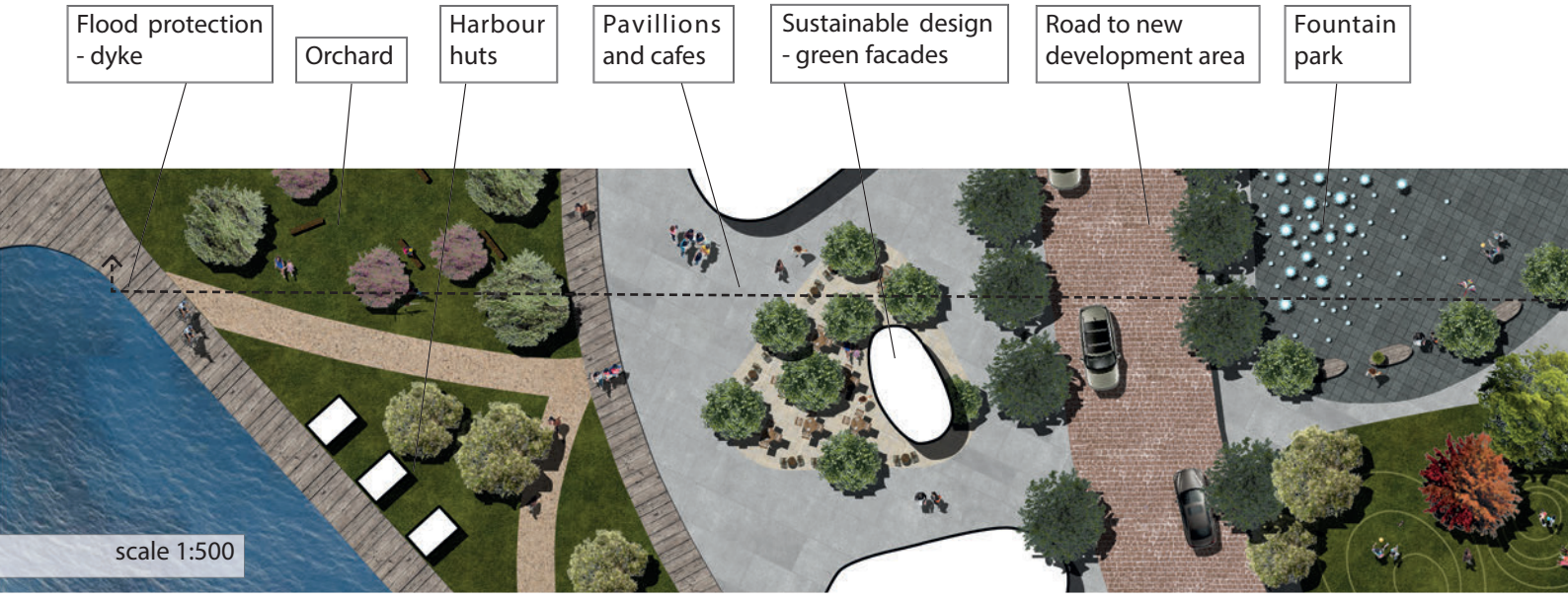

AFTER


BUS TERMINAL
HOTEL
RESTURANT AND ACTIVITY CENTRE
PARK
WATER PLAYGROUND
CAFE PAVILLIONS
ORCHARD
BEACH HUTS AND FOOD STALLS
FISHING DECK
N
0
5
10
25m

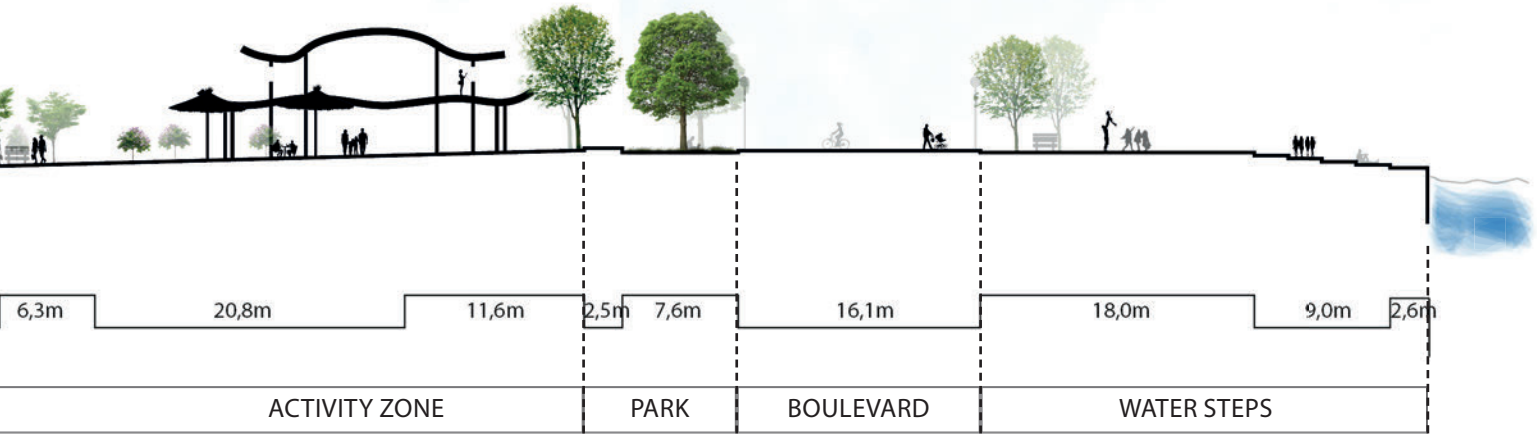

WATER STEPS
RANDERS ANCHOR
WATER BOULEVARD
MOBILE SEATING
OUTDOOR FITNESS
FOOD STANDS
NATURAL PLAYGROUND
DYKE
HARBOUR SEATING
AND PLAY AREA
LINK

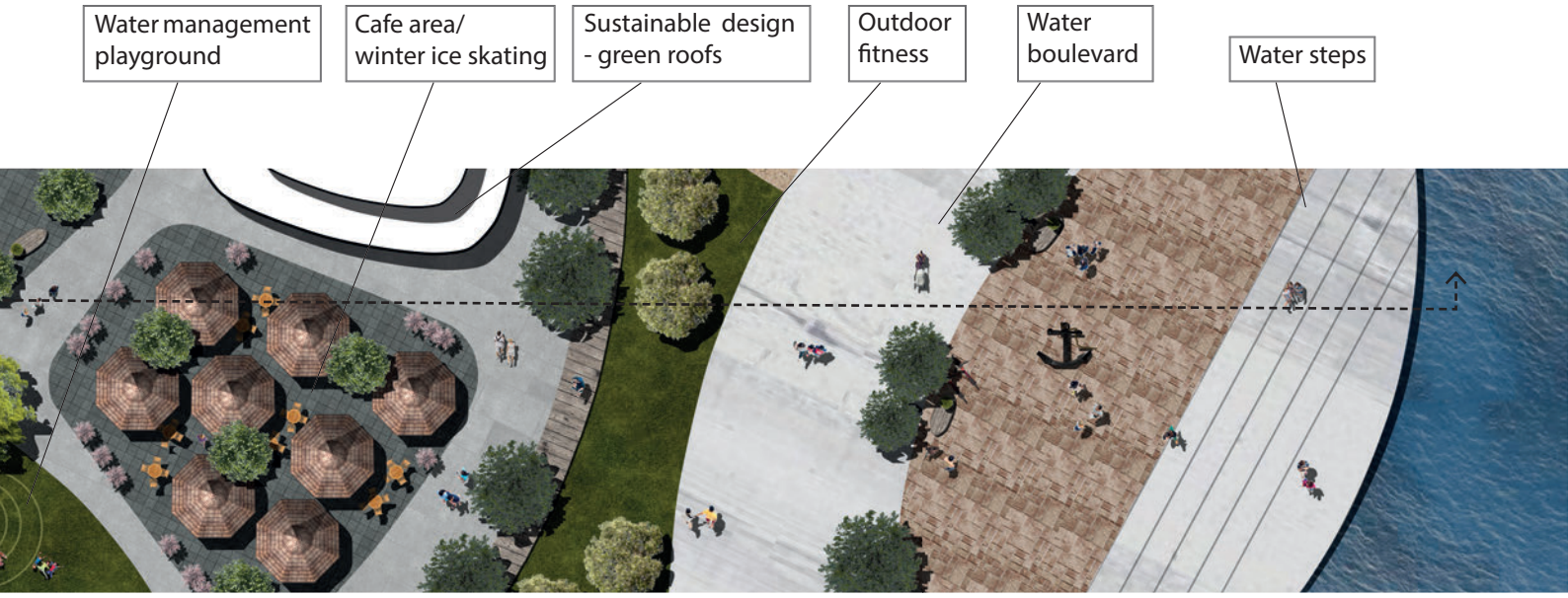
scale 1:500

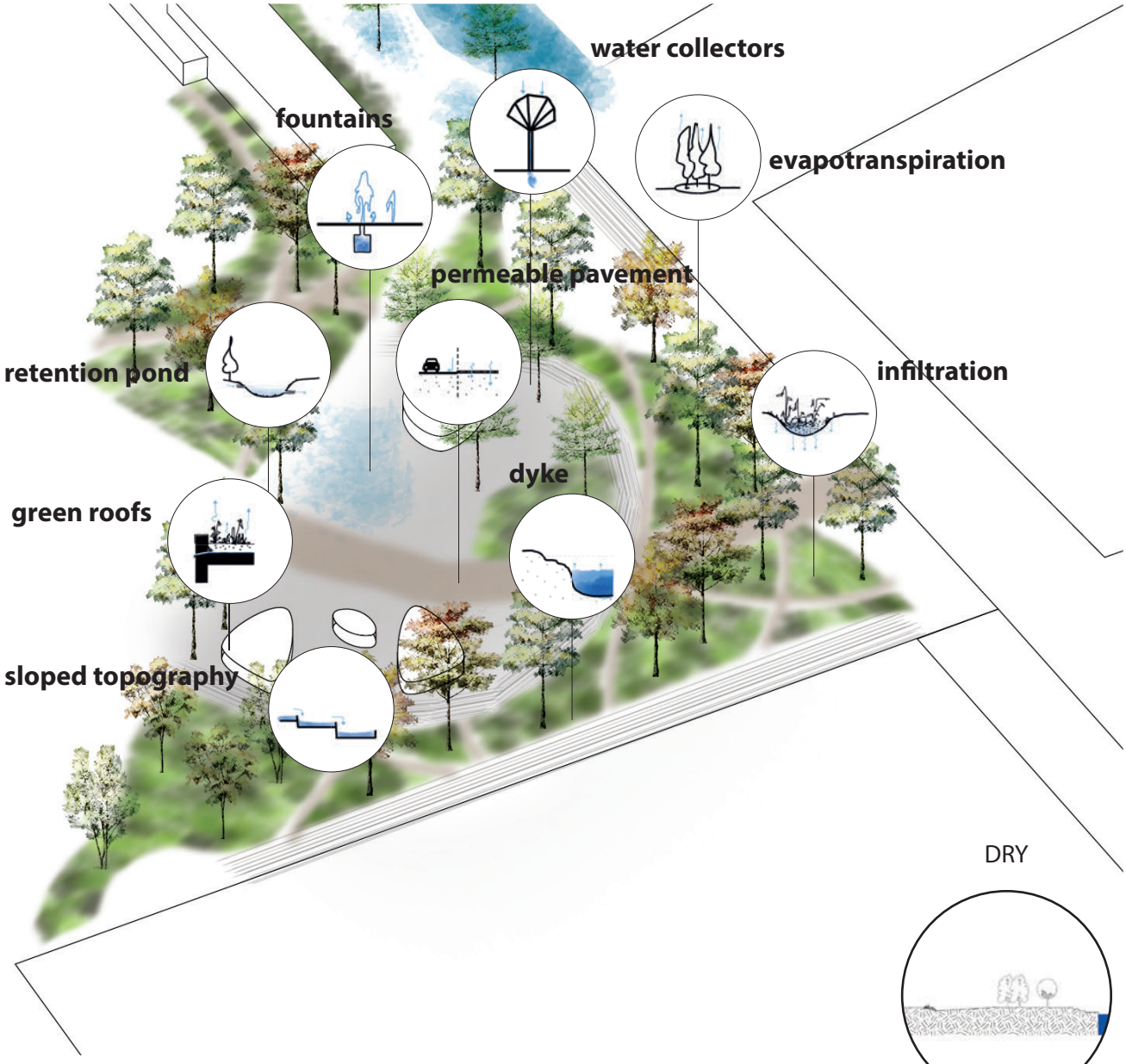



scale 1:500


6,3m
20,8m
11,6m
2,5m
7,6m
16,1m
18,0m
9,0m
2,6m
ACTIVITY ZONE
PARK
BOULEVARD
WATER STEPS


Water management playground
Cafe area/ winter ice skating
Sustainable design - green roofs
Outdoor fitness
Water boulevard
Water steps

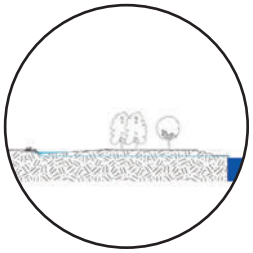




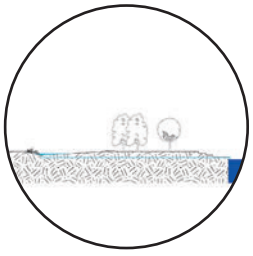

DRY



DAILY RAIN



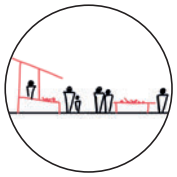
HEAVY RAIN



**Water management**

The link has its own purpose in the water management strategy, focusing on water treatment, flood protection and water collection from the other main streets. The dyke will run along the south edge of the site ad into the new development protecting the city from sea level rise. The dyke will offer recreational aspects and views of the fjord that can still allow people to have a connection to the water. The area incorporates greenery and parks around the central space to provide a buffer from the noise of the bus terminal and the traffic, as well as to clean the air through the additional green roofs and facades. Green spaces and filtration systems will clean the runoff water before it is led back the fjord. Further the central area is sloped to direct the water to the centre and protect the other public spaces from impacted functionality. Water collectors will be used to store water and reuse it in water features.

In dry conditions the water features are supplied with water from water collectors. In rainy events the central area will be flooded, and the water will be distributed through pipes into the fjord.

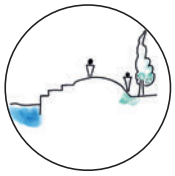


**Markets**

Temporary and seasonal markets enhances the local values and links Randers both regionally and internationally.

**Orchard**

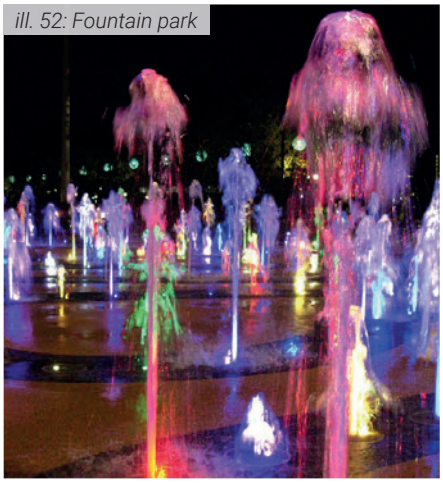
Orchard not only reduces traffic noise and is an important natural solution against climate change, but also allows people to enjoy the diversity of seasonal fruits and through participation gives a feeling of ownership.



**Dyke**

To avoid the threat of rising sea levels, a dyke is introduced. Additionally it also provides such functions as a better view over the water, water steps, play area and a fishing deck to suit all generations and different interests.

*ill. 51: Outdoor fitness*

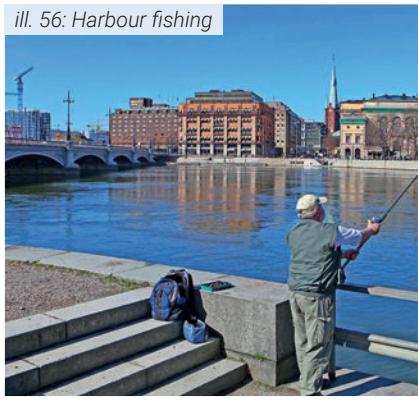


*ill. 52: Fountain park*

*ill. 53: Cafe and pavillions*

*ill. 54: Harbour huts*

*ill. 55: Harbour play area*



*ill. 56: Harbour fishing*

*ill. 57: Markets and pavillions*

BEFORE


AFTER

# 6

# CONCLUSION

This chapter is an overall summary of the master thesis project. It contains a short assessment of the proposed strategy and design for the project site and thus answers the research question. The conclusion considers both bigger scale aspects related to climate change and urbanisation, as well as, smaller scale related specifically to Randers.

Additionally, the chapter reflects upon the process and outcome and brings up a short discussion of how the suggested strategy could be improved for future projects.

## FUTURE OF RANDERS

Raindrop for Randers project tackles the question of climate resilience in Denmark and transforms the chosen site into a more socially and environmentally coherent central location in Randers. Furthermore, it is designed to link the different currently disconnected parts of inner-city and create more attractive and functional public spaces in different weather conditions.

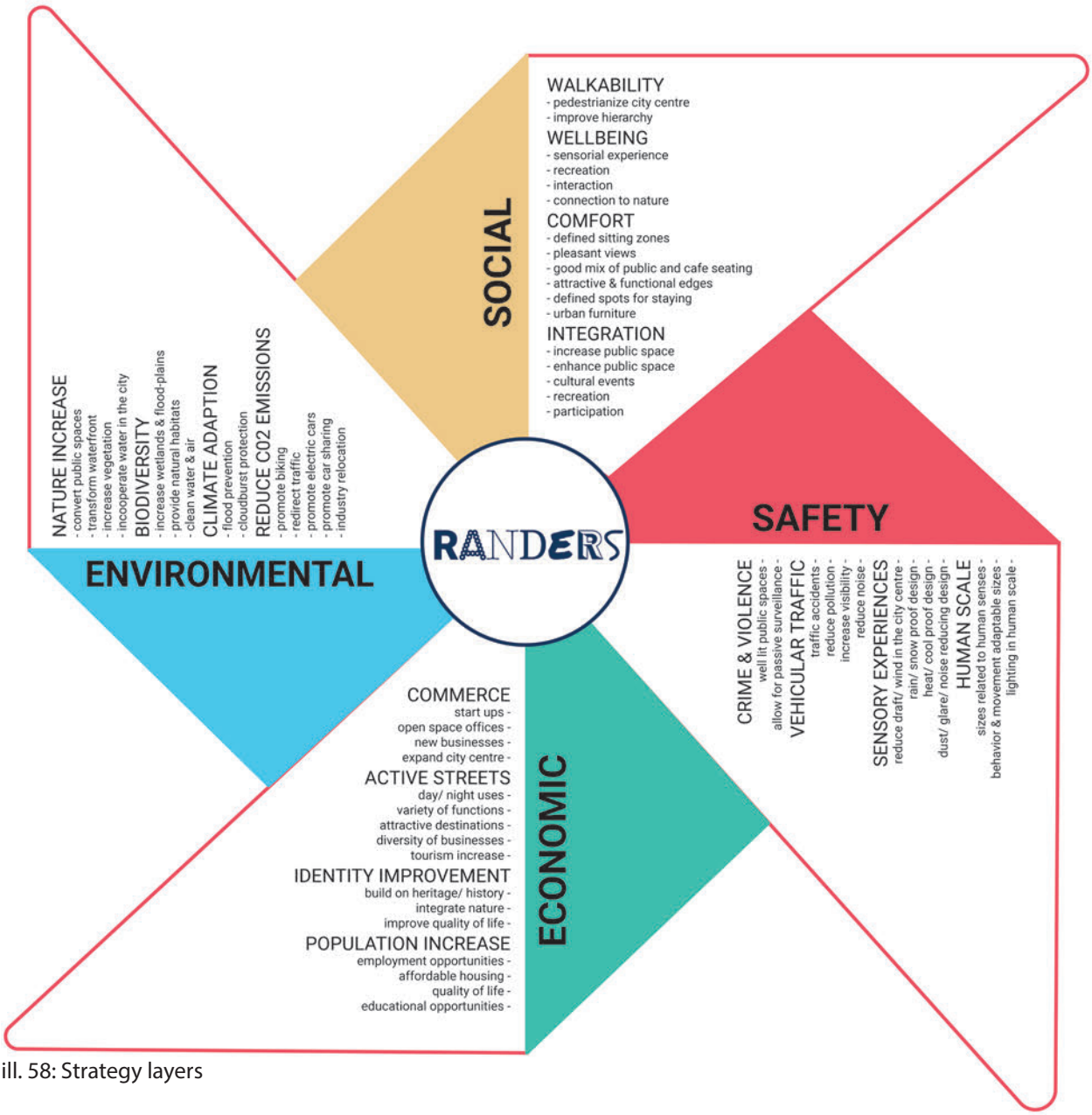
The design for Østervold, is a strategic design solution that enhances the existing features of Randers while creating exciting urban spaces designed to cope with climate change in terms of water management. As a result, the boulevard unfolds delightful spaces, and is responsive to its surrounding context, flooding risks and social needs of both citizens and visitors. Transforming the street into a pedestrian boulevard, will improve connections, social interactions, citizens well-being and quality of life.



The presented design arises by reading and understanding the specific needs of the city, which are required in order to implement the right urban parameters and technical solutions to transform Randers into a livable city. After finding the main components of the site, and analysing its potentials and challenges, the idea of linking the city with water, nature and culture was evolved. With this purpose, the strategic design includes four stretches or so called "drops", which characterise the three potential elements found to enhance the identity in Randers. These components are emphasised in each drop creating unique characters of the boulevard, stitched by nature-based solutions for water management.
Due to the fact that Randers is under a continuous development, the project design cannot be implemented all at once. Hence a strategic design was created, which includes solutions for both short and long term in order to gradually adapt to the city's ongoing growth and search for identity. Though the project will develop over a longer period of time and is partially dependent on Rander's strategic solutions for traffic and rising sea levels, the city is already at a stage, where parts of the design approach can already be implemented. Following the vision, conceptual strategy and the well considered climate responsive interventions, there is an opportunity to start transforming Randers into a more climate adaptive and people responsive livable city. The project takes on a strategic approach to start by implementing the water management solutions on Østervold first, since it is a crucial point for water flow and climate adaptation of the inner city. Once the current industry has moved out within the next 30 years, it will be possible to implement the last part of the strategic plan, called the Link. The proposal will be the connection point between the inner city, nature and new development area.

The proposal will contribute to Randers growth in many ways, not limited to the site. Additionally, the project is designed in a way, that the strategy gives a possibility to expand the design ideas and solutions to other streets in the city. This strategy will contribute to the social, economic and environmental layers that make up a livable and resilient city, as seen in ill. 58. The proposal creates social benefits such as improved walkabilty and social integration through people-oriented approach. The pedestrian street improves safety and connectivity, also offering more spaces for gathering which stimulates social integration and strong community. Economic benefits of this strategic plan include more business opportunities and variety which enhance commerce and trade.

Furthermore, the improved quality of the area and its amenities will contribute to a clear identity and will also stimulate growth in citizens and city development. The strategic plan also contributes to climate adaptation, through incorporation of nature-based solutions and reducing pressure on the existing sewage system. To a limited extent, due to site conditions, the proposal can reduce CO2 emissions by fully pedestrianising the area and promoting environmentally friendly alternatives. Overall the strategic plan has the potential to incorporate other elements and stimulate city growth in all directions.




ill. 58: Strategy layers

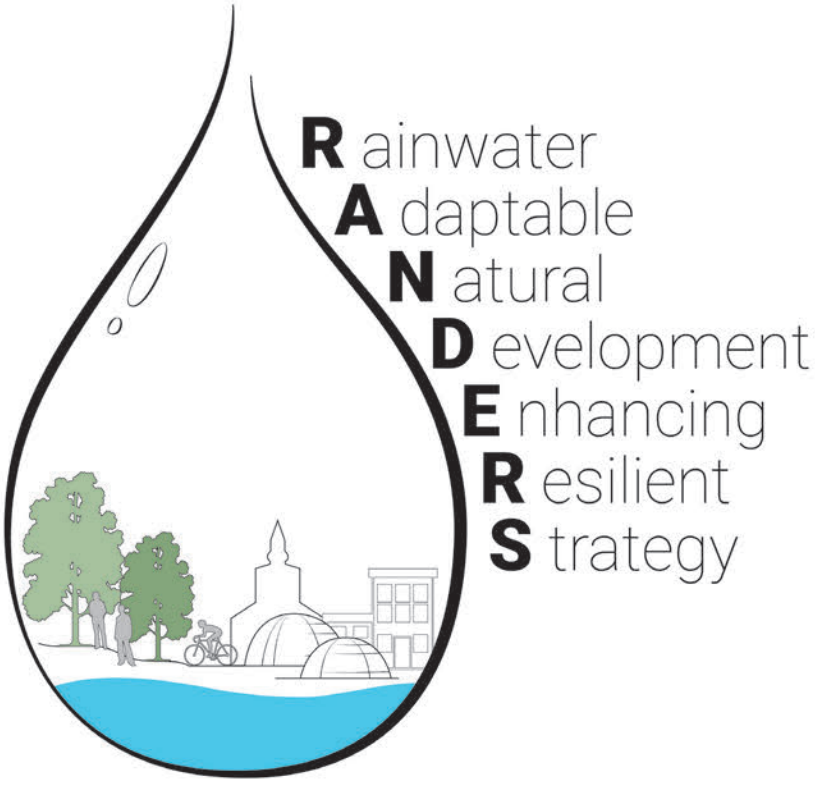
## REFLECTION

A clear vision and a strong concept of the different layers that Østervold contains, are the foundation for the Raindrop for Randers project. The mix of nature, culture, history and water elements are rooted in the main strategy. We envision the project responsive to Randers and its citizens needs, and hereby applicable in real life with focus on such qualities as livability, aesthetics and functionality. Strong community and a sense of ownership are additional values that leads the project towards enhancing the different characters of Østervold and reinforcing the overall identity of Randers. In reflection the project contributes to making Randers more resilient.

As it has been discussed in literature, an important part of the design process is the community's input in order to approach a good and responsive design. However, we did not include the citizens directly in our project design. Instead we collected valuable information about citizen's desires and needs from Randers Municipality's organised events, where various age groups were invited to express their opinions on certain things related to development of Randers city and climate challenges. Based on the publicly available interview results, discussions on social media and summaries from online interactive design softwares, we guide the project as close to reality as possible. The information collected has both the qualitative and quantitative character, which is a good base and start point for the decisions that were made during the project process.

Mobility and infrastructure were discussed during the design phase, since pedestrianization is one of the design strategies. Pedestrianization will have significant impact on the people and their environment, bringing benefits in all aspects of the transformation. However, it was difficult to switch the mindset of a car dependency to alternative means of transport. This transition will take time and further development as discussed in the reflection to convert the current infrastructure and decrease traffic.

Due to climate change and its uncertainty, designing for the future is a challenge. Therefore, the strategic design of the project aims to be future adaptable in terms of time. The design has examples of how different principles and parameters could be implemented according to a specific climate change scenario of increasing frequency and intensity of rainfall. However, it is important to mention that needs and challenges of Randers are changing and developing together with its citizens, too. Therefore the uncertainty of long-term future might have an effect on the project site. Due to this fact, we are introducing a strategic design plan opened to adjustments, rather than a concrete masterplan of the area.


Rainwater
Adaptable
Natural
Development
Enhancing
Resilient
Strategy

# ILLUSTRATION LIST

ill. 1: (bluestemamphitheater, n.d.)
Rain or Shine – Bluestem Amphitheater, n.d., cover photograph <https://bluestemamphitheater.org/blog/rain-or-shine/>

ill. 2: Made by authors, IDP diagram

ill. 3: Made with inspiration from (Miljoministeriet Naturstyrelsen, 2011:p.6), Flood threat. In: Miljoministeriet Naturstyrelsen (2011) Forslag til udpegning af risikoområder på baggrund af en foreløbig vurdering af oversvømmelsesrisikoen fra vandløb, søer, havet og fjorde.

ill. 4-5: Made by authors, Impact of urban development on water cycle

ill. 6-9: (Copenhagen Strategic Flood Masterplan by Ramboll Studio Dreiseitl, n.d.), Copenhagen strategic flood plan
Copenhagen Strategic Flood Masterplan by Ramboll Studio Dreiseitl « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2015/05/copenhagen-strategic-flood-masterplan-by-atelier-dreiseitl/>

ill. 10-12: (Lindevangs Park by Marianne Levinsen Landscape, n.d.), Lindevangs Park
Lindevangs Park by Marianne Levinsen Landscape « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2017/11/lindevangs-park-by-marianne-levinsen-landscape/>

ill. 13-15: (The Soul of Nørrebro by SLA, n.d.), Hans Tavsens park
The Soul of Nørrebro by SLA « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2016/11/nature-based-climate-adaptation-wins-scandinavias-biggest-architecture-award/>

ill. 16-18: (The Zollhallen Plaza in Germany by Ramboll Studio Dreiseitl adopts water sensitive urban design, n.d.), Zollhallen Plaza
The Zollhallen Plaza in Germany by Ramboll Studio Dreiseitl adopts water sensitive urban design by livin spaces, n.d., photographs
<https://livinspaces.net/projects/gardens-and-outdoor/the-zollhallen-plaza-in-germany-by-ramboll-studio-dreiseitl-adopts-water-sensitive-urban-design/>

ill. 19-21: (Queen Elizabeth Olympic Park,n.d.), Queen Elizabeth Olympic Park
Queen Elizabeth Olympic Park | Hargreaves Associates, n.d., photographs
<http://www.hargreaves.com/work/queen-elizabeth-olympic-park/>

ill. 22-24: (Tasinge Plads, 2015), Taasinge Square
Tasinge Plads | Pics | Download |, 2015, photographs
<http://ihc2015.info/skin/tasinge-plads.akp>

ill. 25: Made by authors, water design principles

ill. 26: (Westergasfabriek Park by Gustafson Porter + Bowman, n.d.), Westergasfabriek Park / Gustafson Porter+Bowman
Westergasfabriek Park by Gustafson Porter + Bowman « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2015/01/westergasfabriek-park-by-gustafson-porter/>

ill. 27: (Laasby Sea Park by LABLAND, n.d.), Laasby Sea Park / LABLAND architects
Laasby Sea Park by LABLAND « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2018/06/laasby-sea-park-by-labland/>

ill. 28: (Catharina Amalia Park, Apeldoorn by OKRA, n.d.), Catharina Amalia Park / OKRA landscape architecture
Catharina Amalia Park, Apeldoorn by OKRA « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2015/01/catharina-amalia-park-apeldoorn-by-okra/>

ill. 29: (Hammarby Sjöstad, Stockholm, Sweden, n.d.), Hammarby Sjöstad
Hammarby Sjöstad, Stockholm, Sweden | Urban green-blue grids, n.d., photographs
<https://www.urbangreenbluegrids.com/projects/hammarby-sjostad-stockholm-sweden/>

ill. 30: (Arkadien Winnenden by Ramboll Studio Dreiseitl, n.d.), Arkadien Winnenden / Ramboll Studio Dreiseitl
Arkadien Winnenden by Ramboll Studio Dreiseitl « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2013/04/arkadien-winnenden-by-atelier-dreiseitl/>

ill. 31-33: (Kokkedal Climate Adaption by Schonherr, n.d.), Kokkedal Climate Adaption
Kokkedal Climate Adaption by Schonherr « Landscape Architecture Platform | Landezine, n.d., photograph
<http://www.landezine.com/index.php/2018/12/kokkedal-climate-adaption-by-schonherr/>

ill. 34: Made by authors, walkability diagram

ill. 35: (Byen til Vandet Forum, n.d.), Forum "City by the water"
Byen til Vandet, n.d., photograph
<https://byentilvandet.randers.dk/borgerinddragelse/forum-for-byen-til-vandet/>

ill. 36: (Randers kan få to nye broer, n.d.), Randers bird-view
Randers kan få to nye broer by Building Supply DK, n.d., photograph
<https://www.building-supply.dk/article/view/214275/randers_kan_fa_to_nye_broer>

ill. 37: (Bicycle family, n.d.), Active water management
Stormwater.wef.org, n.d., photograph
<https://stormwater.wef.org/wp-content/uploads/2013/05/Bicycle-Family.jpg>

ill. 38: (Media timeout, n.d.), Public park
Media.timeout.com, n.d., photograph
<https://media.timeout.com/images/100453991/1024/576/image.jpg>

ill. 39: (luminescent park swing boston, n.d.), Luminescent park swings
Inhabitat.com, n.d., photograph
<https://inhabitat.com/wp-content/blogs.dir/1/files/2014/09/Howler-Yoon-Architecture-Boston-Luminescent-Park-Swing-Time-1.jpg>

ill. 40: (Levy Park, n.d.), Natural playground
Static1.squarespace.com, n.d., photograph
<https://static1.squarespace.com/static/52951422e4b0fc3987fbbbb4/5aa9a132e4966b471618e0dd/5aa9a294e2c4830ec1363415/1521066658910/LVPK-92.jpg?format=1500w>

ill. 41: (Contemporist, n.d.), Sculpture park
Contemporist.com, n.d., photograph
<http://www.contemporist.com/wp-content/uploads/2014/12/mo_161214_04-630x433.jpg>

ill. 42: (Outside photo exhibit, n.d.), Media exhibition
Image result for outside photo exhibit | Outside Exhibit | Photography exhibition, Exhibition display, Photo exhibit on pinterest, n.d., photograph
<https://www.pinterest.dk/pin/197525133639953457/?lp=true>

ill. 43: (Clouds brewing, n.d.), Green cafe
15 of Downtown Raleigh's Best Outdoor Restaurants by medium, n.d., photograph
<https://medium.com/@getstealz/15-of-downtown-raleigh-s-best-outdoor-restaurants-7fec595bccf4>

ill. 44&50: (Roombeek the Brook by Buro Sant en Co Landscape Architecture, n.d.), Stepping stones & Stepping stones - winter
Roombeek the Brook by Buro Sant en Co Landscape Architecture « Landscape Architecture Platform | Landezine, n.d., photographs
<http://www.landezine.com/index.php/2011/06/roombeek-the-brook-by-buro-sant-en-co-landscape-architecture/>

ill. 45&52: (Fountains, n.d.), Water playground
Fountains.co.uk, n.d., photographs
<https://www.fountains.co.uk/wp-content/tim/tim.php?src=wp-content%2Fuploads%2Folympic-1-1200x720.jpg&w=1280&h=720&zc=1&s=0&f=0&q=85>
<https://www.fountains.co.uk/wp-content/tim/tim.php?src=wp-content%2Fuploads%2Folympic-6.jpg&w=720&h=720&zc=1&s=0&f=0&q=85>

ill. 46: (Water tree, n.d.), Water tree
I.pinimg.com, n.d., photograph
<https://i.pinimg.com/564x/c2/65/72/c26572aab246a37299d8aceee7c10675.jpg>

ill. 47: (Squarespace, n.d.), Water feature
Static1.squarespace.com, n.d., photograph
<https://static1.squarespace.com/static/52951422e4b0fc3987fbbbb4/5aa9a132e4966b471618e0dd/5aa9a24d41920244ff68fcb8/1521066897265/LVPK-72.jpg?format=1500w>

ill. 48: (A Fun & New Water Fountain Park Beautifies Lima, Peru, n.d.), Water tunnel
A Fun & New Water Fountain Park Beautifies Lima, Peru by ExpertSure, n.d., photograph
<https://www.expertsure.com/2009/05/26/a-fun-new-water-fountain-park-beautifies-lima-peru/>

ill. 49: (20 Best Of Waterfront Landscape Architecture Pdf Inspiration, n.d.), Water boulevard
20 Best Of Waterfront Landscape Architecture Pdf Inspiration | Best Nature and View, n.d., photograph
<http://www.pulauubinstories.com/waterfront-landscape-architecture-pdf/>



ill. 51: (Good yoga, n.d.), Outdoor fitness
Greatriverpassage.org, n.d., photograph
<https://greatriverpassage.org/wp-content/uploads/2017/06/goodyoga1.jpg>

ill. 53: (Portfolios Archive - Venue Projects, n.d.), Cafe and pavillions
Portfolios Archive - Venue Projects, n.d., photograph
<http://venueprojects.com/portfolios/>

ill. 54: (beachhutmain, n.d.), Harbour huts
Secure.i.telegraph.co.uk, n.d., photograph
<https://secure.i.telegraph.co.uk/multimedia/archive/01445/beachhutmain_1445144c.jpg>

ill. 55: (Paprocany Lake Shore Redevelopment, n.d.), Harbour play area
Paprocany Lake Shore Redevelopment / RS + Robert Skitek by ArchDaily, n.d., photograph
<https://www.archdaily.com/775301/paprocany-lake-shore-redevelopment-rs-plus>

ill. 56: (10 of Stockholm's Top Fishing Spots, n.d.), Harbour fishing
10 of Stockholm's Top Fishing Spots by Jozef Brodala, n.d., photograph
<https://theculturetrip.com/europe/sweden/articles/10-of-stockholms-top-fishing-spots/>

ill. 57: (Sculpture digest, n.d.), Markets and pavillions
I1.wp.com, n.d., photograph
<https://i1.wp.com/sculpturedigest.com/wp-content/uploads/2016/08/Sculpture_in_the_Park.png?fit=1435%2C520&ssl=1>

ill. 58: Made by authors, Strategy layers

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# APPENDIX

This chapter contains the main supportive material that was used in the project analyses and design processes.

# WATER MANAGEMENT

## 10 YEAR RETURN PERIOD

Using the following formulas and variables, the volume of the natural pond is calculated for catchment 1.

Reduced area: $F_r$ = 3,2 ha = 3200 $m^2$
Return period: T = 10 years
Rain intensity: i = 0,1514 m/h
Rain duration: h = 2 hours
Specific outflow: a=1 L/s x ha = 3,6 m3/h x ha
Area of the pond: $A_{pond}$= 1526,77 $m^2$

$V = (Q_{in} - Q_{out})h$
$Q_{in} = i \times F_r$
$Q_{out} = a \times F_r$

$V = (484{,}60 - 11{,}52) \times 2 = 946{,}17\ m^3$

$V \leq A_{pond} \times h$
$946{,}17\ m^3 \leq 1526{,}77\ m^2 \times h$
$0{,}62\ m \leq h$

The same calculation is done with the safety factor of 1, resulting in the following dimensions and volume of the pond.
$V \leq A_{pond} \times h$
$1749\ m^3 \leq 1526{,}77\ m^2 \times h$
$1{,}15\ m \leq h$



To calculate dimensions of the channels, the following formulas and variables are used. Catchments 2 and 3 are contributing to the flow through the channels.

C2: $t_r$ = 6 minutes, $i_{5\ min}$ = 310 L/s
C3: $t_r$ = 11 minutes, $i_{10\ min}$ = 230 L/s
Manning number: M = 75 for concrete channels
Slope: I = 0.03
Width of channel: w=1.5 m

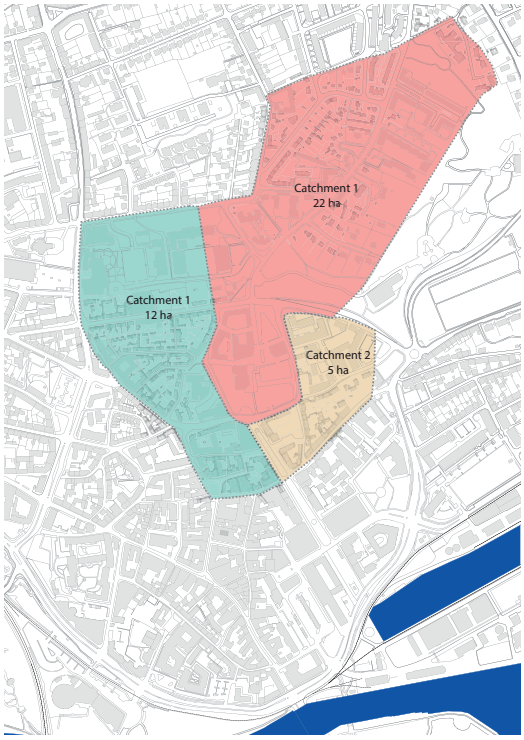
$Q_{in} = i \times F_r$
$Q_{in}$ = 230 x (4,5+4,32)
$Q_{in}$ = 2028 L/s = 2,028 $m^{3/s}$

$Q_{full} \leq A \times M \times I^{1/2} \times R^{2/3}$
$2{,}03 \leq 1{,}5 \times h \times 75 \times 0{,}03^{1/2} \times (1{,}5 \times h/(2h + 1{,}5))^{2/3}$
$0{,}7\ m \leq h$

## 100 YEAR RETURN PERIOD

For a 100 year event the rainfall intensity is 0,2314m/h which would require a detention area with capacity of 11043$m^3$. This means that the whole street would need to be lowered by 0.4m including the proposed pond and pockets. Therefore the strategy is to implement a pumping system to lead the excess water into the fjord.

$V_{total} - V_{pond} - V_{pockets} \leq A_{street} \times h$
$11043\ m^3 - 1749\ m^3 - 642{,}74 m^3 \leq 17933\ m^2 \times h$
$0.48\ m \leq h$



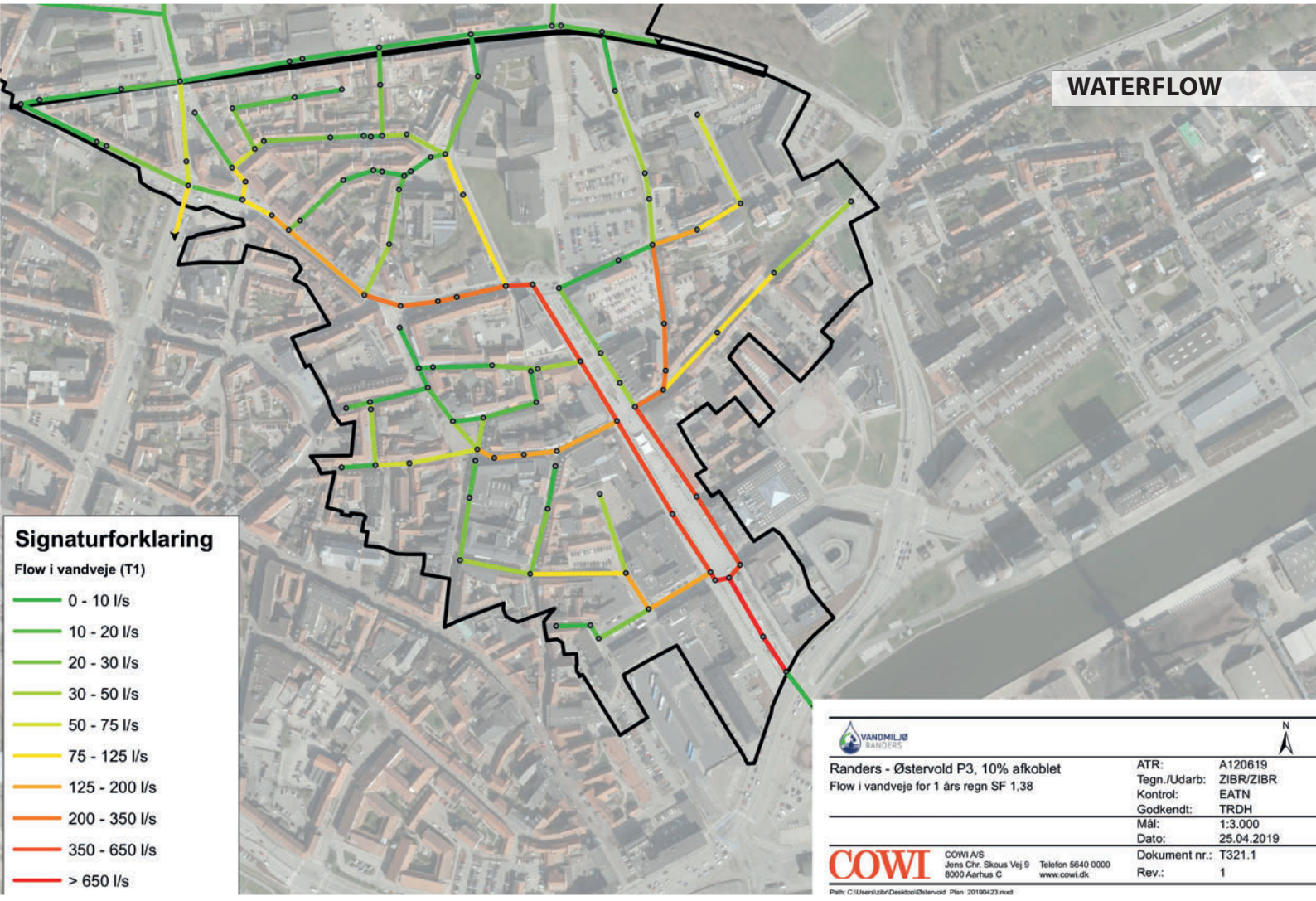

Catchment areas are determined using topography and water flow analysis. The calculation is done using the formulas;

$\varphi$ (red.f.) = $\beta^*\delta^*\theta$
$F_r = F_t^* \varphi$

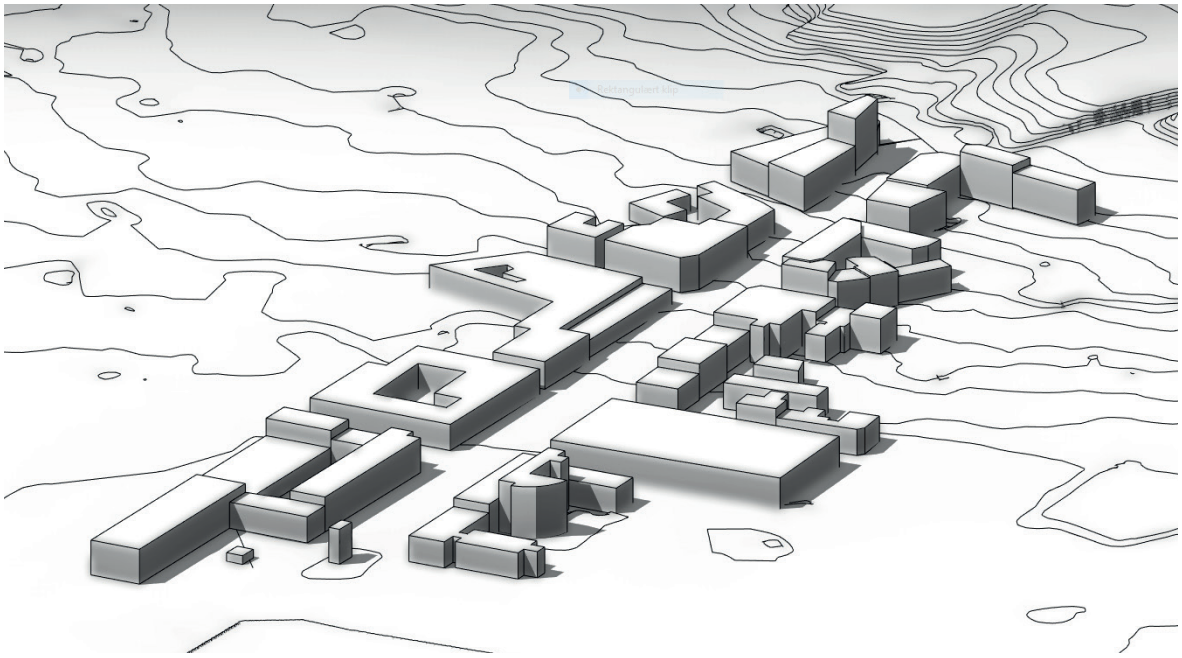
| C1 | |
|---|---|
| *Total Area (ha)* | 8.0000 |
| *Degree of imperviousness (ϐ)* | 0.40 |
| *Degree of connection (δ)* | 1.00 |
| *Hydrological reduction factor (ϑ)* | 1.00 |
| **Reduced Area (ha):** | 3.2000 |

| C2 | |
|---|---|
| *Total Area (ha)* | 5.0000 |
| *Degree of imperviousness (ϐ)* | 0.90 |
| *Degree of connection (δ)* | 1.00 |
| *Hydrological reduction factor (ϑ)* | 1.00 |
| **Reduced Area (ha):** | 4.5000 |

| C3 | |
|---|---|
| *Total Area (ha)* | 6.0000 |
| *Degree of imperviousness (ϐ)* | 0.90 |
| *Degree of connection (δ)* | 0.80 |
| *Hydrological reduction factor (ϑ)* | 1.00 |
| **Reduced Area (ha):** | 4.32 |




**Waterflow illustration from Vandmiljø R anders**



# SUPPORTIVE ANALYSES

## BLUE AND GREEN

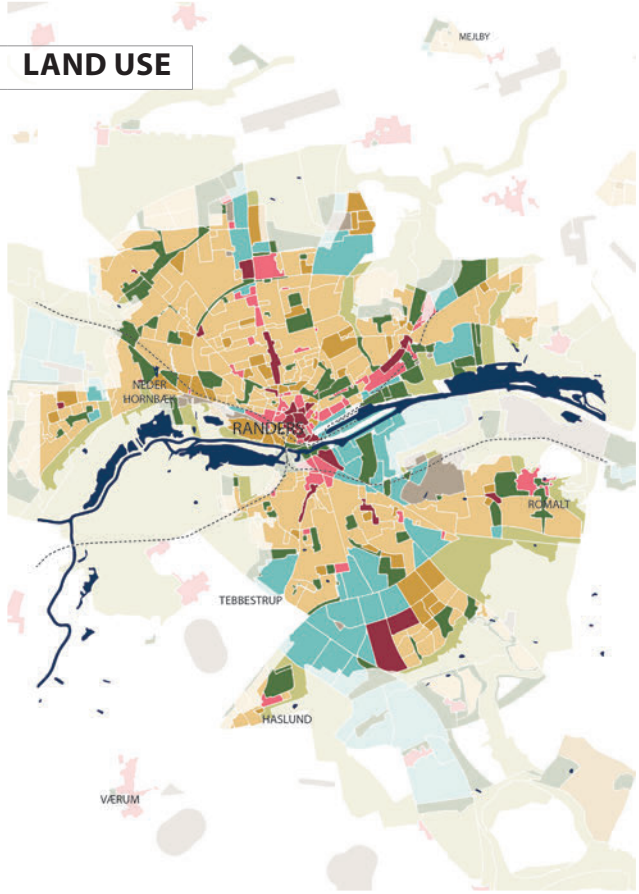

scale 1:50 000
@ A4

- green rural areas
- significant ecological areas
- recreational green areas
- urban zone

The blue and green analysis of Randers gives an overview of the proportion between urban zone and natural areas on a larger scale.



## LAND USE




scale 1:50 000
@ A4

- rural
- recreation
- mixed use
- residential
- public space
- commercial
- technical facilities
- retail

The land use analysis is used to analyse the existing situation and support a mixed zoning in the project site.

scale 1:50 000
@ A4

train station
highway
primary road
secondary road
railroad

The infrastructure analysis provides an overview of the traffic connection on a city scale. It shows the different layers of the roads within the city and also regional connections.



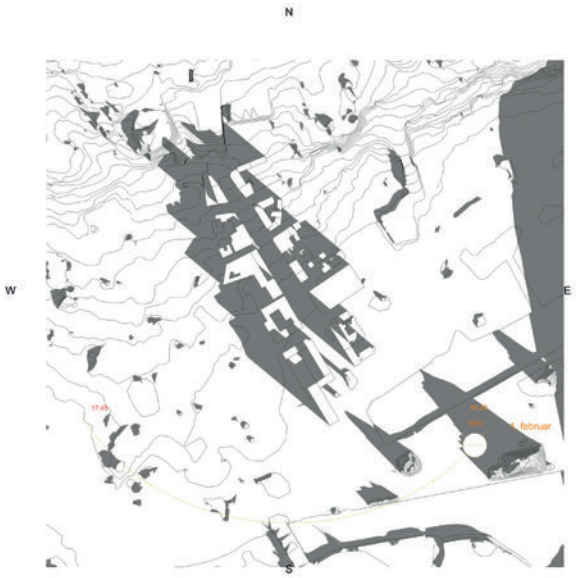

scale 1:2 500
@ A4

6 storeys
5 storeys
4 storeys
3 storeys
2 storeys
1 storeys

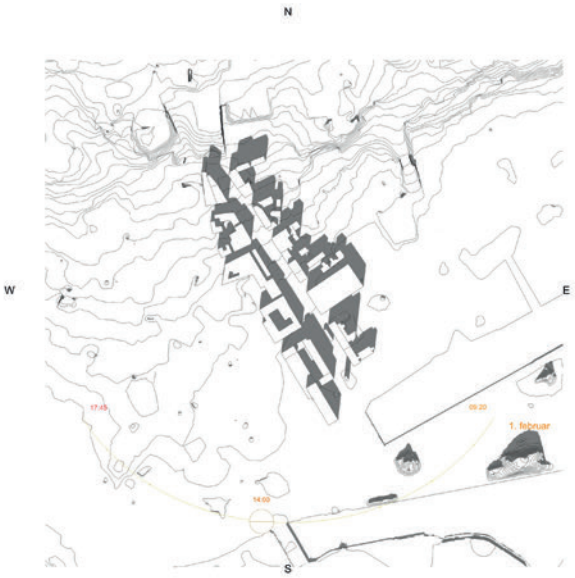
The building heights are used to analyse the existing situation and better plan the new design of the space between based on such factors as human scale, shadows, unpleasant weather conditions (e.g., wind, heat) etc.

# SOLAR ANALYSIS

### FEBRUARY 1ST AT 10:00



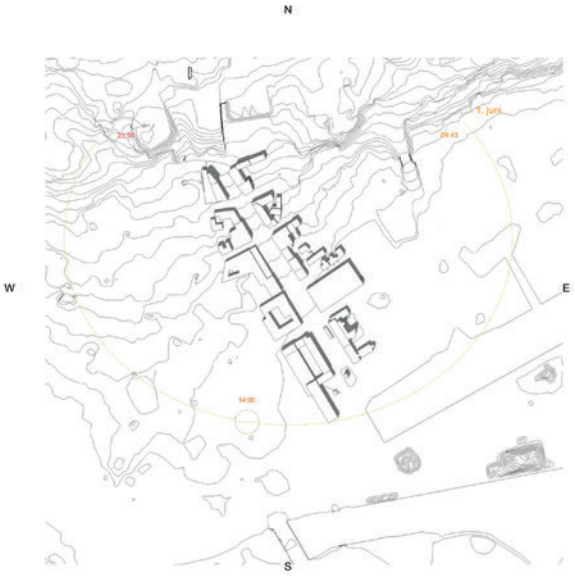

### FEBRUARY 1ST AT 14:00






### JUNE 1ST AT 10:00


### JUNE 1ST AT 14:00




The solar analysis and 3D model allows for an interaction with different scales and explores preconditions for design of the new public space. For instance, how the sun conditions would affect the different locations at the site throughout seasons.

# SITE VISITS

# EXTERNAL SOURCES

**Exhibition and debate at Træløberen, Østervold - combined results 8.08. - 17.10.2015.**
From Byen til Vandet borgerinddragelsesprocessen - ordet er dit (Plan, 2015)

Have you heard about the municipality's vision to combine city with water?

**Yes** (75%) (25%) **No**

What do you think Randers should set focus on in the future?

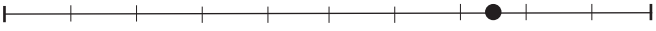
**Nature** (50%) (50%) **Urban development**

What do you see at the biggest challenge in Randers?

**Traffic congestion** (75%) (25%) **Climate challenges**

Which new bridge connections, in your opinion, could create the best possibilities for Randers in the future?

**Bolværkslinjen/ Engbroen** (25%) (75%) **Klimabroen/ Engbroen**



"I think it's a genius idea to bring more water and green in the city centre, though it's currently not possible due to the traffic."

"The international market worked really well. Maybe we could use something more permanent."

"Park at Randers bridge is exactly what we are missing."

"Why to remove traffic from Randers bridge - first one has to find out where the current traffic should be led to before building new bridges!"

"Leave the traffic out of the city centre - and leave the promenade without cars."

"The best ideas for development. - a comment from a person reading the Pixi-folder."

"Vorup Enge is UNIQUE!! The nature area should be car-free."

"It will never come true - talk, talk, talk and no actions - I don't believe it until I see it."

"No more prestige projects, thank you - however, it would make more sense to get more for the money that we need to use on traffic (development and renovation) and climate (adaptivity)."

"Randers is far behind other cities - something has to happen now!"
"Really good idea with the Klimabroen - we want city by the water and more city life."

"Engbroen being connected to Aarhusvej will make the area (North Vorup) very noisy thanks to the new road."

"Bolværkslinjen doesn't lose anything - Rosenørnsgade is still a 'cork."

"I wish for a house-boat right next to Randers bridge with a geranium on the roof."

"I wish for a harbor-bath."

"If you don't do anything, you will close the city."

"There are so many, who are dissatisfied with Østervold - it would be fantastic if instead we could get more water and life."

During the participation process there was a possibility to come up with written suggestions, and several citizens used it. The collected results on facebook can be seen in the appendix 1 in Byen til Vandet borgerinddragelsesprocessen - ordet er dit (Plan, 2015) report.

## Yes, please to City by the Water!

Generally, it is a positive feedback from Randers Kommune and their interest in citizen opinions in as early stage as possible. In the same time the idea about bringing city closer to the water and created new environment in the city centre,has been positively accepted. Many think that it is what will bring Randers back in the city top.

"... The future will bring a competition for the city from the immigrants from the countryside. Randers can and has to be much stronger... Water is just an asset and it reminds us that Gudenå river is nearby." / P.D.Kruse, mail

As for the concrete scenarios, in the written scenarios it cannot be concluded that people prefer one or the other. Many think that Klimabroen will remove traffic too far away from the city centre, others - that for the future climate challenges there should be built a bridge and sluice further away from the city between Harridslev and Assentoft. The majority though agrees on the scenario 3 or 4, as they both work on solutions for the connections over the fjord and the river, and it should be further developed.

## Remember the good recreational possibilities near the water

Many have expressed that once the city is brought to the water or the water to the city, there should be ensured a possibility to stay close to the water. There are suggested such things as, e.g., steps down to the water, "bathing-bridges", swimming, pavilions and good recreational possibilities. It is also said that it is important that there can be many different activities in the same time.

"It is important that there is a place where to sit down and enjoy the view and the atmosphere, and maybe a cafe and small oases, where one can sit or sit next to in peace and quietness with possibilities for both walking, running and cycling without being irritated by the ones, who are sitting there." / S.Andersen, facebook

## Focus on cyclists and pedestrians

In several contributions, there is also a focus on ensuring good connections for bicycles and walking. Several mention that today it is difficult as a cyclist and pedestrian to move around in the area around Randers bridge. At the same time, it is highlighted that one should focus on reducing car traffic.

## Nature and water as a part of the city

In general, it is desired to ensure a view over and access to the nature and water, and also to bring it in the existing city parts, as well in the new developing areas. It is suggested to have green urban spaces, grazing animals in the suburbs and fringes, planting trees by the waterfront and several are excited about the temporary urban furniture at Østervold and at the harbor, and demand more of it.

"We should look at the bigger cities and how they benefit from water, especially, Odense, Aalborg and Copenhagen. We could sail to the middle of Østervold in boats." / R.C.Lindby, facebook

There are many who like the idea of a channel in Østervold and make it possible for cafes around the water in a similar style as other danish cities.