Allegra Fornaca

NO RETREAT FROM CHANGE

A resilient flooding adaptation strategy for Henån (Orust)

Master's Thesis
Examiner: Lena Falkheden
Supervisor: Nils Björling

MSc Architecture and Planning Beyond Sustainability
Department of Architecture and Civil Engineering
Chalmers University of Technology

CHALMERS

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Göteborg, Spring 2018

Abstract

Climate change and, consequently, flooding risk are currently threatening our cities all around the world, urging for municipalities, urban planners, and communities to provide resilient and sustainable solutions.
Numerous measures are being implemented, ranging from engineered to nature-based ones, although invasive solutions such as hard flood-protection structures and relocation strategies still widely support the established paradigm of two contrasting scenarios for cities: dry and stable, or wet and harmed.
This Master's Thesis aims to question this norm, by researching a balance between the built and the natural environment, turning the threat into a resource. From being a disruptive force, water becomes an element embedded in a dynamic landscape, creating new urban qualities and achieving a new equilibrium.

This work was developed within the framework of the *Systemic Solutions for Climate Change Adaptation in Coastal Settlements* project, coordinated by Sweco, which aims at creating an adaptation planning tool for small municipalities in Sweden currently facing flooding risks and having limited budget.
The planning tool will be implemented in Marstrand and Henån, two towns located along the Swedish west coast. The latter is considered as a study case in this Thesis; nowadays Henån is facing different challenges, in addition to climate change effects, which concern socio-economic, as well as urban development, issues.

The research is based on a theoretical framework, finding its foundation in the concept of *Ecological Resilience*, defined as the ability of a system to absorb disturbances and still persist, to change, and reorganize itself. A collection of flooding and sea-level rise adaptation measures was carried out, categorized according to their approach, distinguishing between *grey*, *green* and *hybrid* solutions. Subsequently, an evaluation of these measures was performed, based on the extent to which they allow a dynamic interaction between the urban element and the water.

The result is a set of urban strategies providing resilient adaptive solutions which could enhance new opportunities and values for the town of Henån, tackling its dynamism and transformative capacity.

Ackowledgments

I would like to thank Nils Björling, for his great guidance, expertise, and feedbacks during these intense months; Lena Falkheden, for her professional support throughout the whole semester; Emilio Brandao, Ulf Moback, and Colin Fudge, for their comments and the stimulating discussions we had during the seminars.

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Thank you to my father and my grandparents, you are always in my thoughts.

Marco, Thank you for always being by my side, no matter what. I coul-dn't ask for a better person to share adventures with. There's a million things we haven't done...but just you wait!

Finally, my Mum...Thank you for everything. This is for you: no one has more Resilience.

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A critical perspective

How can the flooding risk turn into an opportunity?

Background

Climate change and, consequently, flooding risk are threatening our cities all around the world, urging for efficient, sustainable, and long-term strategies to protect our urban environment. Cities and communities have established themselves on the edge between land and water for centuries, forming a cultural identity that needs to be preserved. At the same time, a harmonized coexistence between the built and the natural environment needs to be pursued. Today, it is widely accepted that flood-protection measures are necessary, although it has often led to solutions preventing any possibility of variation from an established future scenario. Hard structures are being risen to keep the water clearly separated from the built environment, reflecting a rational convinction of a possible humanly controlled nature and resulting in the delusive creation of a *resistant* city. Alternatively, retreating from the threat, as well as relocating entire communities, are often considered an option, which could be perceived as surrendering to the natural force, denying our cultural heritage of societies historically developed along coastlines and watercourses. These issues are particularly preeminent when it comes to small coastal settlments, facing great challenges with limited availability of resources, as it is currently happening in Sweden. Climate change adaptation becomes therefore a fundamental component of the urban planning process and needs to be pursued with a *resilient* approach.

Research Question

The necessity of finding a balance between the preservation of our physical and cultural identity, and the research of a harmonized coexistence with the natural environment are at the basis of this Master Thesis work. Moreover, the project goes beyond the main adaptation to a future scenario, posing the following research question:

How can the flooding risk turn into an opportunity?

Aim

The Thesis aims at questioning the norm of a single possible *desirable regime* for an urban system (a dry and protected one), working on its dynamism and capacity of constant transformation, achieving new forms of urban qualities through the application of adaptation strategies.

The transition from a *resistant* to a *resilient* city is catalysed by turning the threat into a resource: from being a disruptive force from which the city needs to be protected, the water becomes an element embedded in the urban context, interacting with it. The adaptation strategies create a flexible and dynamic urban environment which can face potential changes of conditions (i.e., rising water level), reaching everytime new possible equilibria. Every element interacts with the water in different ways and at different times, modifying its configuration without limiting the functionality of the overall system. Moreover, the adaptation strategies play a role in the possibility of development of a town, from an economic, social, and environmental sustainability perspective. For instance, they can foster the creation of public spaces and green areas, which bring benefits in terms of health, recreational opportunities, and biodiversity enhancement. Furthermore, the expansion of a city towards the water, without presenting risks in withstanding

the sea level rise, promotes a waterfront development, which could bring economic opportunities, as well as social and spatial ones.
The outcome of the Thesis is not, therefore, a static urban design, but rather a methodology to assess the adaptation strategies and their possible application to a study case.

Method and Process

The Thesis was carried out within the framework of the Naturvårdsverket's funded project S*ystemic solutions for Climate Change Adaptation in Coastal Settlements*, overviewed by Sweco, which will be implemented in the pilot areas of Henån and Marstrand; consequently, Henån was chosen as study case for this Thesis.

An initial investigation on flooding adaptation strategies was performed, by reviewing literature resources, online databases, and conducting interviews with Sweco experts in the Netherlands and in the UK. An externsive theoretical research was carried out as well, focusing on resilience theory, adaptation capacity and responsive diversity concepts, providing a consistent background in support of the design application of the strategies.

The result of the process is a set of strategies for the city center and harbour of Henån, aiming to achieve both adaptation and refurbishment goals for the area.

Delimitations

The complexity of the topic led to a necessary setting of boundaries within which this Thesis was developed. Priority was given to the formulation of a strong theoretical background in order to outline a strategic proposal for the area, which is meant to be flexible and dynamic, rather than carrying out a detailed masterplan suggesting a specific functional program for Henån's city center and waterfront.

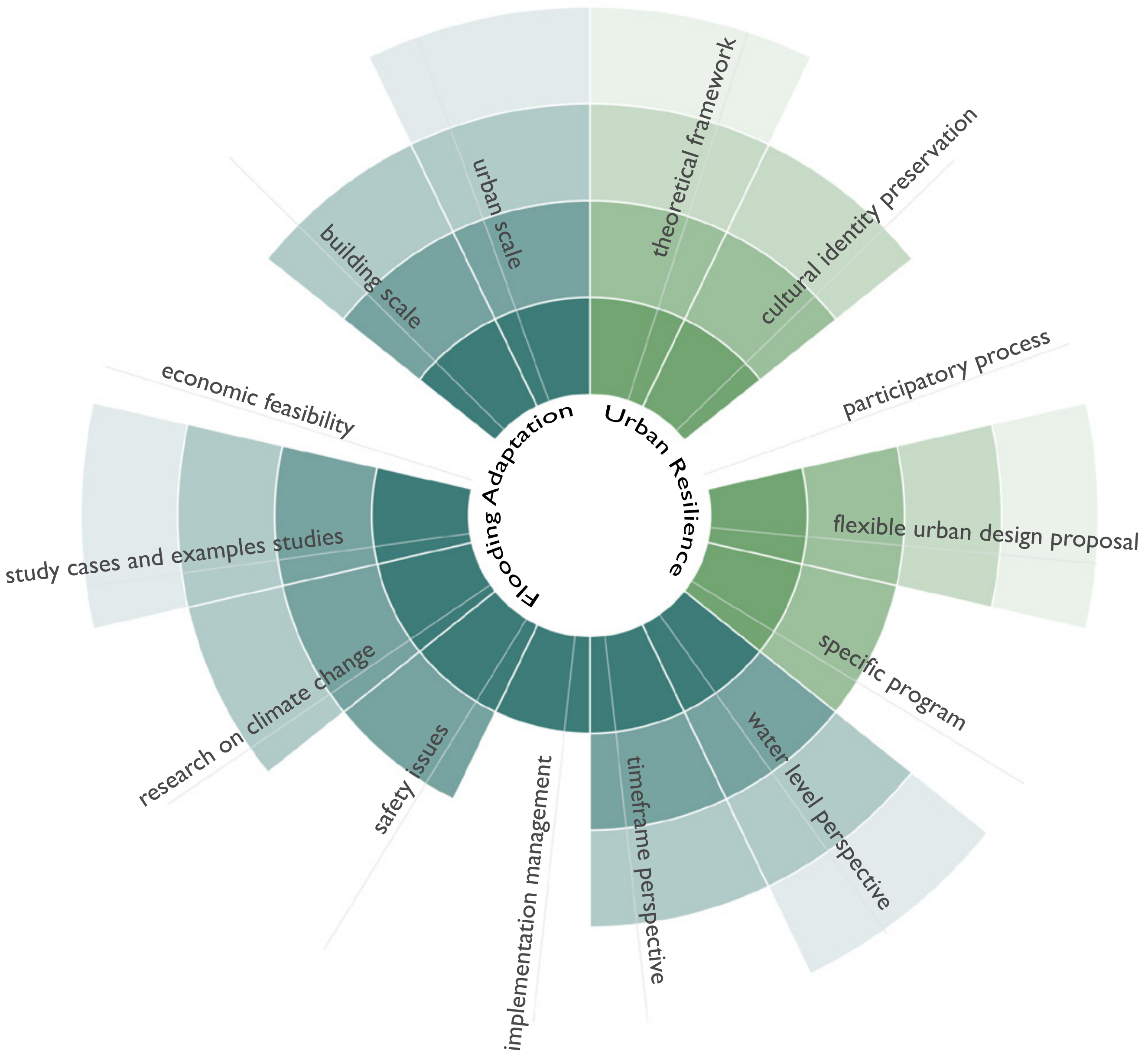


Figure 1.2. Delimitation Diagram

The economic feasibility and the actual implementation management of the strategies was not taken into account, due to limited time and expertise, as well as to the desire of suggesting an alternative approach towards climate change adaptation, focusing more on a change in the mindset, rather than outlining a comprehensive plan for a specific study case.

Reading instructions

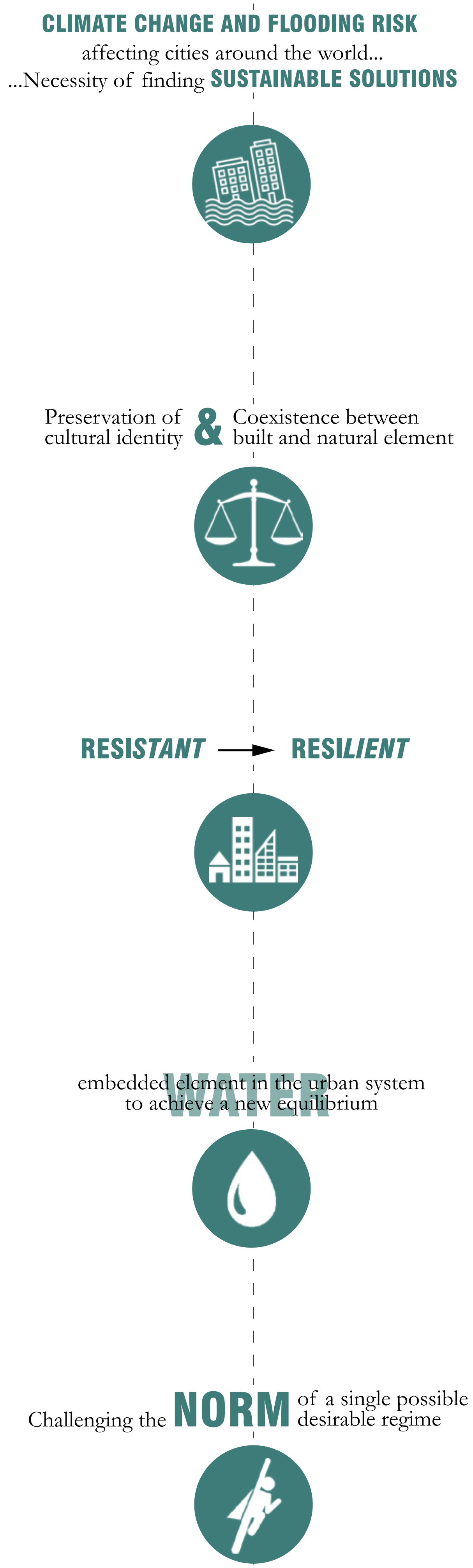
The initial chapters of this Master's Thesis (2-4) provide a general introduction of the background framework within which it was carried out: this concerns the challenge of Climate Change, its causes and effects, as well as the Pilot Project, which sets the premises of the design proposal.

The following chapter (5) illustrates the research on Resilience Theory and Flooding Adaptation Strategies, outlining the main concepts of the former, and presenting the compiled collection of the latter, categorized according to their green, grey, or hybrid approach, providing pictures and definitions for each of them.

Chapters 6-7 present the study case of Henån, pointing out its characteristics and main issues, especially concerning sea level rise and flooding risk.

The design strategy is carried out in Chapter 8, which is organized according to the three main refurbishment and adaptation objectives.

Finally, Chapter 9 draws the conclusions of the Thesis and suggests further issues and questions that need to be discussed.



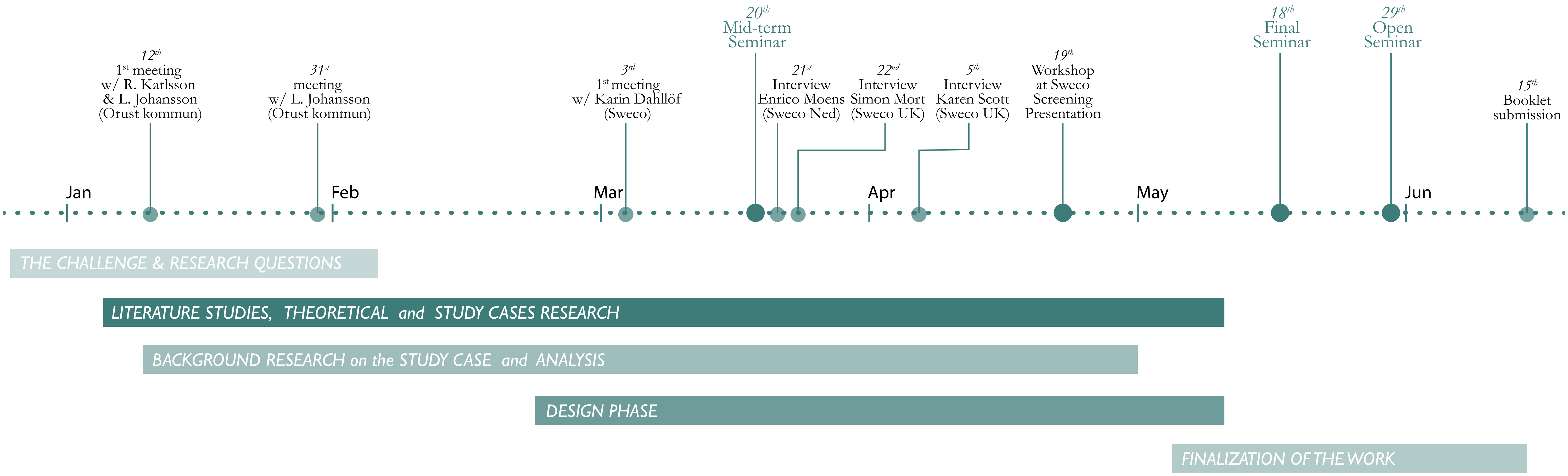


Figure 1.3. Timeline of the Project

Figure 2.1. Popov A., Oceans are in our hands.

The challenge

Climate change and Sea Level Rise

2. 1 Global trends and projections

Climate Change is one of the most significant challenges that are being globally faced. It means a change in the climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods (UNFCCC, 1992).

In its *5th Assessment Report 2013*, the Intergovernmental Panel on Climate Change (IPCC) stated that "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems." The causes of climate change are entirely human-driven: anthropogenic greenhouse gas (GHG) emissions have increased since the pre-industrial era and are reaching higher peaks every year. It is to be highlighted that global emissions of carbon dioxide (CO_2) from fossil fuel combustion and industrial processes have increased by almost 50% since 1990. This has been influenced to economic and population growth, lifestyle, energy use, land use patterns, technology, and climate policies. GHG emissions have led to higher temperatures; global warming has risen significantly in the last 30 years, being the warmest period of the last 1400 years in Northern Hemisphere. The global averaged combined land and ocean surface temperature has shown an increase of 0.85°C over the period between 1880 to 2012 and it is likely to exceed 2°C compared to pre-industrial time by 2100 if necessary measures will not be adopted (IPCC, 2013).

An important milestone in the effort of achieving significant climate policies is the 2015 Paris Agreement ratified at the United Nations Climate Change Conference (COP21) : it was signed by 196 countries and provides a pathway to limit temperature rise to well below 2 degrees. The agreement is ambitious and sends a powerful signal to markets, stressing the urgency of investing in low emission economy (UN, 2016).

2.2 Sea level rise and flooding risk

Oceans and watercourses have been deeply affected by global warming, resulting in higher water temperature due to a substantial increase in ocean heat storage since 1950s. Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1970 and 2010. Consequently, ocean thermal expansion, glaciers melting, and increased precipitation in various regions of the globe are the main causes of sea level rise (IPCC, 2013).

Sea level rise has not been experienced uniformly in all the regions, as it depends also on the fluctuations in ocean circulation. However, over the period 1901-2010, global mean sea level rose by 0.19m and will continue during the 21st century. About 70% of the coastlines worldwide are likely to experience it with ±20% of the global mean, which is projected to range from 0.45m to 0.82m, depending on the region (IPCC, 2013). Over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901, and more effectively since 1951. Heavier precipitations are projected to be experienced during the 21st century (IPCC, 2013), implying greater risks for flooding along the coastlines and the watercourses.

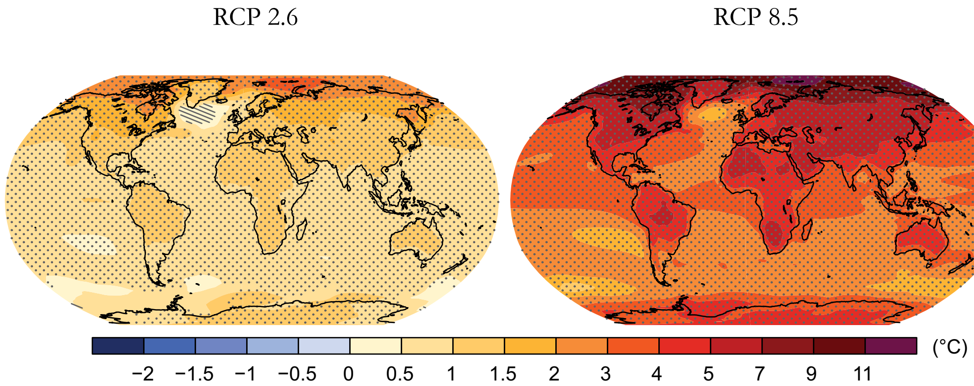


Figure 2.2. Change in average surface temperature (1986-2005 to 2081-2100)

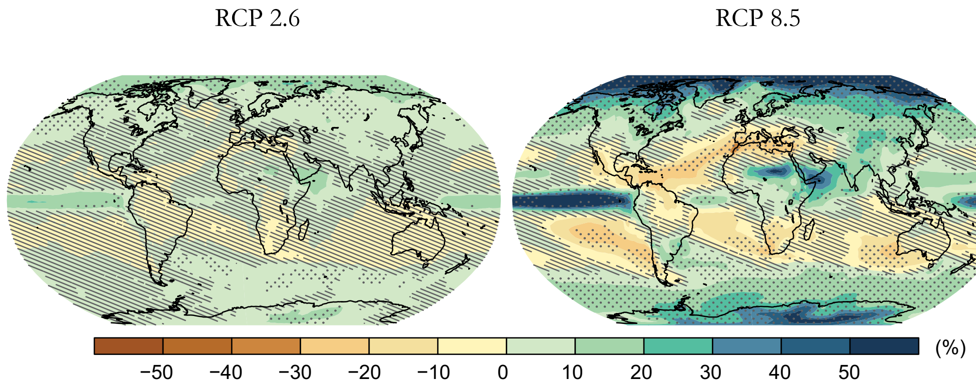


Figure 2.3. Change in average precipitation (1986-2005 to 2081-2100)

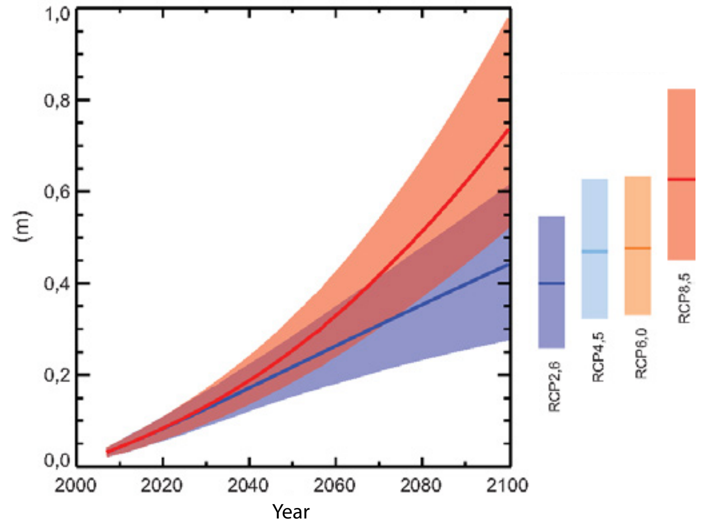


Figure 2.4. Global mean sea level rise projection

2.3 Cities and Climate Change

According to the New Urban Agenda, adopted by the United Nations Conference of Housing and Sustainable Urban Development (Habitat III) in 2016, cities are responsible for over 60% of the global energy consumption, 70% of GHG emissions, and 70% of global waste. As the built environment majorly affects climate change, it also represents one of the most fragile systems, currently highly at risk to experience massive consequences of its effects (United Nations, 2017).

Currently, over 50% of the global population lives in cities, while this percentage is projected to increase up to 75% by the middle of the 21st century (United Nations, 2017). It is evident that urban settlements are currently at the frontline of facing the most significant environmental, social, and economic challenges. Therefore, it is within the cities themselves that sustainable solutions need to be developed, engaging in multi-sectorial process in which different stakeholders are involved.

In this framework, architects and urban planners play a major role, especially regarding climate change adaptation and mitigation strategies. The urban form is an important component of a city's adaptive capacity and resilience, and planners and architects can support it working on various aspects such as land use, environmental planning, water management, building and site design, disaster preparedness, waste management, local economy development strategies, infrastructural design, and so on (UN-HABITAT, 2014).

As 70% of the coastlines worldwide will likely experience sea level rise during this century, it is important to understand how this will affect them: coastlines systems and low-lying areas will increasingly face submergence, flooding and erosion. These dangerous hazards are already happening today, having major impacts on social, environmental and economic aspects. The risk of flooding (both coastal and riverine) is leading to population displacement and migration from coastal and river areas. The occurance of flooding events has caused serious property damage and loss, structural damages to buildings and infrastructures, reduction in food supply, as well as consequences on health and ecosystems (UN-HABITAT, 2014). The impacts will vary according to the region's geographycal and climatic features, as well as to its level of adaptation capacity.

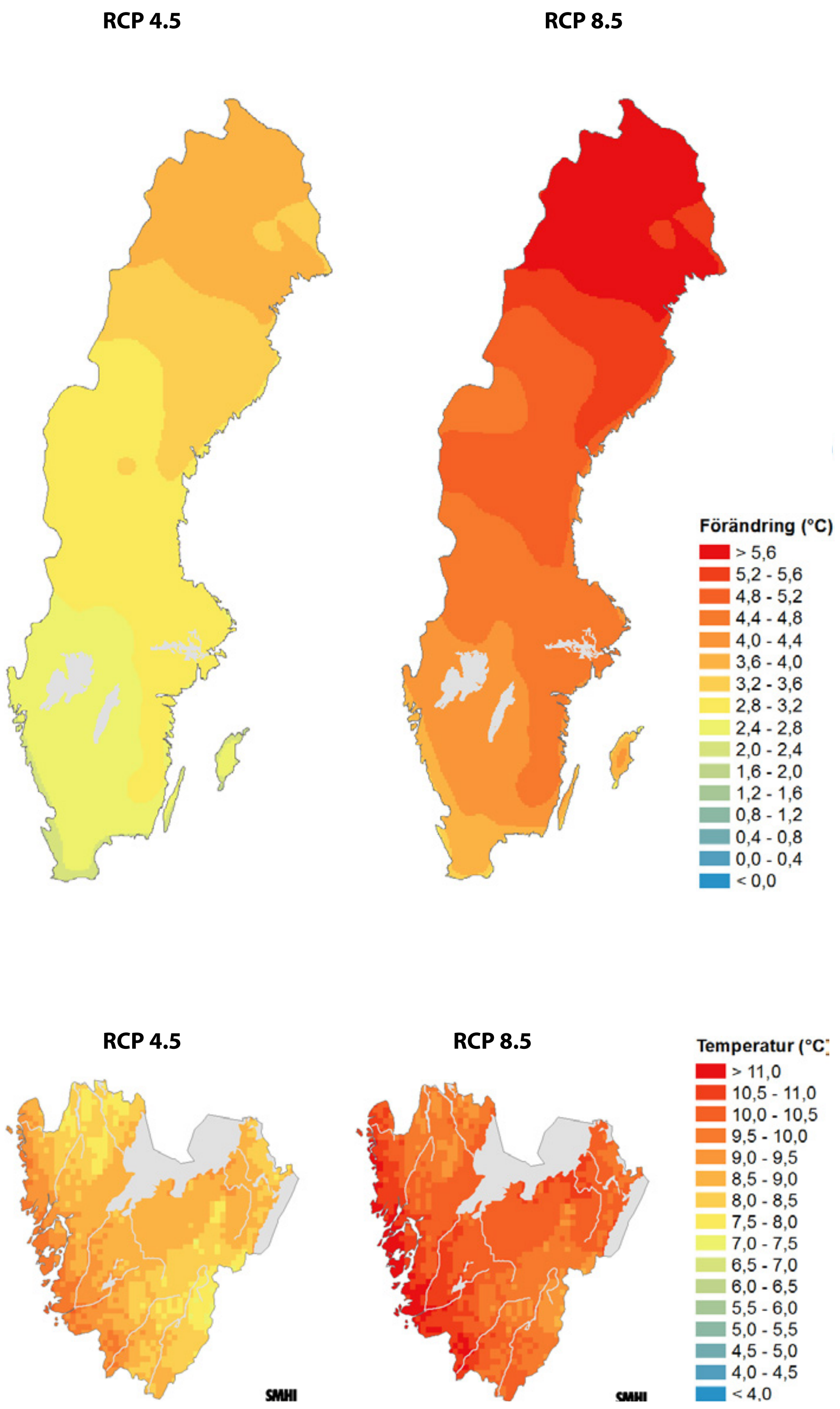


Figure 3.1. Temperature rise in Sweden and Västra Götaland (2069-2098)

The Swedish Context

Sea level rise and flooding risk in Sweden and Västra Götaland

3.1 Climate Change in Sweden

Sweden, as the rest of the Nordic countries, will experience major impacts due to climate change. Temperature will rise more in this region than the global mean, ranging between 3 and 5 degrees by 2080, in comparison to the 1960-1990 period. Precipitation will also increase in most of the country during autumn, winter, and spring time, while it will be drier during summer. Sea levels are projected to rise by an average of 0.88m by 2100, with the Southern and Western coasts being the most exposed ones (Sweden Commission on Climate and Vulnerability, 2007).

In 2009 the Swedish Parliament adopted a coherent policy for climate and energy (Prop.2008/09:162) which includes the initial steps for the country to adapt to climate change. It lays the foundation for a long term process of identification of climate change effects, risk and vulnerability assessments, and development and implementation of adaptation measures. It follows an integrated approach that intend to promote interaction between sectoral and regional activities. The Regional Government offices have adopted 21 regional action plans covering the whole country and proposing almost 800 actions. These concern, among others, flood protection, adaptation of agriculture and forestry, resilience to heat waves. Some local authorities are also implementing local adaptation plans in their municipalities.
The Swedish Meteorological and Hydrological Institute (SMHI) has been given the task to develop a system to evaluate and monitor the work on adaptation in Sweden, providing datas, models and knowledge databases (European Climate Adaptation Platform, 2018).

3.2 Västra Götaland and the sea level rise

Västra Götaland is the second largest Swedish county, in terms of population, and it is located on the western coast. It consists of 49 municipalities and its formal capital is Göteborg.

Concerning climate change effects, sea level rise is the biggest challenge for Västra Götaland's coasts. Currently, most climate analyses project a future water level of +1 m to be reached by 2100. In the last century, the sea level has increased at a pace which has almost doubled over the past 20 years, although the land rise partially counteracts the water one. Rising sea levels affect the county's coastal municipalities, threatening existing buildings and infrastructures, businesses, and valuable cultural and natural environments. It presents a major challenge, both in terms of protecting existing values, and of planning for new urban developments in a way that does not create additional risks and vulnerabilities. In several cities, the sea meets a watercourse, which creates a combination of flood risks coming from different water sources.

Concerning flood risks, they are mainly driven by large-scale air pressure variations, which, along with strong winds coming from the North Sea, affect the water level along the Västra Götaland coast. Then, tides and storm surges can occur, having a disruptive impact, even though usually lasting for a limited time (Berglöv, G., et al., 2015).

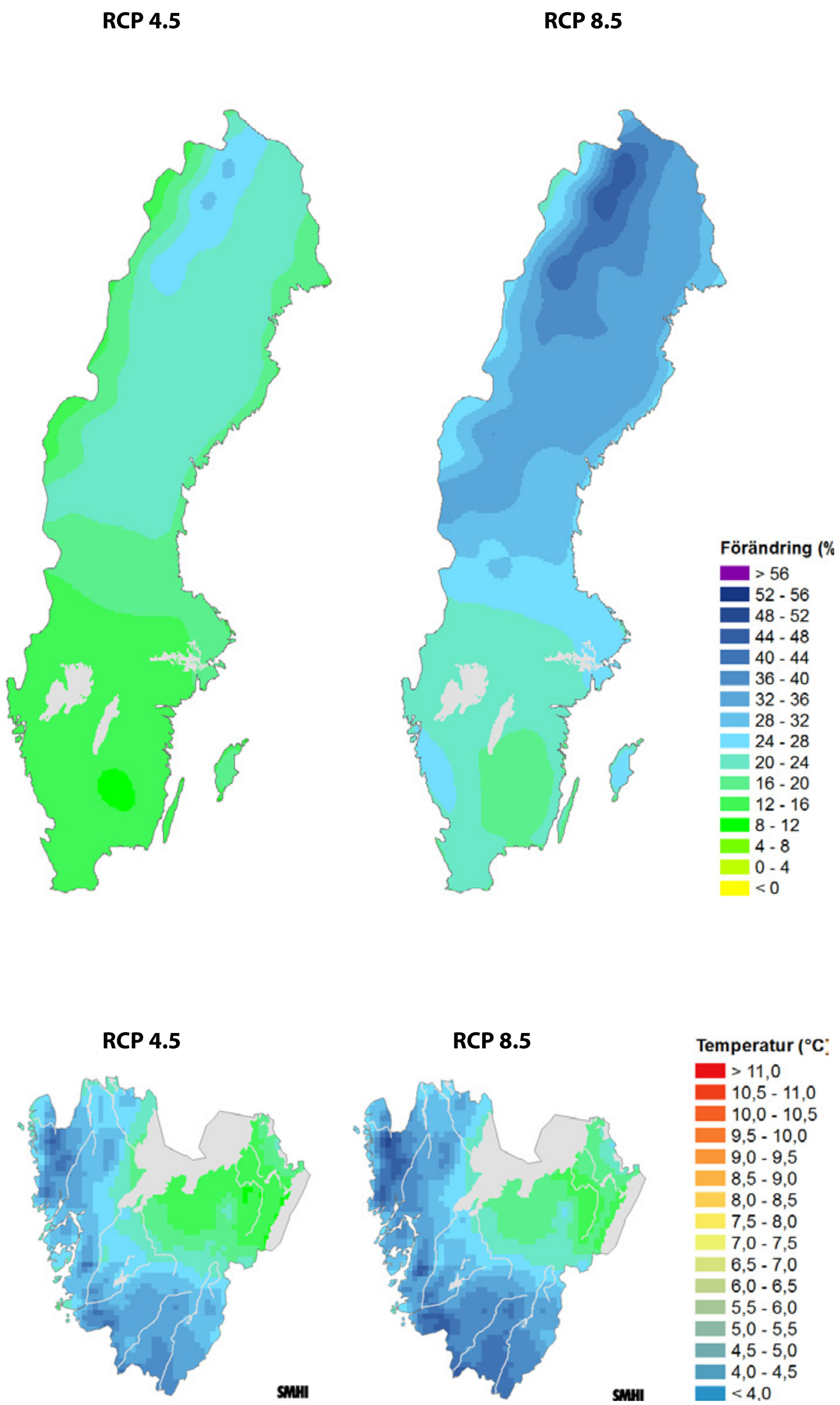


Figure 3.2. Precipitation increase in Sweden and Västra Götaland (2069-2098)

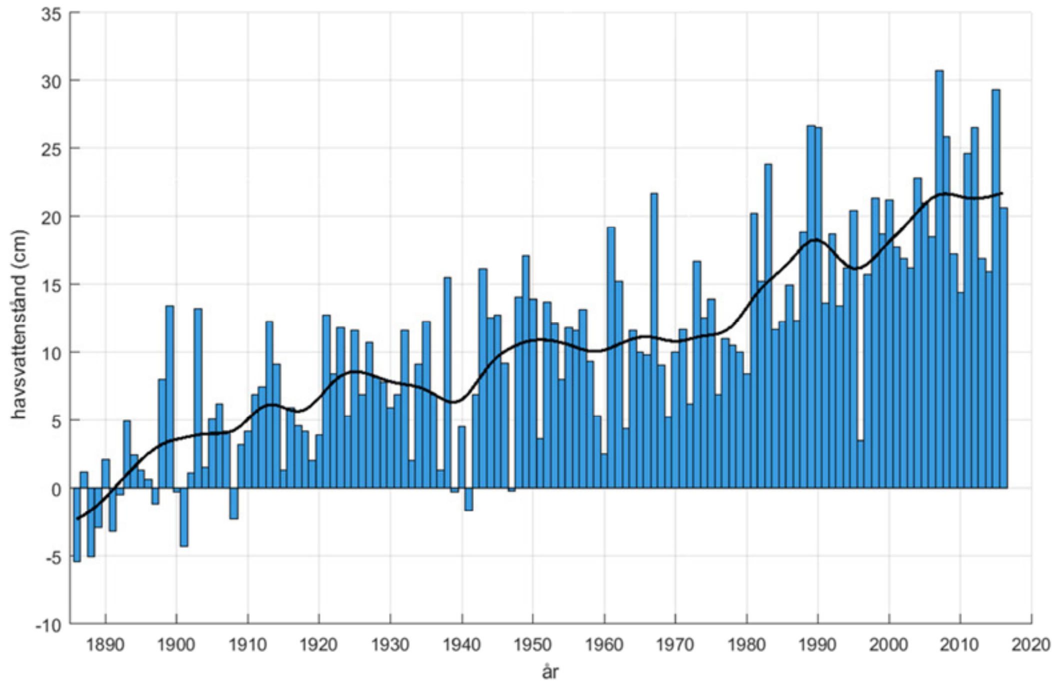


Figure 3.3. Mean sea level rise in Sweden (1886-2016)

Figure 4.1. Västra Götaland

The Pilot project

Systemic solutions for climate change adaptation in coastal settlements

4.1 Project framework

Climate change and, consequently, sea level rising are challenging Swedish municipalities and urban areas. The need to respond to these challenges is essential, but it is well recognized that a sustainable, holistic approach to the matter is required. Over the last years, several planning tools for climate-friendly urban development have been published, such as *Stigande Vatten*, a guide for new constructions in water-based areas, the *Swedish Water Development Report,* and various national flood management guidelines and reports.
In a long-term perspective, national guidelines and methods need to be implemented locally. Nevertheless, local climate adaptation tools, which could provide great support especially to small municipalities across the country when developing municipal urban plans, are still missing.

Systemic solutions for Climate Change Adaptation in Coastal Settlements is a project promoted and funded by Naturvårdsverket, the Swedish Environmental Protection Agency; it will be developed throughout 2018-2019, and its outcome will be a planning tool for managing sea level rise and flooding adaptation in Swedish small coastal municipalities.
These communities are experiencing the impacts of climate change and sea level rise already today, with flooding occurring every year and major water management problems that could get worse in the near future. There is a need for optimized and multifunctional solutions in order to face these challenges, while considering socio-economic factors given by the limited possible action that these municipalities have in terms of demography and budget.
A partnership between consultants, private and public stakeholders will develop a planning tool that will provide sustainable adaptive planning solutions to those municipalities affected by the risk of flooding. The aim is to identify adaptive measures to the flooding risk (the initial phase in which I had the possibility to participate) and then evaluate them in terms of the sustainability framework, expressed in its three definitions: environmental, social, and economic. The method is called Multi-Criteria Analysis and will help selecting suitable adaptive measures based on a sustainability assessment. The tool would be applied to two study cases, Henån (Orust) and Marstrand (Kungälv), two small municipalities on the west coast of Sweden currently facing the effect of the sea level rise. The result of this process will be translated into a handbook which will be accessible by other municipalities facing the same challenges (Naturvårdsverket, 2017).

4.2 Multi-Criteria Analysis

A Multi-Criteria Analysis (MCA) is structured in order to evaluate multiple conflicting criteria in a decision making process: various alternative solutions are presented and analysed in all their aspects, becoming comparable among each other and therefore helping decision makers find the right solution for a specific problem.

In this case, the adaptation strategies will be listed and categorized firstly according to their type: nature-based, "grey", and information and knowledge measures. Secondly, every solution will be evaluated according to sustainability parameteres, expressed in their social, economic, and environmental aspects.

The comparison between these measures and the specific features of the study case taken into consideration, whether it would be Henån, Marstrand, or another municipality, will provide an easy path towards the choice of the right solution for each situation.

4.3 Project's facts

• Coordinator/process manager: Sweco
• Main Partners and Pilot Areas: Orust and Kungälv municipalities

• Reference group for workshops: Municipalities of Tjörn, Stenungsund, Göteborg, Uddevalla; SMHI representative; Västra Götaland County Administrative Board representative.

The budget is set at 1 250 000 SEK

Time frame: 08.01.2018 - 08.07.2019

4.4 Process

I. *Screening of Action Types and Methodologies for Climate Change*: the first phase concerns the understanding of the "state of the art". My contribution resulted in the creation of a database of adaptation strategies, researching on current international solutions and study cases, as well as conducting interviews with experts in the Netherlands and UK. The focus has been on water-related measures, as well as ecosystem services that have multifunctional purposes. In this step, a workshop was organized, where the pilot municipalities together with a reference group discussed the appropriate action database for the tool.

II. *Development of the Multi-Criteria Assessment Tool*: the adaptive solutions found during the first phase of the project will be classified and evaluated according to their level of sustainability (economic, social, and environmental).

III. *Application of the MCA tool in the pilot areas of Henån and Marstrand*. A complete analysis of the natural conditions (topography, water drainage system, hydrology, future water levels), social and cultural values, as well as physical constructions and infrastructures, that need to be preserved, will be carried out.
The choice of the most suitable adaptive solutions will be taken based on the MCA tool.

IV. *Summary of the manual for MCA tool:* In order to share a useful methodology that could help other small coastal municipalities, the results of the three previous phases are compiled in a manual, which will be made publicly available.

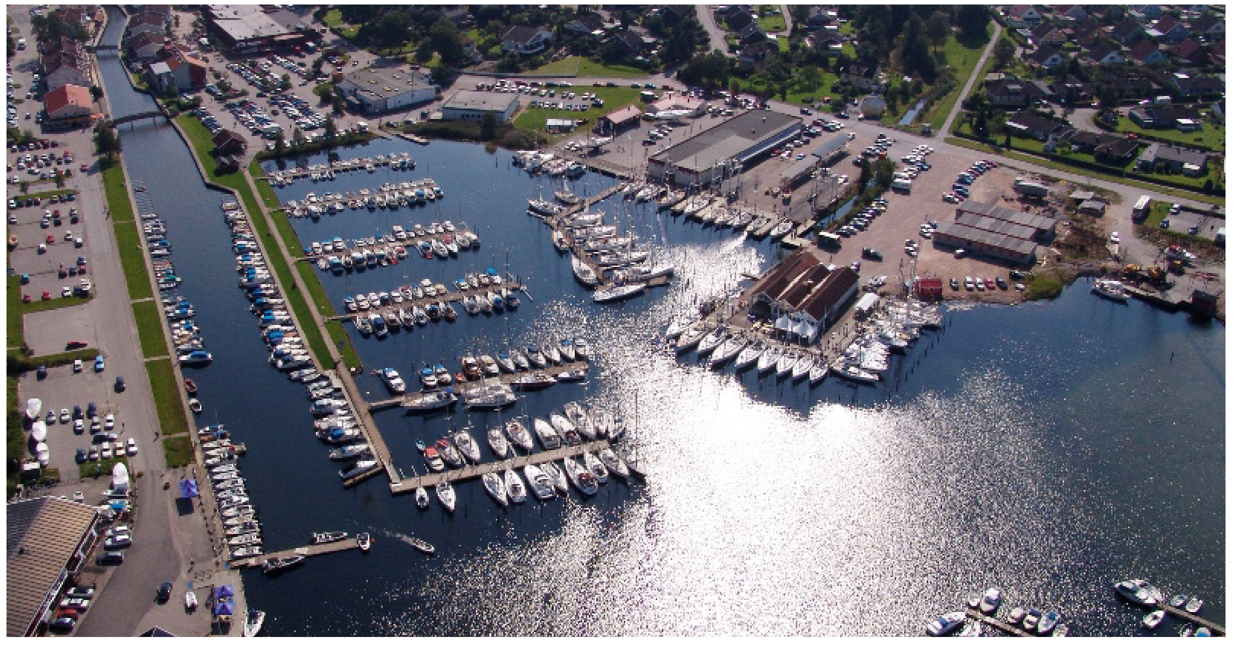


Figure 4.2. Henån

Figure 4.3. Marstrand

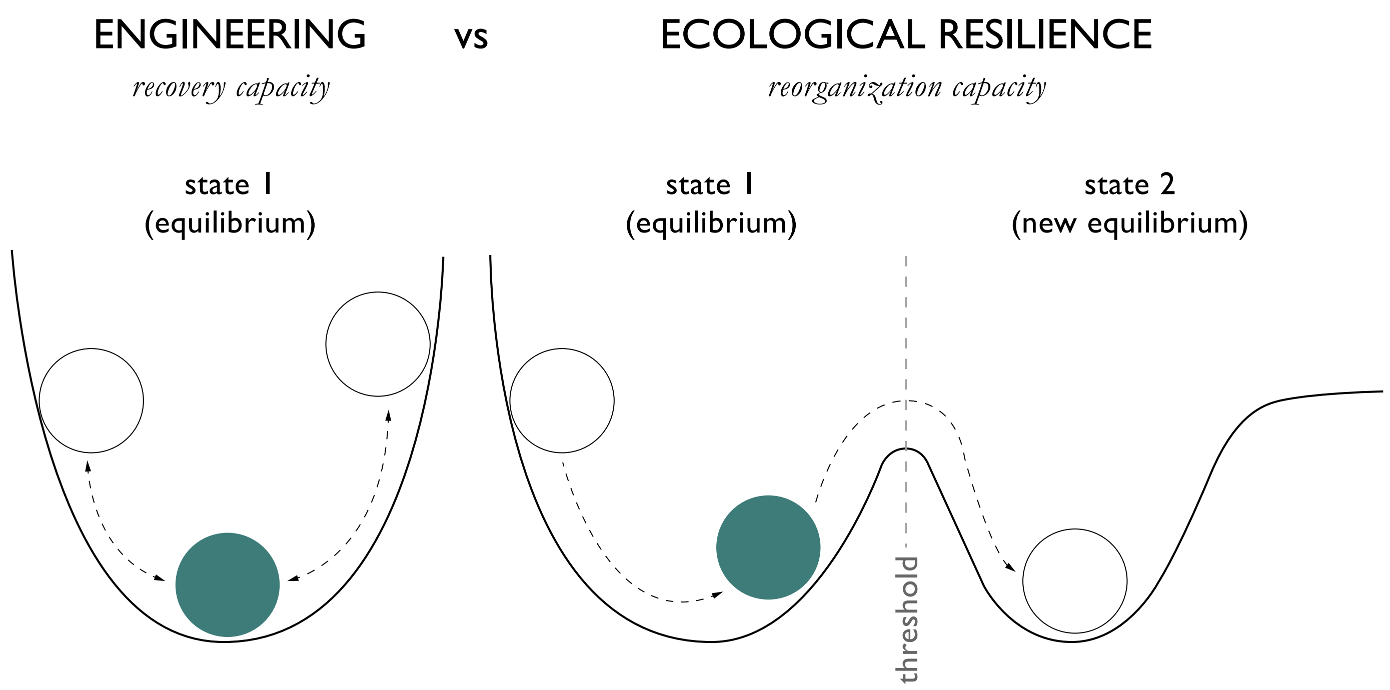


Figure 5.1. Engineering and Ecological Resilience concept

Resilient Strategies

Adapting and Responding to changing conditions

5.1 Theorical Framework

5.1.1 The concept of Urban Resilience

The concept of Resilience has been used as a conceptual framework in multiple disciplines to determine the capacity of a system to persist in the face of disruptions or difficulty. The use of the term in this context can be traced back to studies mainly in the Ecology field in the early 1970s, while it has since been adopted by a wide range of discipline, among which Urban Design (Laboy and Fannon, 2016).

Urban Resilience is therefore the capacity of urban systems to recover and persist their functionality in face of shock or stresses.
Contemporary urbanization is a global multidimensional process, manifesting itself through multiple phenomena, like changes in human population densities, land use, technological development, which are sometimes more rapid than they're possible to be understood and processed.

In addition to that, our urban environment is facing increasing uncertainty due to climate change, resource exploitation, social issues leading to an evolution from the traditional planning process for a predictable future, to planning for an unpredictable one (Ernstson et al., 2010). The impossibility of anticipating changes or future threats leads to the development of strategies founded on resilience, flexibility, adaptability.

5.1.2 Engineering and Ecological Resilience

Resilience is the capacity of adapting and responding to a change of conditions (The Resilient Design Institute, 2012). Resilience is both response and action. It is the ability of maintaining an equilibrium in face of disturbances.

"Maintaining an equilibrium" can mean also to find a new one, as it is more realistic and safe to conceptualize cities and urban spaces as dynamic systems, able to change, modify and adapt themselves to new conditions. In order to do so, a solid and flexible structure is required, involving social, economic and environmental aspects. This resilience vision is defined as *Ecological Resilience*, opposed to the so-called *Engineering Resilience* (Figure 7.1).

According to the latter, Resilience is concerned with the disturbances that threaten the equilibrium of a system and the speed to which the recovery from these disturbances is completed by the system. The concept is to maintain stability, and any deviance from the initial status of the system is considered non-optimal.
According to the Ecological Resilience vision, ecosystems consist of many forms of structures and processes, and in case of disturbances, returning to the previous ecosystem is extremly difficult if not impossible. The resilient concept is, then, defined as the ability of a system to absorb disturbances and still persist, to change and reorganize itself. This resilience concept appears, therefore, as a more realistic paradigma of multi-equilibria, focusing on persistence in a world of flux (Liao, 2012).

5.1.3 Adaptive Capacity and Response Diversity

Considering Socio-Ecological Systems (SES), resilience is taken to mean more than simply the persistence of ecological relationships or of social structure and identity, but also the adaptive capacity to responde to the opportunities and constraints that are presented by perturbations.

A central concern in the study of complex adaptive systems is how to analyze and understand, within a single coherent framework, both change and stability or persistence of those systems, including the possibility of persistence through change (Leslie et al., 2013).
Contemporary theory on complex adaptive systems recognizes that it is necessary to sustain diversity in order to maintain options for a change over time: options and alternatives are, therefore, fundamental requirements for a long-term and sustainable functioning of systems.
Resilience is defined by the capacity of a system of self-organization after an alteration within itself and the degree to which it can build and sustain the capacity for learning and adapting.

Adaptive Capacity can be defined as "the capacity of the system to alter the relative abundance of its components without significant changes in crucial system functions". The components or "species" of a system present three main attributes that affect their performance in the system:
• what they are and do
• how they respond to external drivers
• whom they interact with

How, then, does the diversity of attributes of all components, that contribute to a particular system, affect their combined efficiency in sustaining it? (Norberg et al., 2008)
Within a single ecosystem, its components may have different features and functions, as well as similar ones; they could operate at different times and places, and they could respond in different ways to the same event.

The concept of *Functional Diversity* addresses the necessity for a system to be founded on complementarity. If its components are complementary in their use of resources, they can potentially coexist, achieving a long-term efficient equilibrium in the system and avoiding competition which can lead to a selection of the variety of species and resources, putting the system in danger.

Spatiotemporal Variability is a fundamental cause of diversity and it provides multiple opportunities for species with different attributes to coexist: regulating the interaction between species and resources through space and time can create a dynamic, flexible and efficient system.

Response diversity refers to the range of reactions to environmental change among species that contribute to the same ecosystem function. Responsive diversity, therefore, is correlated to the capacity of a system to respond to changing conditions without a reduction in the functioning of the system (Leslie et al., 2013).
The theories of functional diversity, spatio-temporal variability and responsive diversity are consistent and applicable within an urban system subjected to constant change.

5.1.4 Urban Resilience to Flooding

Climate change adaptation needs to be integrated into urban planning; various approaches have been studied in recent years, one of the most known being the Retreat-Defend-Attack strategies, initially conceptualized by the Royal Institute of British Architects, Building Futures and Institution of Civil Engineers in 2009.

• *Retreat*: In order to reduce potential risk of flooding and consequent damage for a particular site, this strategy involves a managed removal of critical infrastructures and buildings, and their relocation in safer areas. It requires significant investment, in addition to mostly unpredictable socio-environmental-economic consequences. It implies taking a step back from the problem and, it can be argued, without providing a constructive approach to deal with it for future similar situations.

• *Defend*: To defend means to protect an urban settlement from being flooded, not allowing the water to come in. It can require expensive and invasive hard engineered structures and it might cause significant impacts on socio-environmental aspects.

• *Attack*: Instead of retreating further inland, a solution can be to develop the urban settlement towards and on the sea: floating and amphibious structures, stilts that let the water flow underneath the buildings, are just some of the possible solutions and could constitute a whole new potential investment for developers around the world (RIBA et al., 2009).

When it comes to the management of flooding risk within an urban context, resilience theory would challenge the paradigma with which this issue is usually approached.
First, resilience is founded on the acceptance of "inherent variability, uncertainty, and surprise" (Folke, 2003): the artificial suppression of any variability in the system to promote stability would result in resilience erosion. An example could be the forced maintainment of a dry floodplain, going against its purposed function, without acknowledging the possibility of periodic floods as inherent environmental dynamics. Secondly, resilience theory accepts sudden changes as complementary elements of periods of gradual development within a system.

Floods are themselves an element of resilience, as through each event a city could learn how to adjust and adapt its subsystems and structures, building knowledge and refining strategies over time. Nevertheless, too often cities are forced to learn painfully from catastrophic events with severe consequences.

In the evaluation of the capacity of an urban settlement to experience floods and remain in a "desirable regime", the latter is defined by a set of variables (i.e., livelihood security, economic performance, mobility, etc.) thus framing the socio-economic identity of the city. In order to prevent physical damage and socio-economic disruption in face of a flooding event, the strategy would be to work on the *floodability* of the urban environment and its *reorganization* after the critical event. The concepts of adaptive capacity and redundancy become, therefore, fundamental in this regard. Moreover, diversity of available options and flexibility within the city allow the preservation of its functionality in case of disturbances.

Flood adaptation strategies and infrastructures need to be implemented, though it is important to distinguish between the resistant and the resilient approach. Flood-protection and flood-control systems place the city in one or the other opposite conditions: dry and stable, or inundated and damaged (Liao, 2012).
In order to promote a shift in this established vision of flooding adaptation measures, a series of strategies was collected and will be examined in the next Section according to their potential flexibility and adaptability to multiple urban-natural scenarios.

5.2 Adaptation Strategies Database

In this Section, the first phase of the project *Systemic solutions for climate change adaptation in coastal settlements* is carried out, through the screening and compilement of various adaptation strategies.
The collection of adaptive measures has been done by literature review and the consultation of different web-based databases. In particular, the Dutch national "Climateapp" and the European Union Adaptation Platform were the main sources for this investigation.
A series of interviews with 3 representatives from two Sweco offices based in the UK and in the Netherlands were conducted: Enrico Moens (Sweco-NED), and Karen Scott and Simon Mort (Sweco-UK) shared their experiences with flooding adaptation, providing extremely helpful resources during the whole phase.
The presentation of the results of the Screening phase took place during a workshop organised by Sweco with representatives of various municipalities in Våstra Götaland on the 9th of April 2018.

The strategies have been listed according not to the better known *retreat, defend, and attack* concepts, but rather to the nature of their approach, distinguishing between *grey*, *green* and *hybrid* solutions. This method was chosen in order to present a flexible categorization of the role that different solutions can play in a complex strategy.

The adaptive measures were then evaluated according to the extent to which they allow a dynamic interaction between the built environment and the water element, to achieve new urban qualities given by the variability of a landscape in constant change and transition.

5.2.1 Categories

Response to exposure of urban settlements and communities to natural hazards has traditionally relied on *grey infrastructures*; these are engineered, physical structures basically supplanting any function of biophysical systems. Grey strategies provide important means of adapting to climate driven extreme events, although they are often costly to install and maintain, have long-term effects on ecosystems, low flexibility, and in case of failure, they might generate even more damage than the natural hazard itself.

Green and Blue strategies express the role that ecosystems can actively play in the defence of communities from extreme events like floods. They are constituted by biophysical systems to which some management and restoration might apply. They rely primarly on healthy, functioning ecosystems that allow for little or no technological intervention. Well-managed ecosystem are believed to be cost-effective, multifunctional and more resilient in a long-term perspective. Nevertheless, the lack of evidence regarding these aspects has influenced the limited implementations of these measures.

Hybrid approaches utilize combined green and grey strategies. They combine engineering and properly ecosystem functions, and are situated at the intersection of the ecological and technological components of a socio-ecological system. There is increasing evidence that hybrid approaches provide cost-effective hazard protection solutions. They are intended to reduce reliance of the urban system on solely grey infrastructure, while enhancing a sustainable and healthy environment for the inhabitants (Depietri, Y. et al., 2017)

5.2.2 Green Strategies

Figure 5.2

URBAN FARMING AND GARDENING

Areas used for urban farming and gardening that, when compared to paved or asphalted grounds, have a positive contribution to climate adaptation. Increasing the presence of vegetation will increase the water infiltration capacity of the soil, which, in turn, leads to better adaptation to future needs in terms of storm water runoff.

Figure 5.3

RETENTION BASIN

A retention basin is used to manage storm water runoff to prevent flooding and downstream erosion, and improve water quality in an adjacent river, stream, lake, or bay. Sometimes called a wet pond or wet detention basin, it is an artificial lake with vegetation around the perimeter, and includes a permanent pool of water in its design. Sometimes it acts as a replacement for the natural absorption of a forest or other natural processes that are lost when an area is developed. As such, these structures are designed to blend into neighborhoods and viewed as an amenity.

Figure 5.4

DITCHES

A ditch is usually defined as a small or moderate depression created to channel water. A ditch can be used for drainage, to drain water from low-lying areas, alongside roadways or fields, or to channel water from a more distant source for plant irrigation.

Figure 5.5

COASTAL WETLANDS

Highly productuve and biodiverse environments, which filter sediments and protect coasts. Coastal wetlands (or tidal marshes) are saltwater and brackish water wetlands located in coastal areas. They provide natural defence against coastal flooding and storm surges by wave energy dissipation and erosion reduction, helping stabilise shore sediments. Wetland restoration aims at re-establishing natural functions of wetlands that have been degraded by natural and human activities. One method is to add sediment to raise land above the water level and allow wetland plants to colonise, or to modify erosion processes that are degrading wetland areas. Alternatively, rewetting drained coastal wetlands by blocking drains and reducing groundwater extraction is an effective restoration technique for brackish wetlands. A more resource intensive technique is the transplantation of vegetation from healthy marshes or specialised nurseries (e.g., LIFE Barene project).

Figure 5.6

MANAGED REALIGNMENT

Setting back the line of hard flood defences to a new line, further inland and/or on rising ground to recreate intertidal habitats between the old and the new defence. The wetland will serve as a buffer zone where storm surges will be attenuated. Managed realignment can involve deliberate breaching or complete removal of a coastal defence such as a dike, or the relocation of defences further inland.

Managed realignment and wetland restoration reduce the need for hard coastal defences. Even in combination, these approaches can reduce the need to heighten and broaden dikes, leading to a positive impact on the landscape.
A healthy wetland can also be able to cope with sea level rise as long as sufficient sediment is available, and that sea level rise does not exceed local accumulation rates.

Managed realignment can significantly reduce the cost of coastal defence and erosion protection measures, notably as less further works on coastal defences, such as heightening or

broadening, will be required. As coastal wetlands reduce the impact of waves, it is also likely that maintenance costs will be lower. However, the main difficulty in implementing managed realignment involves changing land use; it can result in the relocation of buildings and activities, possibly at high costs (including expropriation), or in the loss of land used for recreation and agriculture.

Figure 5.7

GREEN INFRASTRUCTURES

Green corridors created in the urban environment. The capacity of vegetation to retain water is an important flood prevention feature that can reduce peak discharges.

Figure 5.8

NATURAL EMBANKMENT

A natural embankment is a gradual transition from water to land that is at least 5-10 m wide and made up of a succession of different vegetation zones with aquatic flora in the deeper water (i.e., pondweed and water lilies), bankside flora on the embankment (i.e., reeds and rushes), and river and marsh woodland (i.e., willows and ash) on the drier banks.
A natural embankment contributes to bank protection, water storage, enhancing biodiversity, improving water quality, cutting management, and maintenance costs.

Figure 5.9

DUNES

They offer good protection against floods, storm surges, and wind. They are dynamic elements and evolve over time. Nevertheless, they are vulnerable to coastal erosion and anthropogenic pressures. If they are well managed, dunes can offer a high degree of protection against flooding and erosion.
They also provide valuable habitats for animal and plant species. Dune rehabilitation or the construction of artificial dunes is beneficial to the beach ecosystem. Implementation time: 1-5 years. Life time: 5-25 years.

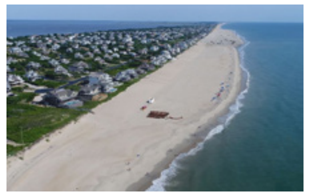


Figure 5.10

BEACH NOURISHMENT

This is an expensive option that involves the transportation of sand to the coastline; it is the artificial placement of sand on an eroded shore to maintain the amount of sand present in the foundation of the coast, and in this way to compensate for natural erosion and, in a greater or lesser extent, protect the area against storm surge. The process involves dredging material (sand, pebbles) from a source area (offshore or inland) to feed the beach where erosion is occurring. Beach nourishment is a flexible and fast coastal management option compared to hard construction, and it is adaptable to changing conditions. It can complement other grey measures such seawalls or groynes, and green measures such as dune reinforcement. Besides flood and erosion protection, beach nourishment can provide benefits for coastal tourism, recreation activities, and coastal habitats preservation.

Beach nourishment is usually an ongoing process, which leads to higher costs over time and repeated disturbance of the ecosystem. Nourishment does not end erosion; it only provides additional sediments on which erosion will continue. Finding a source with sufficient quantities and good-quality sand can be challenging, and the dredged sand should match the sand present on the site in terms of grain size, colour, and composition.
Nourishment of beaches can remain in place for intervals that vary from 2 to 10 years.

5.2.3 Grey Strategies

Figure 5.11

SEAWALLS

Vertical structures protecting from inundations and erosion. They can be made of stone, concrete, cement, wood, or other materials. It can lead to an entirely artificial littoral, and the erosion of beaches in front of seawalls can cause their disappearence, with all their habitats and ecological functions. A seawall provides a high degree of protection against coastal flooding and erosion. It fixes the boundary between the sea and land, which can be beneficial if important infrastructure or buildings are located on the shoreline. Construction costs are high but these structures usually require low maintenance.

Figure 5.12

DAMS

They are built perpendicularly to a stream, controlling its flood risk. In coastal areas, movable dams are placed at the mouth of large rivers to prevent flooding caused by storm surges. Examples are the Maeslantkering and the Oosterscheldekering in the Netherlands or the Thames barrier in southern England. The cost of these structures is extremely high. Dams are also used to generate hydropower and are combined with other infrastructure.

Figure 5.13

DIKE

A dike is an elongated artificially constructed embankment or levee, which protects low-lying areas against higher water levels. These structures are multi-layered and inclined to better absorb wave energy: they are usually made of clay and sand, while rock or concrete are used to protect the water facing outer slope against waves. Most dikes are constructed parallel to the course of a river in its floodplain or along low lying coastlines. It can form a lingering feature in the landscape and can be used for both recreational and infrastructural needs.

Figure 5.14

BREAKWATERS

Wooden, stone, or concrete structures destined to shield a particular zone from direct wave action. Their purpose is not to resist floods. A breakwater is a coastal structure projecting into the sea that shelters vessels from waves and currents, prevents siltation of a navigation channel or thermal mixing (e.g. cooling water intakes), or protects a shore area. A breakwater typically comprises various stone layers and is typically armoured with large stones or concrete armour units. A breakwater can be built at the shoreline or offshore (detached or reef breakwater).

Figure 5.15

ARTIFICIAL REEFS

They are used as breakwaves and erosion protection, especially in the Netherlands and in the US. Artificial reefs (or reef breakwaters) are rubble mound breakwaters of typically single-sized stones with a crest at or below sea level. They are usually constructed offshore (often parallel to the shore). They are not particularly intrusive and (depending on orientation) can have less impact on longshore processes. Similarly to breakwaters, artificial reefs reduce wave energy and protect the beach from erosion. They can be continuous or segmented.

Figure 5.16

GROYNES

Stone, wood or concrete structures placed perpendicularly to the coastline in order to reduce sand and sediment transport due to littoral drift. It is an alternative measure to beach nourishment and it helps stabilising coast segments that are retreating. A groyne is a shore protection structure built perpendicular to the shoreline of the coast (or river), over the beach and into the shoreface (the area between the nearshore region and the inner continental shelf), to reduce longshore drift and trap sediments. A groyne system is a series of groynes acting together to protect a beach.
Rock is often used as construction material, but wooden, concrete, steel, rubble-mound, and sand-filled bag groynes can also be found. Rock groynes are generally preferred as they are more durable and absorb more wave energy due to their permeable nature. Timber or gabions may be used for temporary structures.

LAND RAISE

A historical example of raising coastal land can be seen in the Wadden Sea coast and barrier islands (now Denmark, Germany and Netherlands): here, small settlements were built on small man-made hills, called *warften* in German and *tierpen* or *wierden* in Dutch, to protect against storm surges.
In the 1990s, the level of many embankments and streets in Venice (Italy) was raised to strengthen protection against flooding due to high water events and to counter, at least partially, the effects of sea-level rise and ground subsidence. It can be difficult to 'raise' areas with modern urban and industrial areas and infrastructure. This can also be the case for fragile historical areas, such as St. Mark's Square in Venice.

Figure 5.17

FLOODABLE DIKE

Basically two dikes with a floodable area in between that can be used either when dry or when wet. A floodable dike is designed to protect a floodplain against frequent high water levels. The dikes crest level is designed relatively low, so it is flooded in extreme high water levels. In this way the flood plain can be used for, for instance, agriculture, in normal conditions, and for water storage, in extremely wet conditions.
A secondary dike further inland is frequently used to protect the vulnerable hinterland against extreme high water levels. It can form a lingering feature in the landscape and can be used for both recreational and infrastructural needs.

Figure 5.18

BUILDING ON POLES

Through the elevation of buildings on poles a solid foundation is created, along with the possibility for the water to flow underneath it.
The ground floor level should be built above the design water level (for new constructions).

Figure 5.19

DISMOUNTABLE/TEMPORARY STRUCTURES

Dismountable and temporary buildings can be an option for flood prone locations. Buildings can be easily relocated to other places.

Figure 5.20

SEALABLE BUILDINGS

The exterior of buildings can be made waterproof to prevent flood water entering the building. All gaps and holes should be sealed below design water level. In case of a flood the building will not be damaged and normal operation can immediately restart after the water has subsided.

Figure 5.21

RETREAT AND RELOCATION OF BUILDINGS AND INFRASTRUCTURES

This measure refers to the retreat or relocation of settlements, infrastructures, and productive activities from the original location due to high exposure to risks such as flood, sea-level rise, and storm surges. It is considered in particular in coastal areas. In southwestern France, a shoreline road in the municipalities of Sète et de Marseillan (Languedoc-Roussillon region) was moved inland as it was threatened by erosion of the beach. This allowed the reconstruction of a larger beach and dune system, which together should provide greater protection against erosion. (2012)

In a long-term perspective, spatial planning and building permissions can incorporate provisions for managed retreat. One approach is the use of 'setback' requirements in planning documents.

In areas with low population densities, the costs of retreat (including compensation and infrastructure costs) could be significantly less than other grey or green measures to protect assets where they are.
The retreat of settlements and infrastructure can be combined with the recreation of natural features, such as vegetation buffers, wetlands, or dunes, that can provide landscape and biodiversity benefits as well as protection against erosion, debris flows, and floods.
Retreat strategies can be controversial and may result in strong opposition, in particular from affected homeowners.


Figure 5.22

FLOATING AND AMPHIBIOUS STRUCTURES

Floating and amphibious buildings are built to be situated in a water body and are designed to adapt to rising and falling water levels. Floating houses are permanently in the water, while amphibious ones are situated above the water and are designed to float when the water levels rises. Amphibious structures are usually fastened to flexible mooring posts and rest on concrete foundations. If the water level rises, they can move upwards and float. The fastenings to the mooring posts limits the motion caused by the water.


Figure 5.23

FLOATING AND AMPHIBIOUS INFRASTRUCTURES

Road transport infrastructure and evacuation routes that are prone to flooding need to be flood-proofed to reduce the vulnerability and negative impacts of flooding. Available options to achieve this are not only maintenance of infrastructure and the use of appropriate design and materials, but also creation of floating or elevated roads for evacuation routes.
Floating roads are literally roads that float on the water. Ideally, they are flexible in both time and space; they do not only float but can also move to accommodate a changing water level. Instead of a fixed bridge it consists of a series of floating pontoons on which vehicles can drive.
Floating roads are less expensive than bridges. Elevated roads on top of a bank are cheaper to construct than bridge-like roads, but both investments will only be returned once flooding occurs. After construction, both floating and elevated roads do not need more maintenance than any other road.

5.2.4 Hybrid Strategies

WATER SENSITIVE URBAN AND BUILDING DESIGN (WSUD)


Figure 5.24

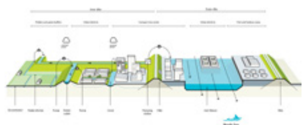


Figure 5.25

It is an emerging urban development paradigm aimed to minimise hydrological impacts of urban development on environment.
It integrates stormwater, groundwater supply, and wastewater management in order to:

• protect existing natural features and ecological processes;
• maintain natural hydrologic behaviour of catchments;
• protect water quality of surface and ground waters;
• minimise demand on the reticulated water supply system;
• minimise wastewater discharges to the natural environment;
• integrate water into the landscape to enhance visual, social, cultural, and ecological values.
• reduce potable water demand through measures such as water efficient fittings and appliances, rainwater harvesting, and wastewater re-use;

• treat in a decentralised manner urban stormwater for re-use and/or discharge of receiving waters;
• integrate stormwater management into the landscape, creating multiple-use corridors that maximise the visual and recreational amenity of the development;
• plan for water conservation, improve quality of storm water, achieve integration with elements of urban design.

Reducing hardened, impervious surfaces and accurately design drainage of urban spaces, in combination with the use of pervious roads, penetrable concrete, and water passing pavements, helps to enhance the infiltration of storm water in underlying surface, reducing runoff into sewerage systems and urban spaces, attenuating flood peaks, reducing the urban pollution load in run-off, as well as reducing the risk of damages due to drainage system failure by flooding, facilitating groundwater recharge.
Sustainable Urban Drainage Systems (SUDS) are made up of one or more structures built to manage surface water runoff; they tend to mimic natural drainage. SUDS often incorporate soil and vegetation in structures that are usually impermeable (e.g. green rooftops) Sustainable Urban Drainage Systems (SuDS) temporarily store the water from these intense precipitation events, and give water the possibility to slowly infiltrate/percolate into the soil. SuDS connect impermeable surfaces to the underground, and in this way drain water from the paved surfaces in the city, preventing urban areas from flooding.


Figure 5.26

WATERWAYS NETWORK

A network of water ways is mainly focused on connecting water bodies which are located near to each other. By connecting them with culverts and canals, a larger water system is created. This increases the storage capacity of the system and, therefore, reduces the flood risk.


Figure 5.27

WATER SQUARES

This type of square can combine water storage with the improvement of the quality of urban public space. The water square can be understood as a twofold strategy. Water storage facilities become visible and enjoyable. It also generates opportunities to create environmental quality and identity to central spaces in neighbourhoods. Most of the time the square can be used as a recreational space. When heavy rains occur, rainwater, collected from the neighbourhood, will flow into the water square for a short timespan. After it has been in use as buffering space, the filtered water is returned to the water system.


Figure 5.28

BIOSWALES

They are green, linear, sloped retention areas designed to capture and convey water, while allowing it to slowly infiltrate the ground over a 24 to 48 hour period.


Figure 5.29

GREEN ROOFS

A green roof, or living roof, is a roof of a building that is partially or completely covered with vegetation planted over a waterproofing membrane. It may also include additional layers, such as a root barrier and drainage and irrigation systems. Green roofs help lower urban air temperatures, mitigate the heat island effect and store rain water.

DEEPEN WATER BODIES

One way to increase the capacity of water bodies is by increasing the depth of rivers, canals, and ponds. In this way flood risk is reduced, as rivers are able to transport a larger amount of water and ponds and lakes have a larger retention capacity.

Figure 5.30

IMPROVE SOIL INFILTRATION CAPACITY AND POROUS PAVEMENTS

Improving the soil infiltration capacity means improving the permeability of the soil. If the infiltration capacity of the soil is increased, more water will percolate into the soil and less water will runoff directly. This will reduce peak runoff and promote groundwater recharge.

Figure 5.31

RIVER RESTORATION

River restoration embraces a great variety of measures having in common the emphasis on natural functions of rivers, which may have been lost or degraded by human intervention. Tidal wetlands help maintain the functioning of estuarine ecosystems and create natural land features that act as storm buffers, protecting people and property from flood damages related to sea level rise and storm surges.
Benefits of this adaptation option include: increased protection from flood related to high precipitation events due to increased flow capacity of the river system during flood events, and/or reduced speed of water flow; increased protection from flood related to sea level rise and storm surges; increased habitat quality and/or diversity; maintenance of functioning of aquatic or estuarine ecosystems; increased groundwater recharge.

(climate-adapt.eea.europa.eu; climateapp.nl; urbangreenbluegrids.com; buildingwithnatureinthecity.com; WWF et al., 2017; interviews with Karen Scott, Simon Mort, and Enrico Moens from Sweco UK and NED)

Conclusions from the Research phase

Urban Resilience is the capacity of urban systems to recover and persist their functionality in face of shock and stresses. It is the ability of maintaining an equilibrium in face of disturbances; it can also mean finding a new equilibrium, following the Ecological Resilience approach, which is defined as the reorganizational capacity of a system after a disturbance. This method is adopted as the theoretical basis for this Thesis, along with the concepts of Adaptation Capacity and Response Diversity, according to which the components of a system can respond to changing conditions in different ways, without altering its overall functionality.

Resilient Flooding Adaptation, therefore, questions the concept of "desirable regime", aiming at creating an urban system whose components (the Adaptation Strategies) contribute in various ways to respond to the challenge, adaptating to different conditions, without preventing the urban system from functioning.

Despite the different types of approach that the Strategies have (green, grey, and hybrid), they can collaborate towards the creation of an Adaptive Urban System, showing flexibility and capacity of transformation.

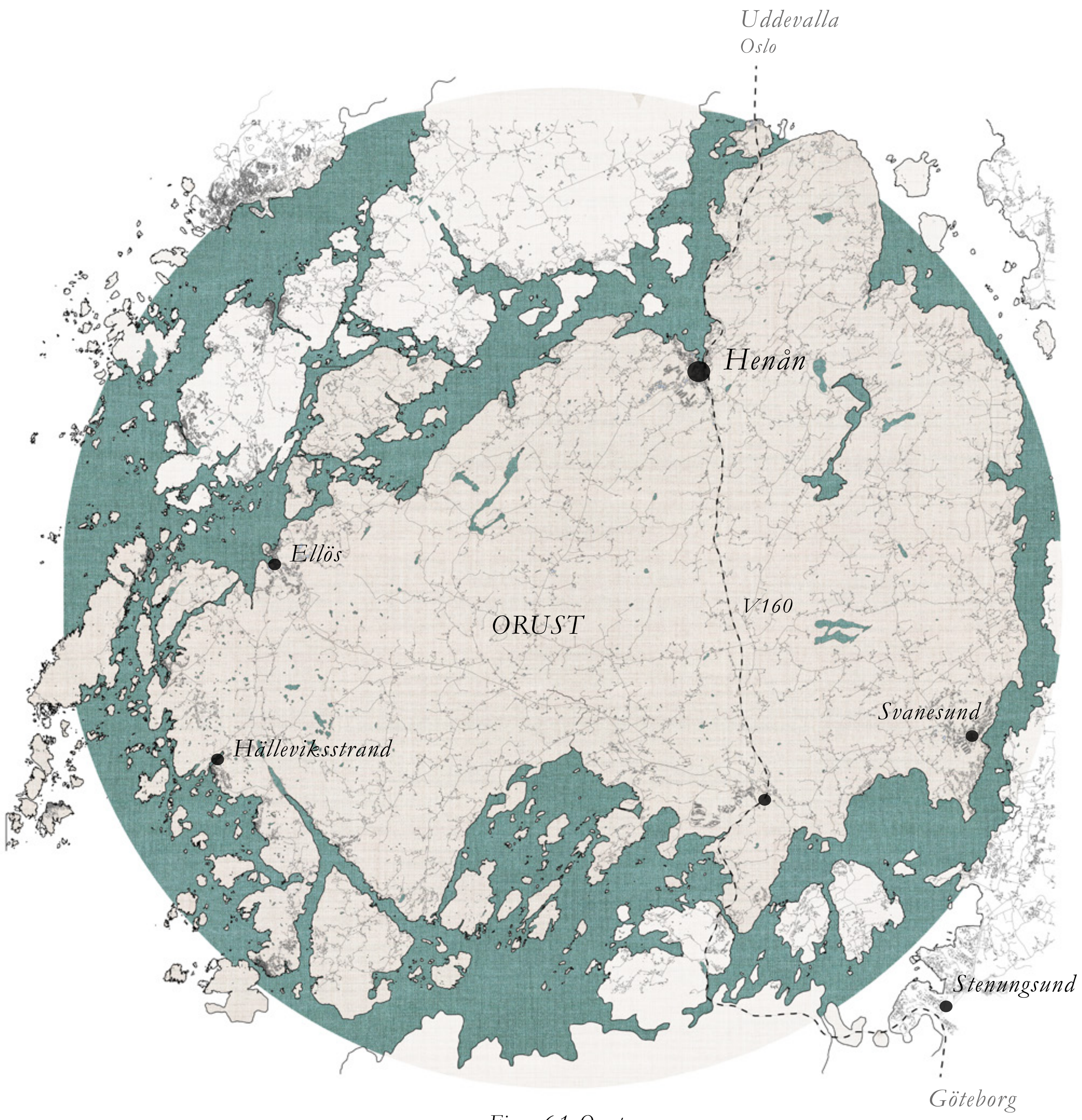


Figure 6.1. Orust

The study case

Henån (Orust municipality)

6.1 Orust Municipality

Number of inhabitants 15 093 (2016-12-31)
Municipality land area 389 km²
Island surface 346 km²
Residents per km² 39

Orust is an island municipality. It is the largest island of the west coast, and the country's third largest island after Gotland and Öland. The island is about 45 km long in the west-east direction and about 40 km long in the north-south direction.
Orust is located six miles north of Göteborg and three miles southwest of Uddevalla. Fixed bridge links exist in both directions. In addition, there are two ferry lines connecting Orust with the mainland.

The municipality was formed in 1971 after a number of mergers. In addition to the island of Orust, a large and lively archipelago with islands such as Gullholmen, Käringön, Lyr and Malö Flatön, belongs to the municipality.

Orust is a typical rural community where about 60 percent of the population lives outside the urban area. The municipality lacks major metropolitan areas. On the other hand, there is a pearl band of smaller communities along the coast - especially in the western part. The municipality's central city, Henån, is the largest urban area with about 2200 inhabitants.
Orusts has 15,000 inhabitants and it is Sweden's most densely populated rural area. During summertime its population triplicates.
It offers a variety of housing environments with rental rights, condominiums, and own accommodation. Rental apartments are available in all major locations and also on the carless islands of Käringön and Härmanö. There are many detailed plans going on as villa areas are exploited across the island.

Orust has been inhabited for a long time, the first settlement found is almost 11 000 years old. At the end of the 19th century, 19 000 people inhabited the island, and most of them lived in the western parts. The number then decreased until the 1960's to only 8 500 inhabitants, when the two bridges Tjörnbron and Nötesundsbron were built, and, after this, the east coast was developed.
Henån grew in the intersection between the bridges, becoming the main town of the municipality.

For a long time, Orust has been a popular site for recreation. The stream of tourists traveling to the island and its surroundings has increased since the 1940's, when workers got the right to paid vacation. During the 1950's, many small houses were bought by summer guests and turned into summer houses, and at the same time many new summer houses were built, initially not controlled by the municipality. Eventually, restrictions on the exploitation of the island were created.

With an aging population and a projection of a lower number of inhabitants in the future, the threats to the Orust community are multiple:

- An increase in the need of facilities for elderly people, in terms of structures and qualified staff;
- A less diversified population, tending towards an older and not working one;

- A limit in the creation of a lively and resilient community that could sustain the system all-year around.

The difference between the number of residents on the island in summer and winter determines another challenge for a more comprehensive development of Orust. A multi-seasonal approach needs to be taken into account in order to facilitate successful strategies during the whole year.

The increase number of local businesses is seen as a positive sign of economic growth and job creation, as well as of attraction of young workforce.

The high number of commuters from and to Orust for working underlines the importance of the main ways of communications, as well as the need to develop a smarter and well-organised transporation system (Orust Kommun, 2016).

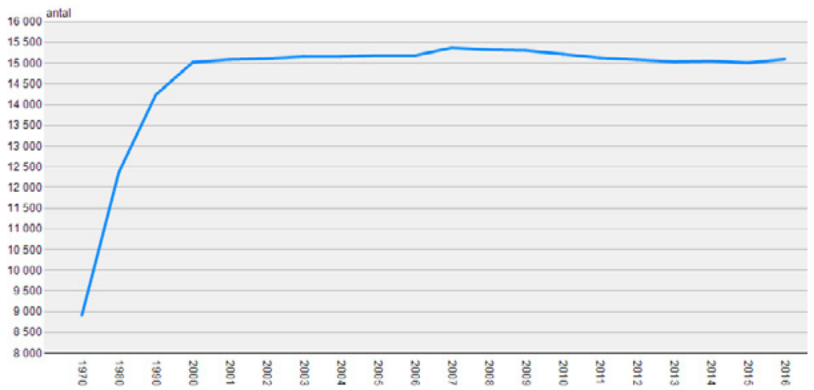


Figure 6.2. Orust demography 1970-2016

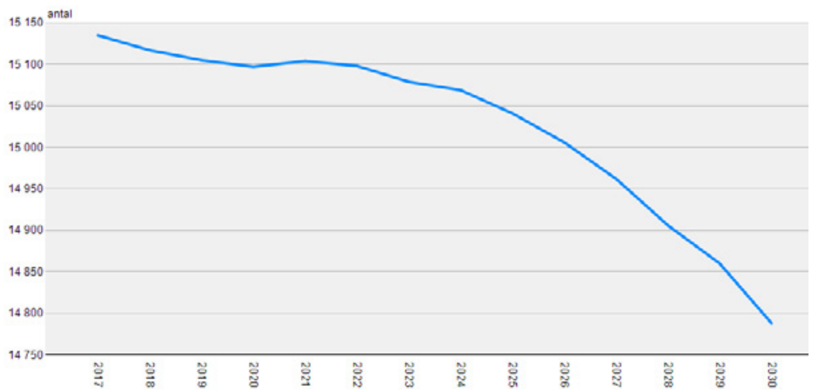


Figure 6.3. Orust demography projections 2017-2030

Henån	2 296
Svanesund	2 110
Ellös	1 223
Varekil och Svanvik	1 016
Mollösund	228
Hälleviksstrand	194

Figure 6.4.
Population distribution in Orust (main villages)

0-5	682
5-14	1 411
15-24	1 532
25-44	2 845
45-64	4 856
65-79	3 283
80-w	924

Figure 6.5.
Orust population by age

2014	1 952
2012	1 905
2011	1 839
2010	1 781
2005	1 991*
2000	1 752*

Figure 6.6
Local business development 2000-2014

Inom kommun	3 942
Utpendlare	3 325
Totalt	7 267

Figure 6.7
Employed inhabitants (within the municipality and commuters)

Stenungsund	950
Göteborg	840
Uddevalla	467
Tjörn	251
Kungälv	191

Figure 6.8
Commuters from Orust (2015)

Uddevalla	330
Stenungsund	181
Tjörn	175
Göteborg	156

Figure 6.9
Commuters to Orust (2015)

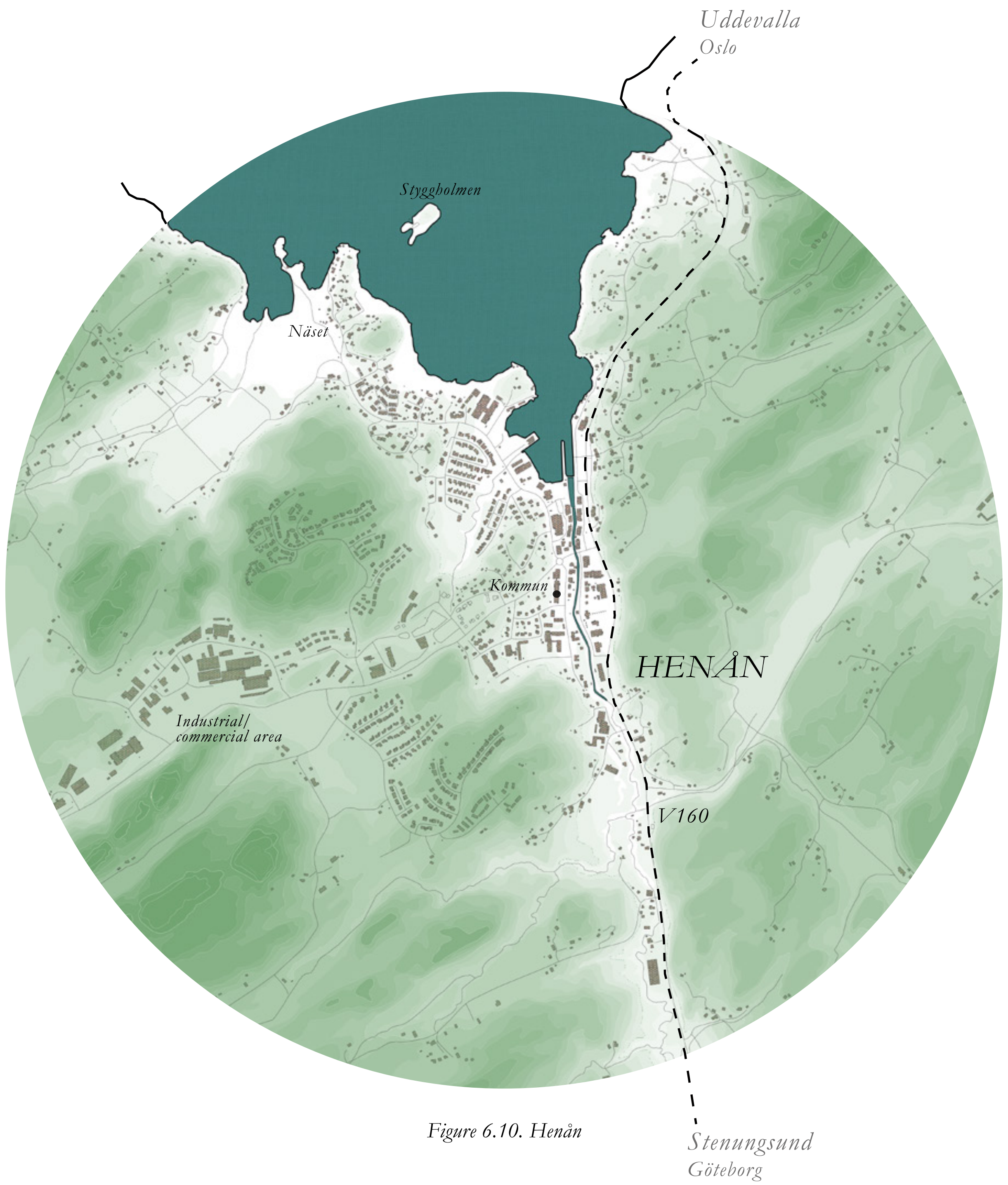


Figure 6.10. Henån

6.2 Henån

6.2.1 Location and features

Henån is the main village of Orust kommun and it is situated in the northern part of the island. It took its name from the river passing throught it.

Henån has a population of 2200 inhabitants, which triplicates during the summer. As the rest of the island, it is one of the main touristic attractions in the Bohuslan province, hosting a great number of seasonal guests.
It is well connected to Uddevalla and Stenungsund by the V160 and buses are running every half an hour allowing an easy commuting to Göteborg.

The harbour is a central and important part of the village, although currently it feels undervalued due to its planning and limited accessibility. It can host a good number of private boats, although it reaches its full capacity only in the summer. Shipyards are present along the waterfront, while large areas are devolved to parking spaces which are extensively used in the summer but rather scarsely during the winter season, creating wide empty public spaces not adequately enhanced.

The town center finds itself within a pedestrian area which features as the main square; here some small shops, restaurants, and a supermarket can be found, as well as the library-culture house, standing out as a central building for the community. The town center runs along the Henån canal, although it does not extend until the waterfront, leaving a buffer zone between the built environment and the sea, occupied by parking lots.
Proceeding towards the south, public functions and the municipality itself are placed in continuation with the "central spine" defining the town backbone. In the eastern and especially western part of the town, residential areas are mostly found, presenting mostly residents' single-family houses, rather than summer houses.
The most significant residential development of Henån was carried out from the 1960s, following an increasing economic growth that led to massive urban developments in the whole country. At the time, farming lands and fields were converted into buildable areas and the touristic relevance of Orust started to come into light.

6.2.2 Social structure and potentials

It is registered that the majority of inhabitants are aged between 45 and 79 years old, increasing the amount of people settling on the island to retire and therefore lowering the number of active workers. Younger people are moving more and more to the main land and to bigger cities, where jobs and education opportunities are provided.

The difference of population and liveliness of the town between summer and winter is leading towards a limitation in the variety of inhabitants (considering age, income, occupation), which could impact on the further development, both economically and socially speaking, of Henån.

The necessity of investing on local business, more cultural and leisure activities suitable for younger generations, and generally developing a community capable of attracting people all-year around, would create a more resilient and sustainable social structure.

A variety in income would also be necessary to avoid *gentrification*, due to the high prices of the houses on the island and the limited availability of cheaper apartments.
(Orust Kommun, 2016; Chalmers students, 2017)

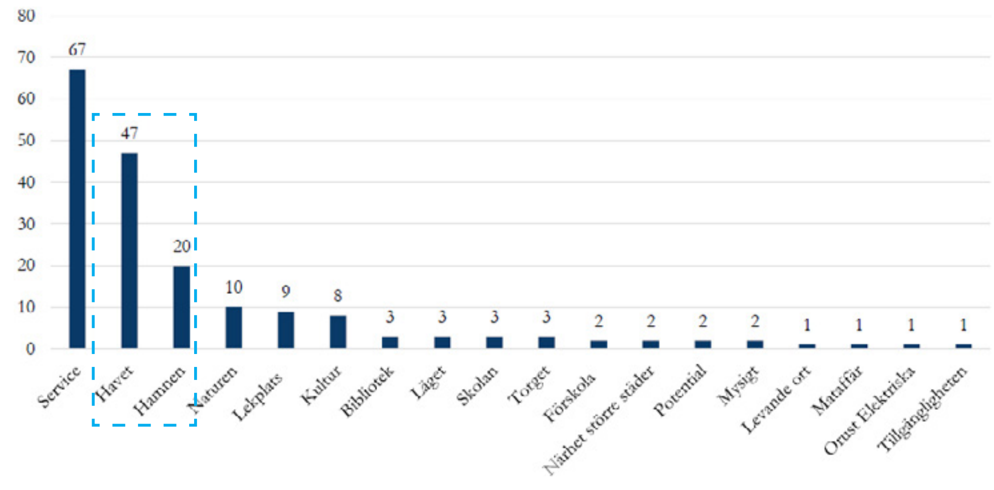


Figure 6.11. What is the best feature of Henån?

43%
The sea and the harbour

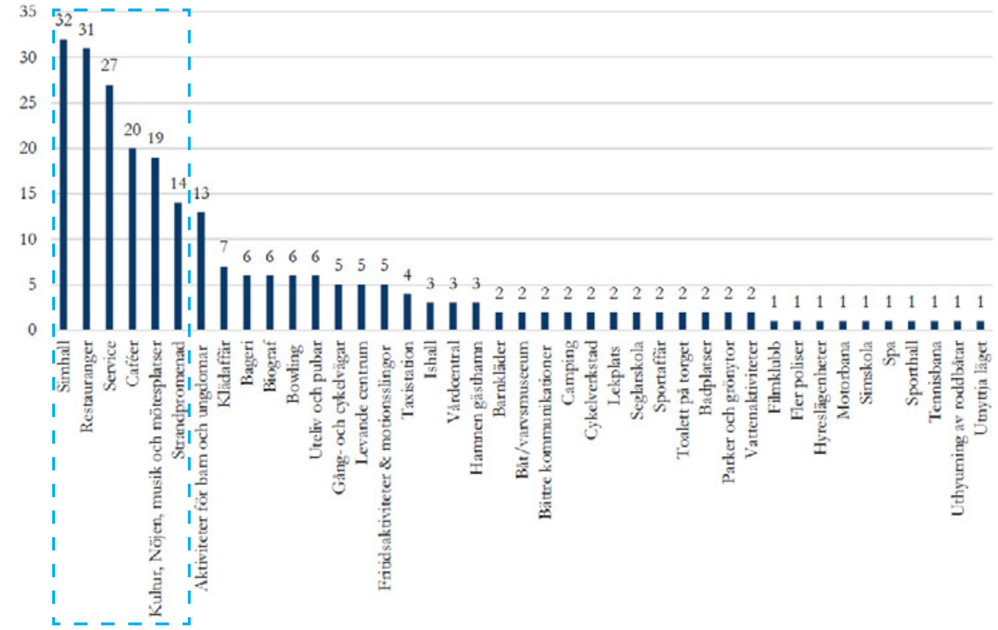


Figure 6.12. What kind of services do you miss in Henån?

92%
Meeting, culture and eating places

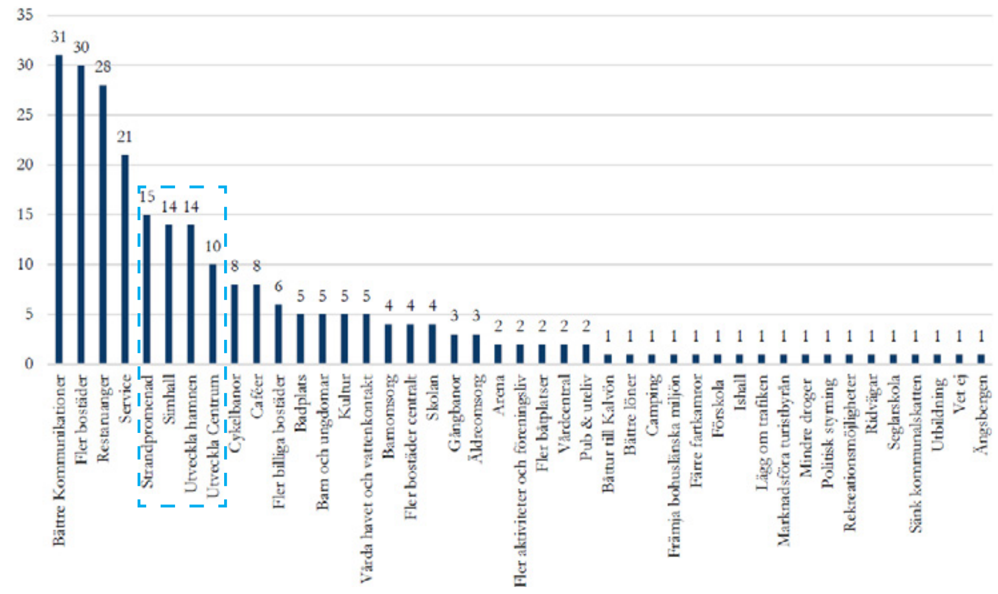


Figure 6.13. What do you think it could attract more people to live in Henån?

34%
A refurbished waterfront, harbour
and city center

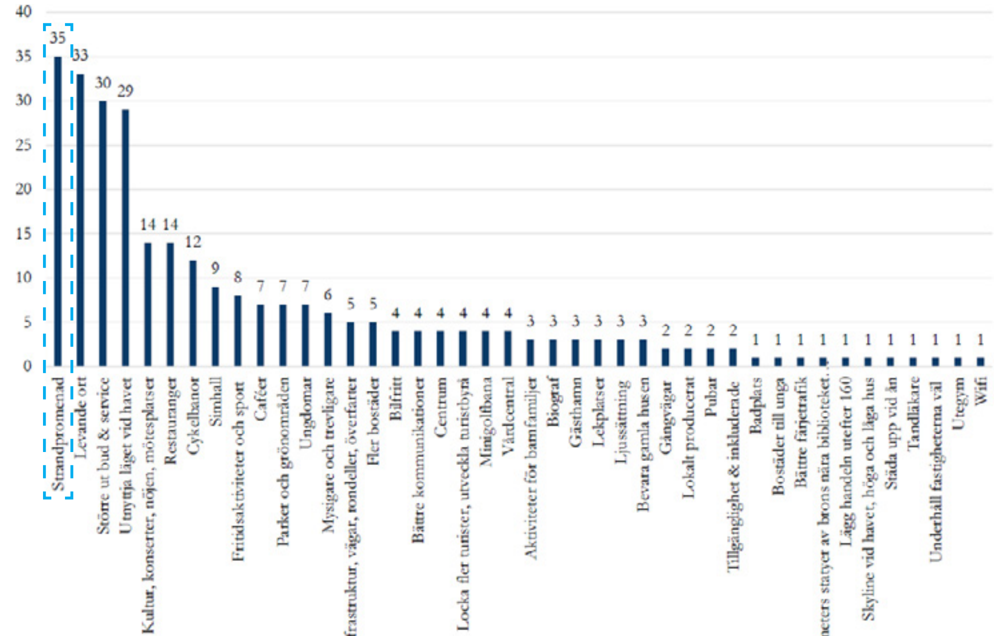


Figure 6.14. How would you like the center of Henån to be in 10 years?

22%
Waterfront boardwalk

6.2.3 The public survey

During the summer of 2017, residents and visitors of the Henån area were given the opportunity to participate in a civil dialogue to give their opinions about the town. The purpose was to gain in-depth knowledge of people's needs and attitudes in the area. The dialogue process is linked to an ongoing project for Henån and Svanesund. Information about the citizens' dialogue was spread through both physical (e.g. bulletin boards in the area), as well as via digital channels like the municipality's website, Orust.se, and social media.
On Orust.se, citizens had the opportunity to express their views on a digital map of the Henån area and answer a questionnaire survey.

The City Center

It is mentioned on several occasions that there are no parking spaces for visitors in the area, and that there is a general wish to build a parking garage to leave space for walkways and cafes. It is desirable to refurbish several buildings as well as to have a staffed police station back.

The Harbour

In the port area there have been several requests about what it could be used for. To better illustrate these, they have been categorized under the heading Recreation, Service, and Structure.

Recreation

There is a desire to maintain the green areas, as well as the view of the harbor and the sea. Several people mention the latter as an extremely important symbol for Henån to be preserved but also further developed. There is a wish for a proper waterfront, perhaps extending it to Näset and Småholmarna. Many people think the harbor is undervalued and should be refurbished.

Service

Several people comment that there are numerous possibilities of improvement for the port area. Many mention that the surface can be used for various types of meeting places for the people. A new swimming pool is largely auspicated, although the volleyball and boule courts available today are well appreciated. More restaurants and cafes are felt as necessary complementary features. An open public toilet is a missing element as well.

Structure

The desire to come close to the water is also emphasized here. Many mention that the parking spaces should be moved to strengthen the connection between the square and the harbor. Many also point out that housing should be built near the water. Moreover, walking and cycling paths should be expanded in the area.

The survey was answered by 155 people (Orust Kommun, 2017).

Figure 7.1. Henån's flood map and main functions

The impacts
Risk and vulnerability assessment

7.1 Past and current issues

On behalf of Orust municipality, Sweco Environment has developed a flood investigation for Henån, in order to create a basis for future planning decisions. It is to be noted that RH2000 is the elevation system used in this investigation.

Henån has experienced recurring floods for a long time, and these phenomena have intensified in recent years. The eastern part of the harbour has been the most affected so far. The historically high water levels in central Henån have caused negative consequences in the form of damaged buildings and the flooding of the important infrastructure element of the town, the V160, connecting Henån with Uddevalla and Stenungund.

The town faces recurrent floodings throughout the year, with a higher frequency during the winter months, as shown in the diagram (Figure 6.3). Temporary hide tides usually last a few hours: the longest-lasting events occured in 1985 and 2011, when the sea level rose up to +1.2m for a duration of 11 hours. Extreme sea water levels are generally linked to strong wind conditions and low air pressure, which are constantly monitored by SMHI's measurement stations in Vinga and Måseskär. The highest water levels are registered in combination with strong wind coming from north-west.

The existing water drainage system in Henån is thought to be in poor conditions and necessary measures need to be taken in the near future in order to avoid further damages. Drainage of the areas along the Henån river is carried out by water pipes directly into the river; however, the system is considered insufficient when the sea level and the water flow increase, causing an overflow and consequently the flooding of the surrounding areas.
The present conditions of the quays and the structures along the watercourses require a necessary refurbishment too (Sweco, 2016).

7.2 Sea level rise and future projections

The sea level rise projections for Sweden are set at an average of +0.88 m by the end of the century. Nevertheless, the South and West coast of the country are the most exposed to the flooding risk, and, therefore, the level taken into consideration for future adaptation planning is set at +1 m by 2100.

Taken into consideration the datas collected by the SMHI's measurement station in Stenungsund during the last 10 years, it is noted that the highest sea level value registered was +1.44 m.

Regarding storm surges and seasonal flooding caused by heavy precipitations and strong winds, a water level of +2.5 m is believed to be reached by the end of the century (Sweco, 2016).

Consequently, two water levels will be considered in the adaptation plan:

- **+1 m**, to be reached slowly but steadily supposedly by 2100;
- **+2.5 m**, to be experienced in a more abrupt and quick way through seasonal floods that are expected to happen even in the near future. These conditions are predicted to last for a time span from a few hours to a few days.

Observing datas collected from the Stenungsund station regarding the last decade, and creating a visualization of the sea level during an average year, it is noted that the lowest values are to be found from March to the beginning of June, an increase is then registered proceeding to the end of the year, while values tend to decrease around the beginning of January. Peaks have still been experienced at the end of February (Figure 6.3).

In conclusion, both a short-term and a long-term perspected need to be taken into account when planning for flooding adaptation: the progressive but slow increase in the sea level rise goes along with cyclical phenomena of floodings, occurring occasionally but with a strength that intensifies every year.

7.3 Vulnerabilities and impacts

A spatial risk analysis has been carried out, considering the impacts created by both the rise in the sea level, and the occurrance of flooding events. The reason why it has been called *spatial* is because, due to limited time, resources and competence, a complete risk analysis could not be executed. A proper analysis would have included all the economic, social and environmental impacts, that these events might cause, investigating them thoroughly, showing how some direct effect could indirectly provoke further consequences on other elements of the ecosystem.

It is well known that flooding events could cause serious damages to the drainage system, for example, implying environmental and economic consequences which are difficult to project and quantify.
It was not taken into consideration, as well, that part of the affected population of the town might decide to move further from the coast due to the risk of flooding, resulting in severe repercussion on the socio-economic situation of Henån.

Some indirect, though equally crucial, effects could not be assessed, although the awareness of their existence is not missing; the economic loss, for example, deriving from the impossibility to deliver goods and products to the local retails due to the contingent unavailability of infrastructures (i.e., roads).

Taking into consideration a water level of +2.5m occurring in case of storm surges and seasonal floods, it is immediately recognizable that the most exposed areas are the ones located in the centre of Henån (as visible in the flood-risk map, Figure 6.1). In fact, basically all the commercial and public facilities situated in this area would be affected, resulting in physical damages for the built structures, as well as for economic loss for the present activities. Two schools and the culture house are moreover of particular interest, as they are regarded as more "sensitive" elements due to their role in the community. The flooding of the main square of Henån would also represent a great loss in the town dynamics.
In the north-western part of the harbour, an elderly-care center is located, presenting issues of flooding risk, although not as dangerous as in the town centre.
The waterfront areas hosting shipyard activities are majorly at risk, while the numerous parking lots along the coastline are projected to be flooded as well.

One of the most crucial situations in this flooded scenario is represented by the exposure of the main infrastructure system to the water. In particular, the V160 road is the main communication way to Uddevalla, and its complete inundation could have significant consequences, both physical, economic and logistic.
Nevertheless, a limited number of residential buildings would be affected by the water flow in this projected scenario.

It is to be noted that additional risks derive from the water runoff coming from the surrounding hills, which is greatly intensified in case of heavy rains and storms (Figure 6.2).

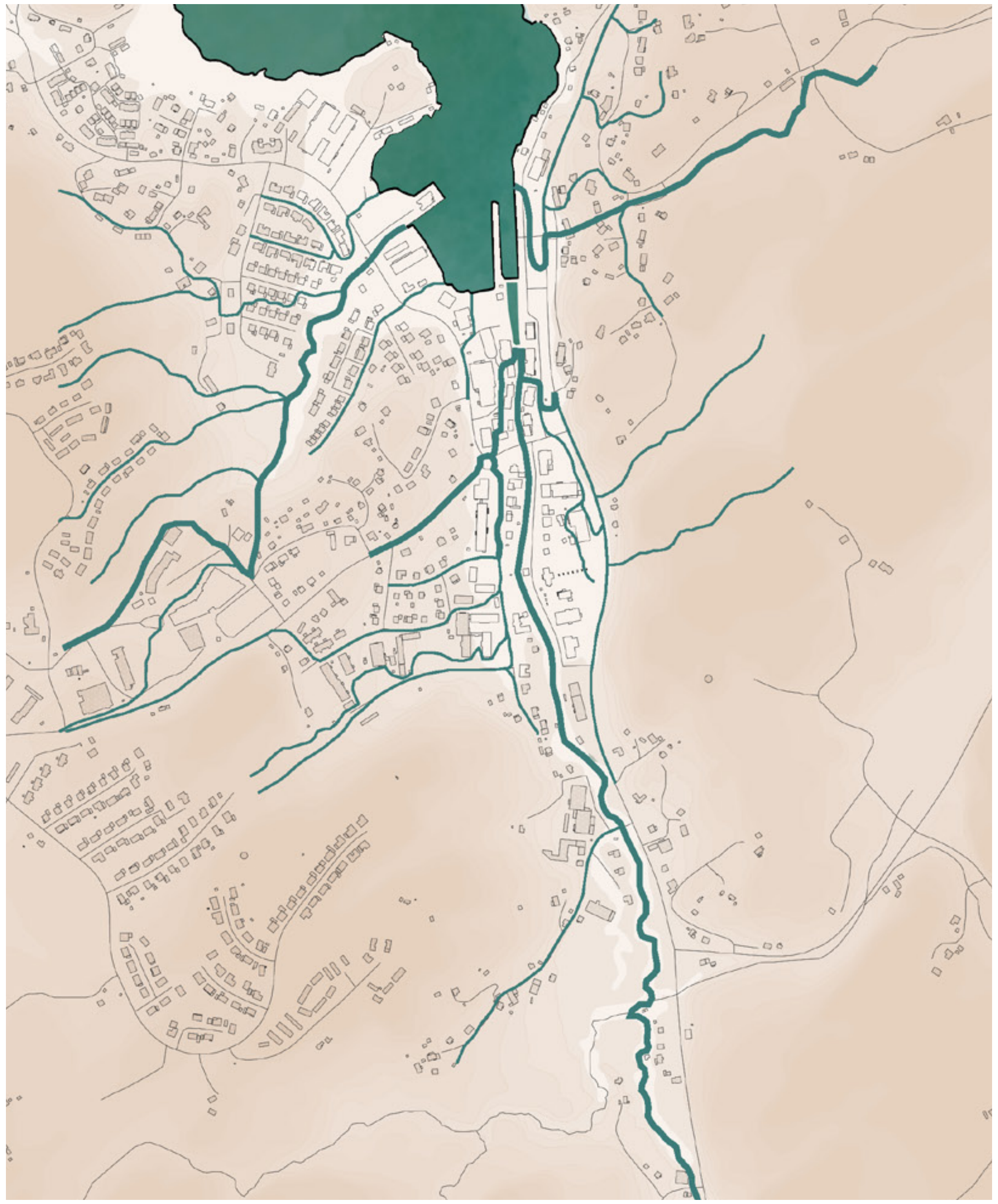


Figure 7.2. Main waterflows in case of heavy rains

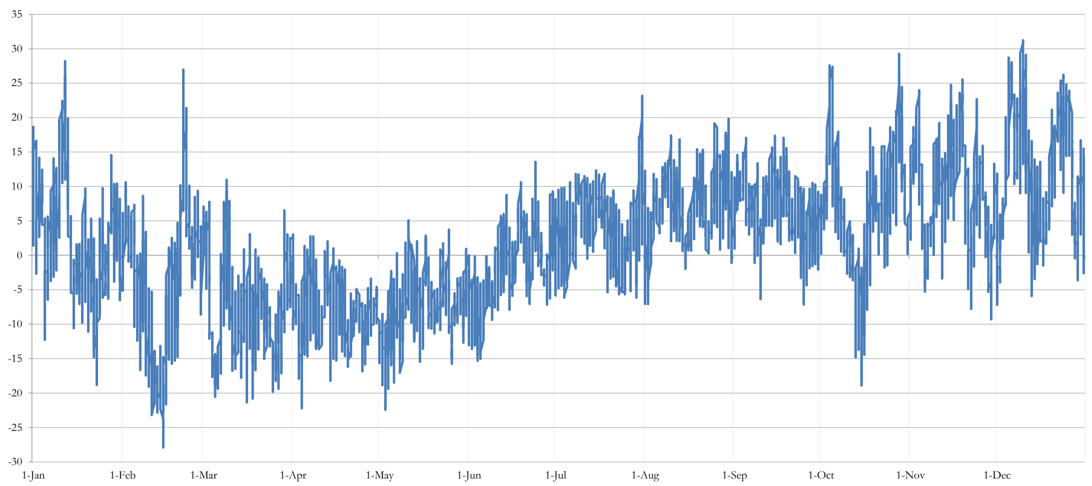


Figure 7.3. Sea level rise trend within an average year, based on datas collected by the measurement station in Stenungsund (Jan 2008 - Jan2018)

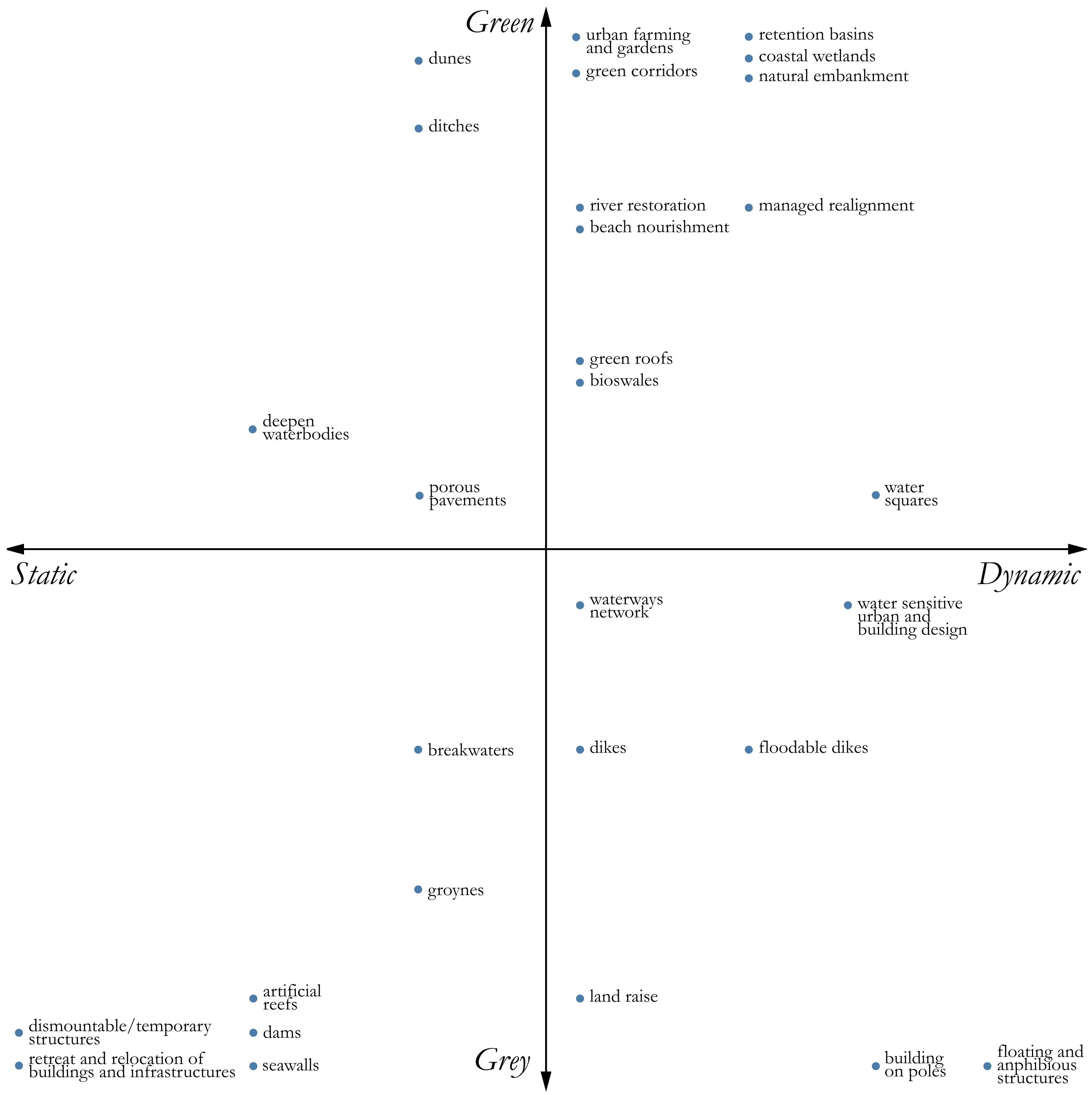


Figure 8.1 Categorization of the adaptation strategies

Design

Resilient Adaptation Urban Strategies

8.1 Evaluation and Selection of the strategies

After a first screening of possible adaptive solutions, the necessity of evaluating them, in order to select the most suitable ones, poses numerous issues regarding the choice of the evaluation criteria. The MCA tool, which will be developed within the Pilot Project, takes into consideration the level of sustainability of every measure, according to the three main categories: social, environmental and economic. Nevertheless, the purpose of this Thesis is to find strategies which enhance a strong and dynamic relationship between the natural and the built element, creating a harmonic coexistence in face of constant change. For this reason, the adaptation strategies were listed according to their more or less potential of integration between the nature and the city, the sea and the land. The term *Dynamic* refers, moreover, to their capacity to adapt to new conditions (i.e. dry/flooded), either persisting in their original function, or changing to another one, equally fitting the overall system. Following the initial categorization *green/grey/hybrid*, a combined diagram was developed (Figure 8.1).
In the course of the design process, a constant update of this diagram was done, due to the discovery of new potentials for each strategy.

Through these adaptive strategies, the system can, therefore, bear new conditions and persist in its functioning; nevertheless, in order to achieve new possible equilibria and a more resilient approach, it is necessary to take a step forward. The adaptation strategies become then vehicles for new opportunities of urban qualities and development, carrying the system towards a new configuration, not *despite*, but *thanks to* the flooding risk and its consequences. Flooding adaptation becomes a resource, rather than an obstacle or a mere necessity.

In order to achieve this goal, the objectives of the flooding adaptation strategy are coupled with more specific urban development ones, aiming at improving the current situation in a selected study case and leaving room for further progress, thanks to the *dynamicity* that the adaptive measures can provide.

Capacity to adapt to new conditions (i.e. dry/flooded), either persisting in their original function or changing to another one, equally fitting the overall system.

8.2 Design Strategy and Process

Due to the necessity of setting a framework for the application of this methodology, the flooding risk map of Henån was studied, and urban analyses were conducted, pointing out the current risks and potentials of the Bohuslan town. The projected sea level rise and flooding risk could have a significant impact on the current coastline and on the way the town is developed along it, and, moreover, they require measures providing protection for the inhabitants and the infrastructures. At the same time, the possibility of refurbishment of certain areas, especially the harbour, has great

Fig. 8.2 The study case area

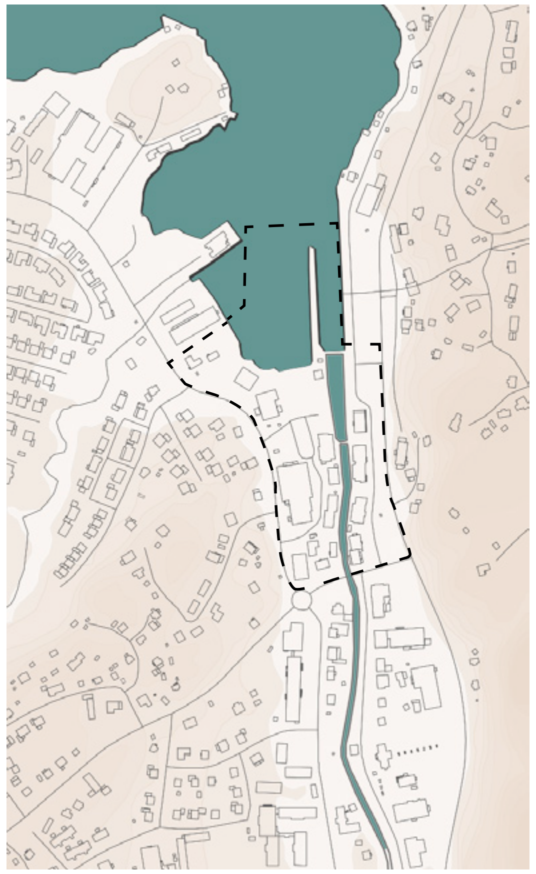
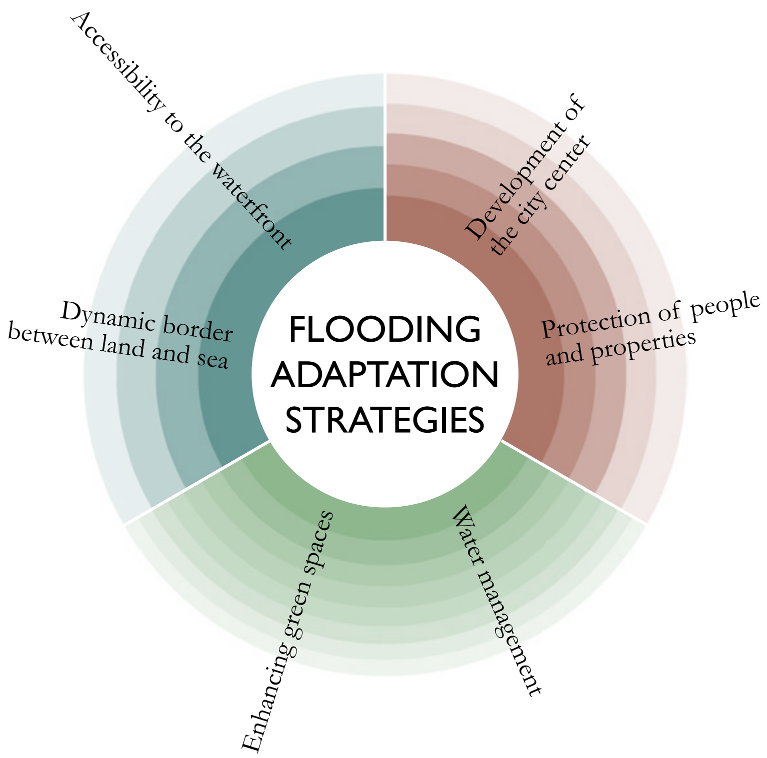


Fig. 8.3 Selection of the study case

potential to bring further benefits to the town. The research of a balance between the future natural conditions and the potential development of the urban settlement resulted in the choice of Henån's city center as the study case. This is currently identified with the main square on which the majority of commercial and cultural activities takes place. A series of retail units, a cafeteria, a restaurant, the ICA supermarket, and the culture house are located here. Despite the significant proximity to the waterfront, it is not felt as a public space, due to the large amount of surface dedicated to parking lots. The connection between the heart of the town and its most important feature, the harbour, is absent, underlying a potential future development, taking into account the projected sea level rise in the next 100 years. Moreover, the refurbishment of the harbour resulted as a preeminent issue in the public survey conducted by the municipality (Chapter 5.2.3)

The results of the analyses highlighted three major objectives for the achievement of new urban qualities and three for the overall adaptation approach: the adaptation strategies become, therefore, the tool thanks to which these goals are reached, ensuring flexibility and responsive diversity, following the dynamicity categorization, as it will be further explained in the following Sections.

URBAN QUALITIES	ADAPTATION GOALS
Accessibility to the waterfront	Dynamic border between land and sea
Development of the city center	Protection of people and properties
Enhancing green spaces	Water management



8.2.1 Accessibility to the waterfront | Dynamic border between land and sea

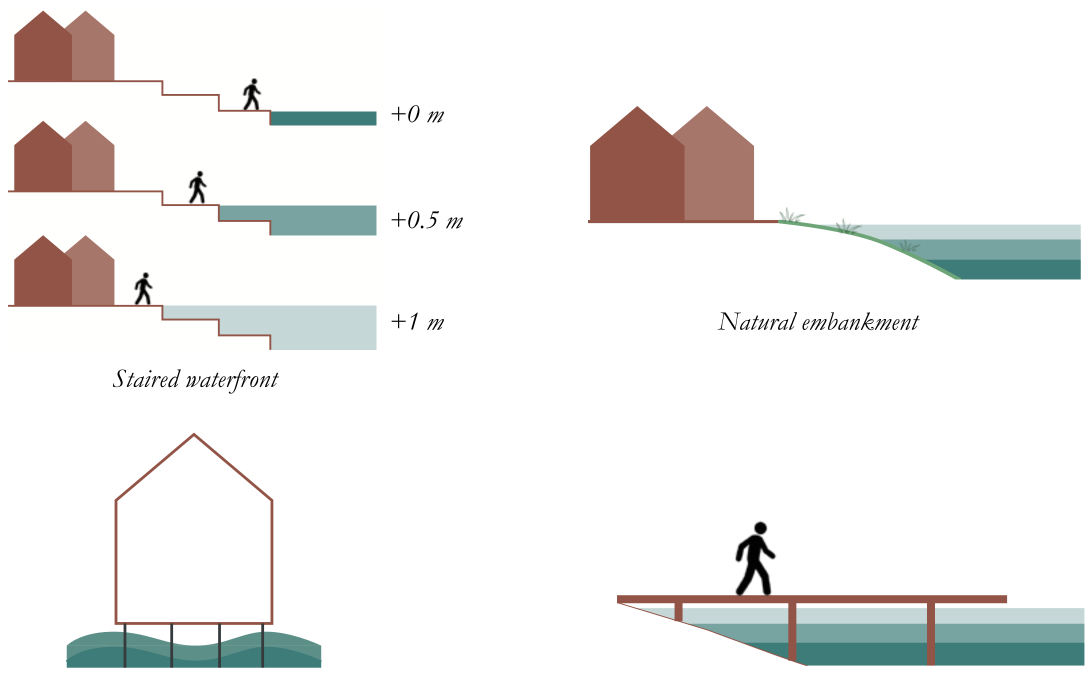
The current situation of Henån's waterfront presents a strict separation between the natural and the built environment. The land and the sea are clearly confined within borders that leave no room for flexibility or future changes. The initial proposed solution of a hard barrier protecting the town from the future sea level rise and flooding risk would have amplified this division, while a more resilient approach would be to work with the water, welcome it into the town landscape, and accept the future scenarios, although unpredictable to some extent.

As the water comes to the land, the built environment can, nevertheless, be developed towards the sea, without retreating from the future risks, but achieving a new relationship between Henån and its waterfront. The latter becomes then accessible in its entirety, through a series of pedestrian paths and walkable structures that are shaped by the future levels of the sea: a continuous waterfront is, therefore, guaranteed.

In order to achieve this goal, four main adaptation strategies were used. The border between land and water becomes more flexible and less strictly defined through the creation of natural embankments (green sloped areas functioning as buffer zones) and steps that can easily adapt to future sea levels or temporary water rising. These can provide public spaces for sitting and recreation, bringing people closer to the water. The development of the urban area towards the sea is achieved by constructions on poles, whether they were buildings or piers, letting the water come in without interfering with their functioning.

The waterfront becomes a dynamic space, establishing new connections between the elements of the urban system, and able to face future conditions, constantly modifying itself and creating new qualities.

FLOODING ADAPTATION STRATEGIES



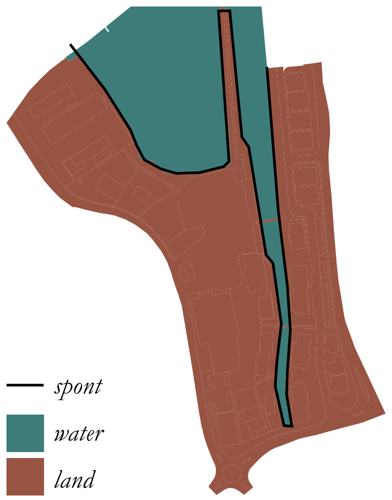
Staired waterfront

Natural embankment

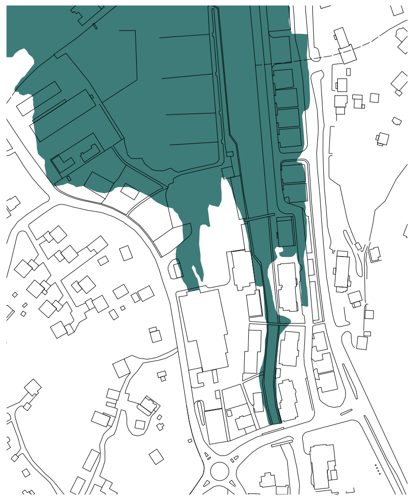
Buildings on poles

Pedestrian piers on poles

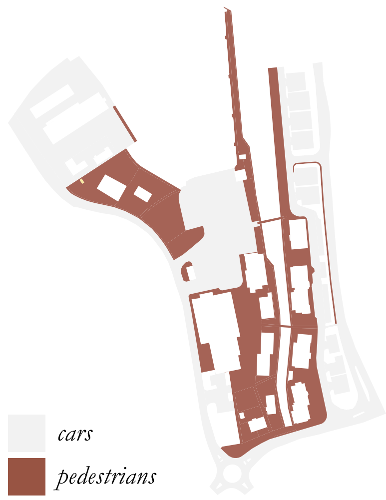
URBAN ANALYSIS



Strict separation between land and water with proposed engineered solution

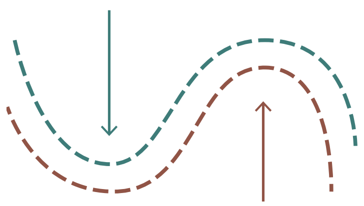


Sea level rise projection by 2100 (+1 m)

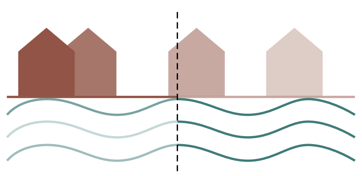


Cars/pedestrian usage of land

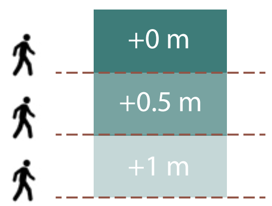
OBJECTIVES



Dynamic and flexible border: the water comes towards the land, the city goes towards the water



No strict separation between land and sea Pursue of a more resilient and flexible solution



Accessible waterfront despite the rising sea level

DESIGN CONCEPT

8.2.2 Development of the city center | Protection of people and properties

The city center of Henån presents limited diversified activities, consisting mainly of small shops and the large ICA supermarket. The library and culture house is the main public building, an important focal point in town. Envisioning a future economic development based also on business and touristic opportunities, a wider range of functions should be found in the city center and around the waterfront. Offices and commercial activities can, therefore, replace the supermarket, which could be moved in a more convenient area, removing most of the parking space needed for this kind of activity from the immediate waterfront. In this way, the heavier traffic to the area is avoided, promoting a car-free city center. The limited number of parking lots still needed can be located along the main access roads (Ängsvägen and V160).
The plots further from the sea would be destined to private investors, while leaving the waterfront to public property, which could be developed by the municipality, with the realization of other public facilities in addition to the library, such as a music hall.

Due to the projected risk of flooding (up to +2.5 m), the primary concern of the adaptation strategy is to guarantee the safety of the inhabitants, providing escape routes and easily reachable safe zones. Consequently, the preservation of buildings and infrastructures is of high importance and needs to be treated differently case by case in the adaptation process.

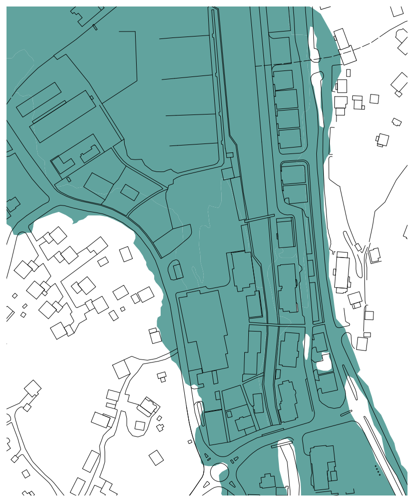
A hierarchical system of infrastructures was designed, organizing them according to their role as possible safe routes and their vulnerability to the risk of flooding. Three categories were identified:

- Primary infrastructures (I) are pedestrian paths and vehicular roads located at a level of +2.7 m, creating a safe zone around the site area and offering at the same time a strong connection between the two sides of the river;
- Secondary infrastructures (II) are pedestrian paths defining the main trajectories along which the settlement is developed. They are located at +1.5 m and are easily accessible by all the activities on site, allowing a sufficient time to evacuate in case of water rising. At the instersections between I and II, light structures can be found offering quick vertical connections;
- Tertiary infrastructures (III) represent the remaining pedestrian areas, being located at ground level, ranging from +0.3 m to +1 m and, therefore, highly vulnerable of being flooded first.

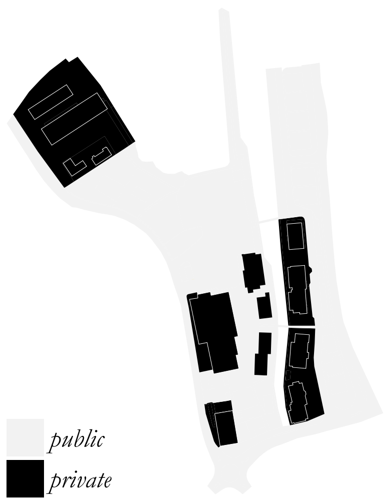
Three strategies were considered suitable concerning the adaptation of buildings to the flooding risk.

- Existing buildings would be dry waterproofed, through sealable openings and waterproof treatment of the façades;
- The new buildings, hosting retails and offices, would be wet waterproofed, allowing the water to come inside, working on the *floodability* of the first floor in case of storm surges and more serious events, and limiting its functions to less permanent activities like commercial ones, while locating the offices from the second floor up;
- The building development along the waterfront could be carried out through constructions on poles, as explained in the previous Section, safely preserving them also in case of future permanent sea level rise.

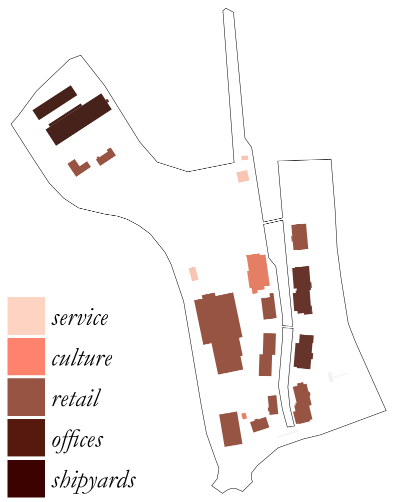
URBAN ANALYSIS



Flooding risk (+2.5 m)

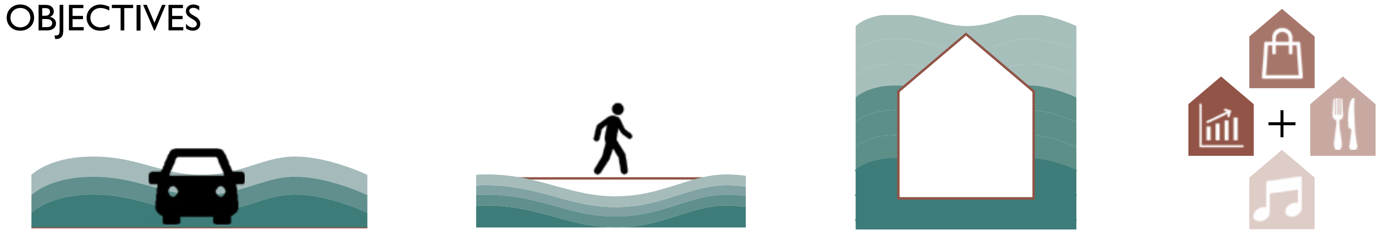


Land Ownership



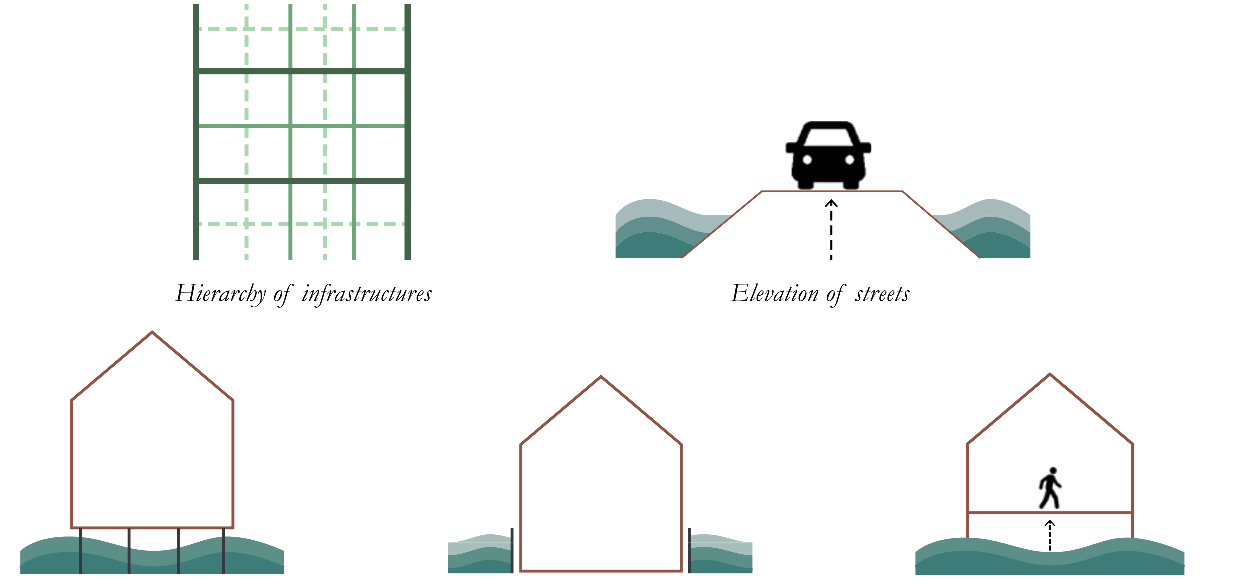
Functions distribution

OBJECTIVES



Protection of the infrastructure — *Protection of people* — *Protection of buildings* — *Development of more various types of businesses and functions*

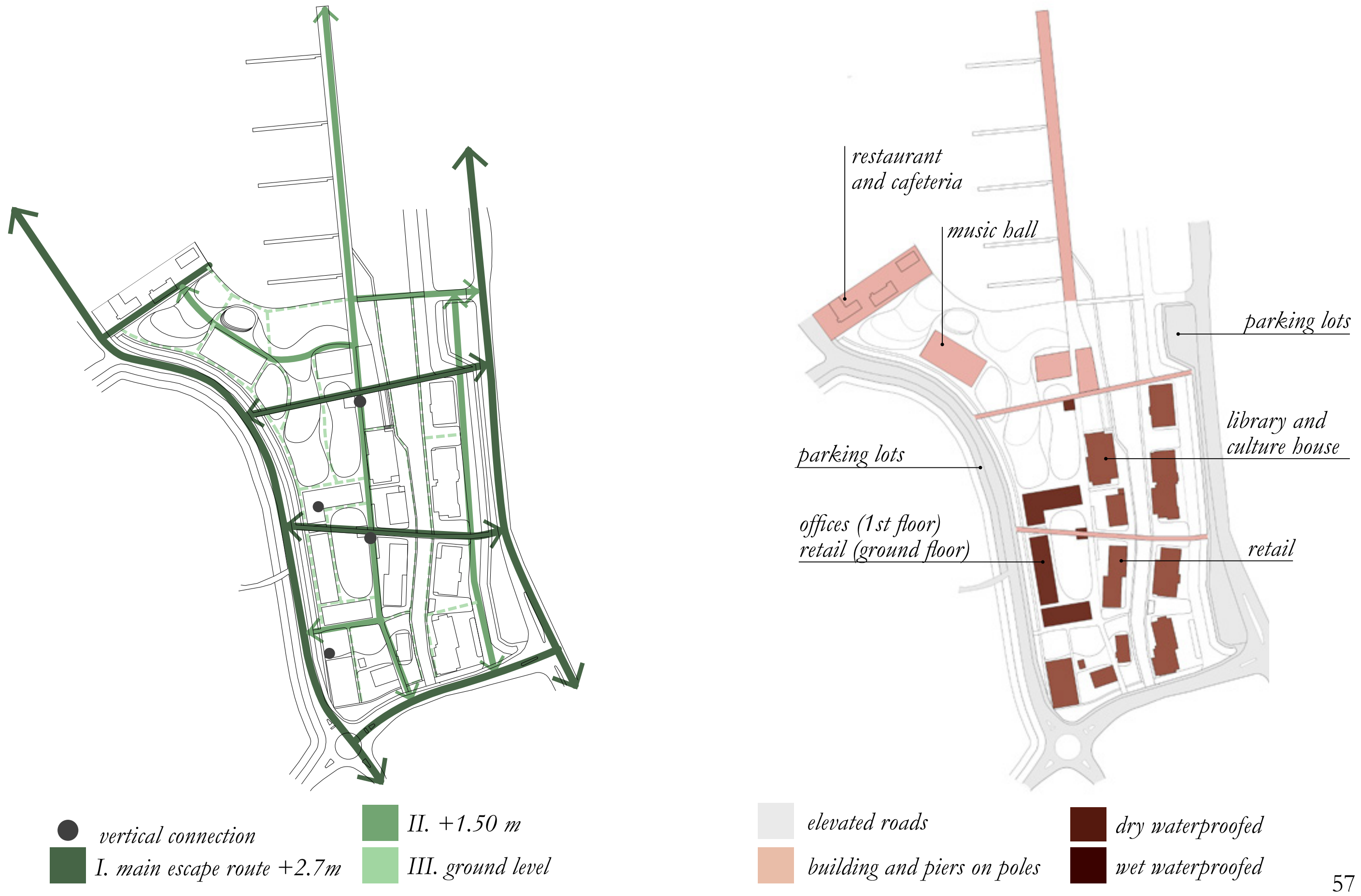
FLOODING ADAPTATION STRATEGIES



Hierarchy of infrastructures — *Elevation of streets*

Buildings on poles — *Dry proofed buildings* — *Wet proofed buildings*

DESIGN CONCEPT

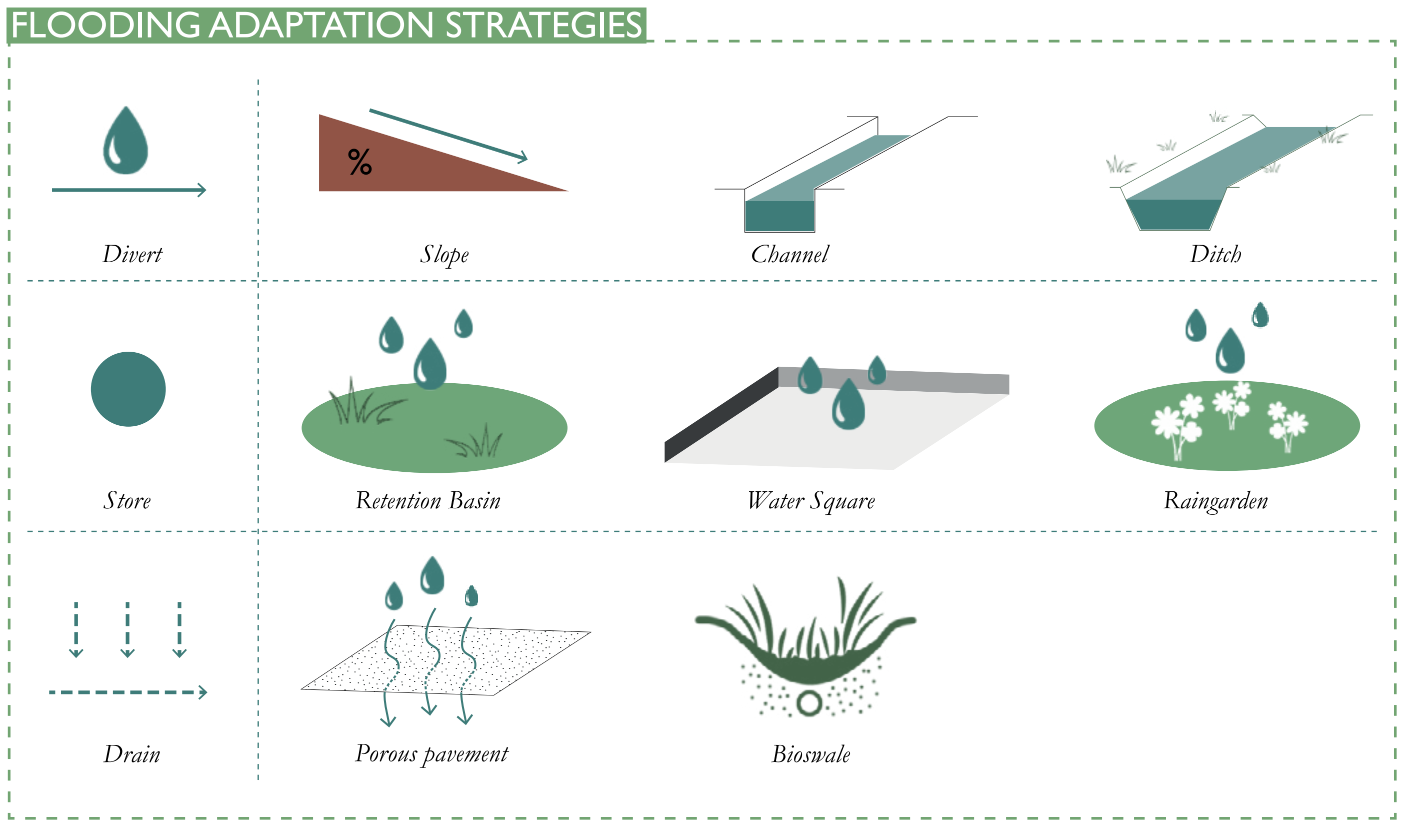


8.2.3 Enhancing green spaces | Water management

As the city center of Henån is currently open to car access, the amount of public green surface areas is very limited and, nevertheless, underused. Through the conversion of the parking spaces along the waterfront into green areas, significant improvement is achieved in terms of recreational opportunities, health, and biodiversity enhancement. Proceeding towards the inner part of the town, the green areas become more “designed” compared to the ones closer to the water, which present a more natural and spontaneous configuration. They provide sitting places and playgrounds and can host events and markets.

Through the interviews conducted with Sweco experts in the Netherlands, it was suggested that the main concern in facing a flooding risk in a town like Henån should be the management of the water in excess, through a strategy involving the diversion, storage, and drainage of the water back to its original source (the sea or the canal), creating a network of measures that actively participate in handling the flooding event. This network of strategies consists of various elements collaborating together but giving, at the same time, important benefits: the creation of necessary retention basins, bioswales, and raingardens improves the quality of the urban environment, offering spaces for recreation, while playing an essential role in the flooding risk management. Water squares can provide dynamic and exciting public spaces, turning into temporary ponds and fountains when it’s needed.

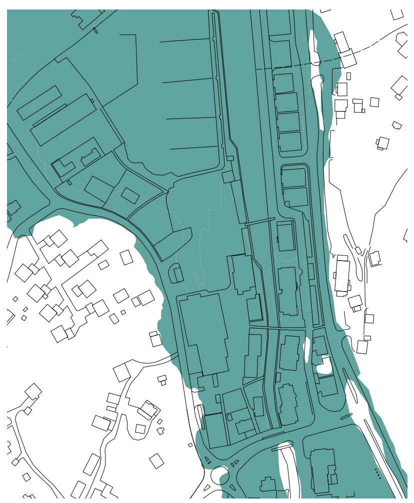
Urban spaces are, then, designed to be flexible, modifying their role in the urban system according to the situation, responding in different ways to a change of conditions. After the occurrance of a flood event, the water is slowly drained firstly from the water squares and, subsequently, from the retention basins to the sea, determining a conceptual "two-phases" aftermath scenario.



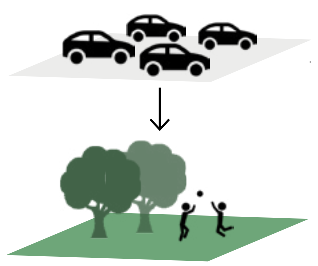
URBAN ANALYSIS

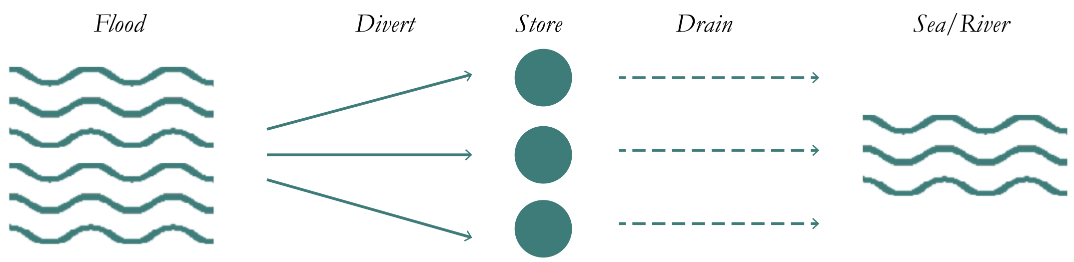
Hard/Green surfaces

Cars/pedestrian usage of land


Flooding risk (+2.5 m)

OBJECTIVES


Turning parking spaces into green, recreational areas



Water management Strategy

DESIGN CONCEPT

Fig. 8.4 *Masterplan*

Future sea level +1 m (2100)

8.3 The Design Strategy

The application of these methods and strategies resulted in a masterplan proposal for the area (Figure 8.4). This is not meant to be a definitive design, but rather the suggestion of a possible comprehensive strategy, using adaptation measures as a resource in order to achieve both a flooding risk management and the refurbishment of the area. It is a flexible urban space, which is meant to adapt to future conditions, leaving room for further development, if necessary. It is a "work in progress", in the attempt not to present a static solution, but rather a system that can carry on and reshape itself through constant change.

The rising water shapes the landscape, the built environment creates room for it without denying the creation of a lively urban scape, which develops along the main axes, opening up to public flexible spaces.
A mutual and dynamic relationship between the architecture and the natural element is established: every element of the urban system interacts with the water in different ways and in different timescapes, always providing new experiences, making the system evolve to different configurations and creating new identities.

In the following pages three sections of the proposal will be further explained, showing which adaptation measures were used and how they could work together to achieve the preset goals of the design strategy.
The sections will be followed by a visualization of the expected response of the urban system to a flooding event (Figure 8.8).

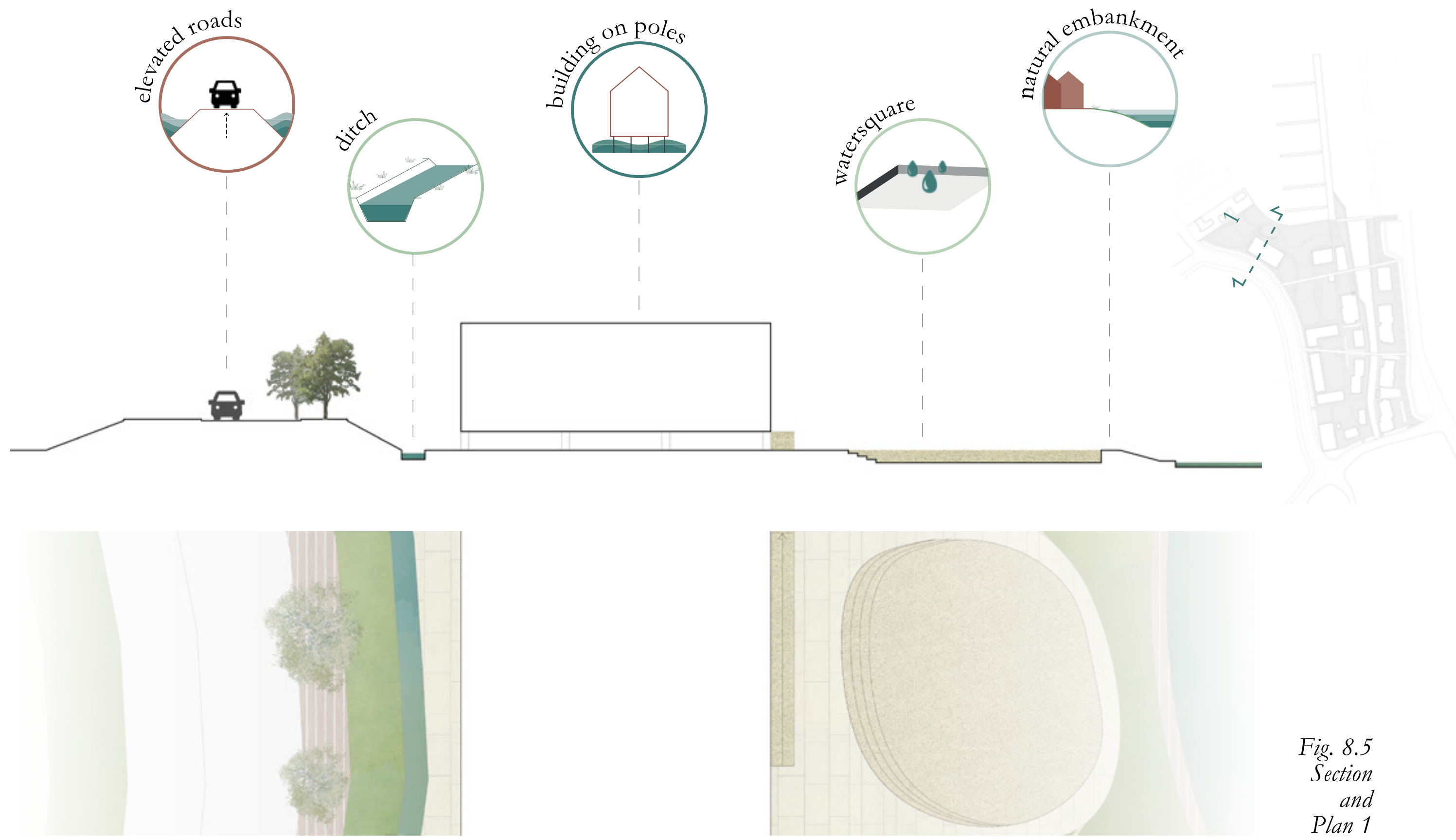


Fig. 8.5 Section and Plan 1

Section and Plan 1 (Figure 8.5) show a possible configuration of the immediate waterfront area, where an important facility could be located for the community, e.g., a music hall. The building stands on poles, which avoid it to be flooded, while it is surrounded by an urban lanscape apt to interact with the water in different ways. The boardwalk is complemented by a natural embankment, creating a flexible buffer zone for the water to flow and a pleasent recreational space to enjoy the proximity of the sea. The water square in front of the music hall can be used as open theatre in "dry" conditions, while turning into a pond with a fountain in case of water rising. The ditch plays an important role in the diversion of the water during storm surges. In order to protect one of Henån's main road, this has been elevated with the addition of parking lots and a green pedestrian path connecting the whole site.

Section and Plan 2 (Figure 8.6) offer a comprehensive view of the entire site from West to East, on the two sides of the canal: the area is "enclosed" within the two main roads (Ängsvägen and V160) which are elevated in order to be protected, and they serve as safe zones in case of significant flooding events. The connection between the two sides is constantly guaranteed by the creation of a pedestrian path on poles, which crosses the entire site, reprising the role of the two existing bridges. The elevated passage can also be used as access for emergency vehicles. Moreover, it is openable in different parts, in case taller vehicles are required to pass underneath.
The public open spaces differ from each other in various ways, according to their role in the water management and to the spatial experience that they provide.

The western green area is, here, designed as a raingarden, offering a variety of flowers and plants that create a biodiversed environment and can work as a storage area in case of water runoff. Designed according to the future sea level of +1 m to be reached by 2100, it will, therefore, eventually be covered by water, turning into the new waterfront.
The watersquare, thus, finds itself facing a projected waterfront, as well as directly interacting with the adjacent culture house, a focal point for Henån's community. It represents the heart of the urban settlement, setting a stage for cultural events or markets, while contributing to the management of the water in excess by storing in it in case of necessity.
Along the canal, a series of strategies, like natural embankments and stairs, bring the inhabitants closer to the water and, at the same time, support the drainage system.

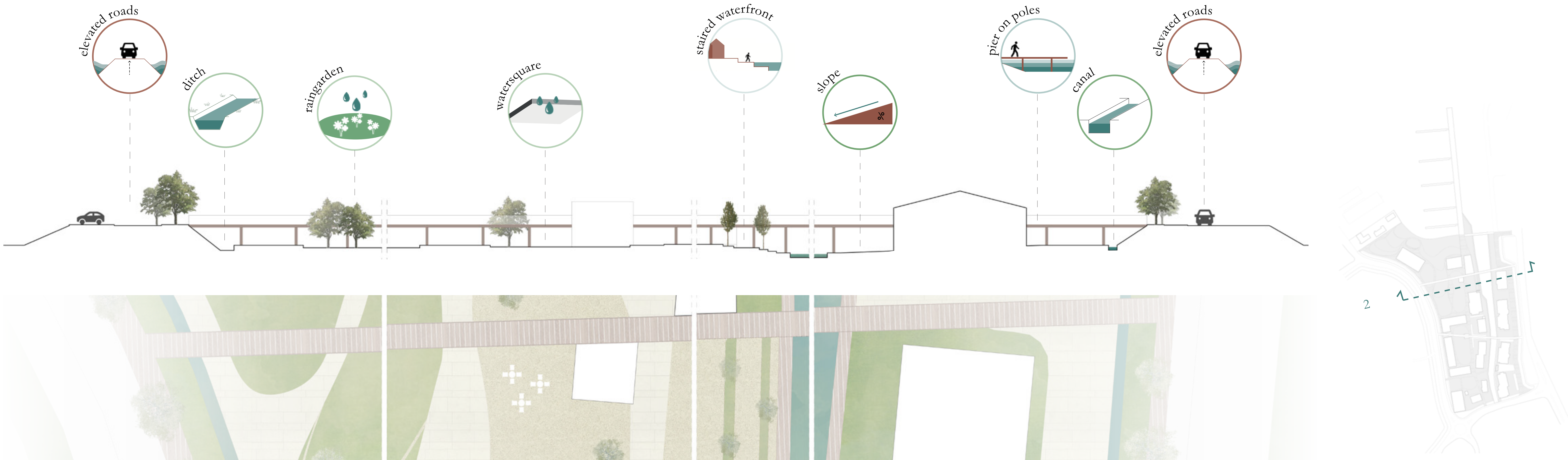


Fig. 8.6 Section and Plan 2

As well as *2*, *Section and Plan 3* (Figure 8.7) show a cross-view of the entire site, across the canal and within the main elevated infrastructures, which are connected by a second pedestrian path on stilts.
The main public space is represented by the water square surrounded by commercial activities and offices: old and new buildings interact with a central garden and playground, which become a storage area in case of flooding. The water is, then, diverted and drained thanks to the ditch and the bioswales closely located: these turn, from being simple green corridors, into canals, creating an interesting waterscape in the urban settlement.

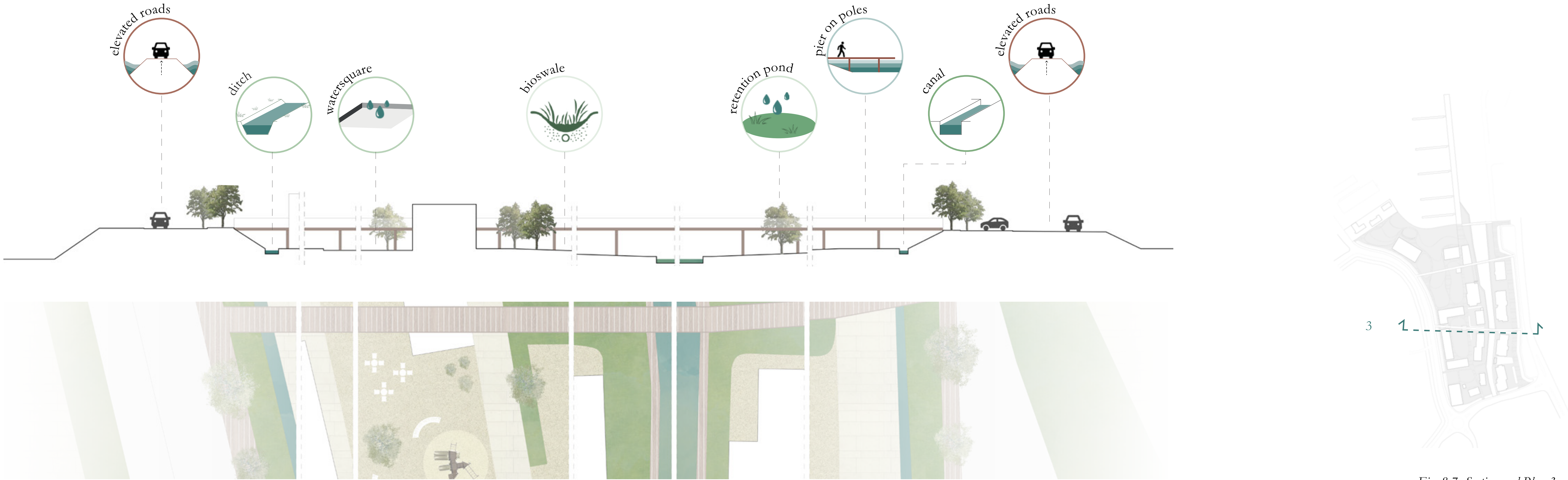
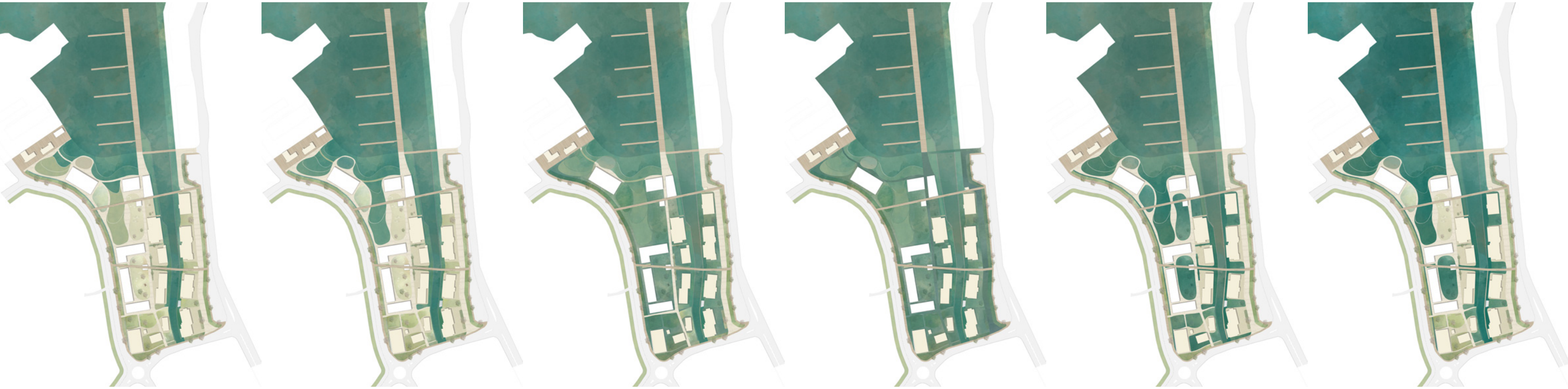


Fig. 8.7 Section and Plan 3

Fig. 8.8 Visualization of the response of the urban system to a flooding event



+ 0.5 m

The natural embankments leave space for the water to come in.

+ 1 m

A new coastline is formed, as the urban scape is shaped by the water.

+ 1.4 m

The primary and secondary infrastructures provide escape routes to the safe zones.

+ 2.5 m

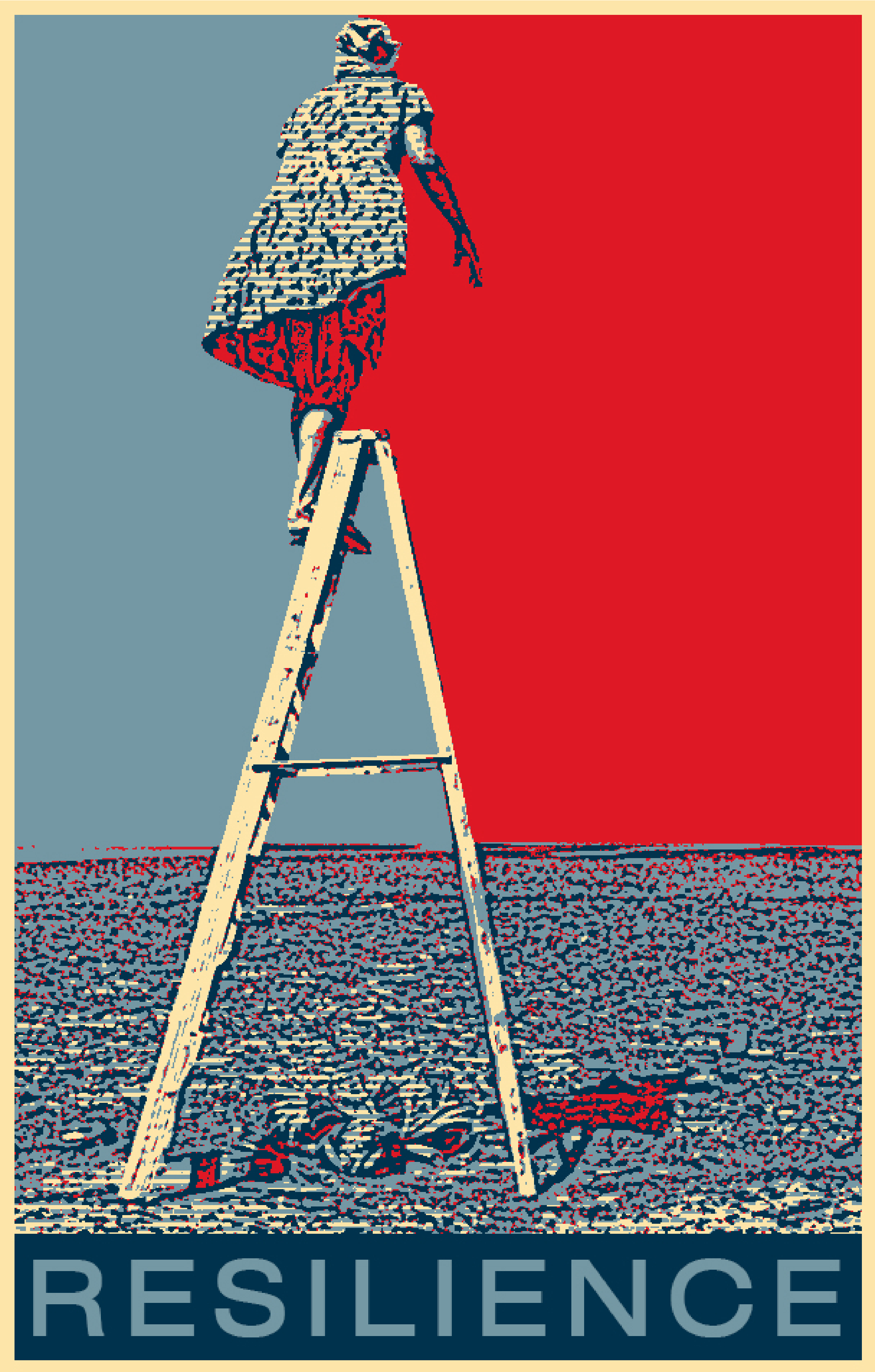
The primary infrastructure offers accessibility to the site through both movable and fixed structures.

Diversion and Storage phase

The water is diverted to the storage areas through canals, slopes, and ditches.

Storage and Drainage phase

The water is slowly drained to the main green storage areas, and eventually drained back to the sea.



What's Next?

Conclusions and further discussion

Sea level rise and flooding risk represent new conditions that our urban environment will need to face more and more in the near future: if nothing will be done to mitigate the causes of these events, their ackowledgment as part of our urban lives will be inevitable. Cities, in the form of institutions and practitioners, have been applying different strategies in order to deal with change; from constructing solid barriers between the land and the water, precluding any interaction between the two, to relocating buildings and communities, refraining from dealing with the problem in the first place. These solutions have brought sometimes more damage than a real flooding event would have caused, resulting in socio-economic-environmental challenges which could have been avoided following a resilient approach. Flood-protection solutions attempt to present the delusive image of a *resistant* city, while rare but catastrophic events provide lessons at high prices. A shift in the approach towards flood management would turn the focus to building *resilience*, rather than maintaining stability (Liao, 2012). Every flooding event becomes, therefore, an opportunity to build knowledge and to work on the structure of the system in order to make it more flexible. An urban system presenting high transformative capacity can adjust itself through iterative processes, acknowledging the flooding events as part of its dynamics and continuously learning from them.

This Master Thesis attempts to provide a methodology in order to tackle flooding adaptation from a resilient perspective, while making a step further and turning the flooding risk into an opportunity for the urban system to develop. Embracing the presence of water becomes, therefore, the main feature of the future urban scape, from which multiple benefits can be gained. Every element of the system interacts with the water at different rates and times, creating a dynamic landscape which can successfully cope with both a temporary and a permanent condition of rising sea level. The design strategies aim at safeguarding people and properties, offering flexibility in the use of public spaces, and managing the water runoff, while establishing a stronger relationship between the community and its natural environment, currently hardly perceived.

The design strategy challenges the norm of a single desirable regime for an urban system, which would be presented uniquely in a "dry" condition. Overcoming the "threshold" (a flooding event) thus means for the system to learn from this experience and react to it, adjusting itself and reaching a new configuration; this is positively different from the previous one, as new, diverse, qualities are discovered. The flooding risk can, therefore, turn into an opportunity, as the Adaptation Strategies can make an urban system reach more than just adaptation goals. How can we define these other opportunities?

• *The achievement of new urban qualities from a social, environmental, and economic sustainability point of view.* For instance, public spaces and green areas can enhance recreational opportunities and biodiversity in Henån's city center, as well as significantly contribute to the management of water runoff. Moreover, the development of a waterfront able to cope with an inevitable sea level rise can bring important benefits from an economic and touristic perspective.

Fig. 9.1 Image produced by the author, inspired by the Venice Biennale of Architecture 2016 cover picture (by Bruce Chatwain)

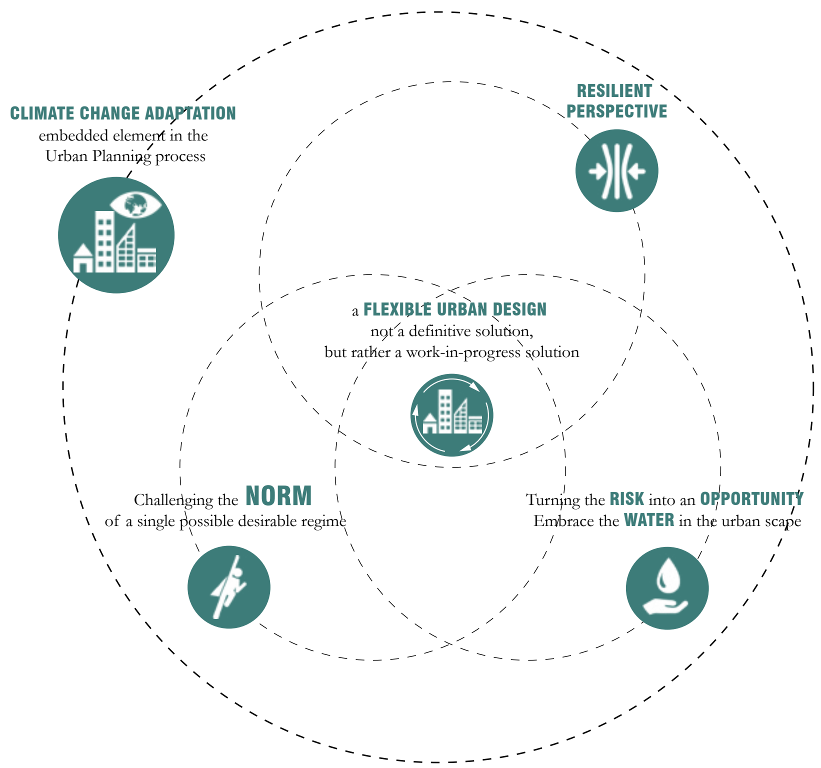
• *The development of flexible cities, able to withstand changes, disturbances, unpredictable challenges, without denying their identity.* Cities and communities have always established themselves on the border between land and water, and this cultural identity should be preserved. Urban settlements should not surrender or move further from the sea, but, instead, learn to handle the new challenges and evolve, applying strategies that ensure flexibility. For instance, the use of amphibious structures, whether buildings or infrastructures, guarantees their functionality in case of rising water levels, without precluding their accessibility to the people and the continuation of water-related activities happening along the waterfront, which may represent important features of the place (e.g., shipyards).

• *The attempt of creating a harmonic coexistence of humans and nature in the same environment, without preventing one another from expressing themselves.* The sea level is rising, caused by human actions, and it will not stop unless something is done immediately. In the meantime, cities have to live with this challenge without compromising their features and functionality, while preventing major damages from happening. Creating room for the water to come in and become part of the urban scape acknowledges its presence and does not constrain it within hard barriers. The water is free to flow and become a protagonist in the urban system. Nevertheless, the city is designed in order to provide facilities, infrastructures, and public spaces which would not be put at risk by the sea level rise, but rather embrace it and persist through the change of conditions. Water squares are an example of that, as they can be used for markets, recreational activities, or cultural events, while turning into fountains or ponds in case of a flooding event, offering a pleasant spatial experience in any case. Furthermore, the waterfront itself is designed as a flexible space, through natural embankments or stairs, giving the water room to move inland, although ensuring the accessibility to the pedestrian path along the shoreline, guaranteeing a continuous walking passage despite the level of the sea.

The implementation of this approach raises further issues and challenges, which highlight the complexity of the matter.

As a starting point, the acknowledgment of Climate Change Adaptation as a necessary component of Urban Planning processes is still far to be accomplished by municipalities. Understanding the risks and developing a strategy to face these challenges often contrast the weight that economic, ownership, and management issues have in these matters. It becomes hard to set priorities, while maintaining a long-term perspective: the political framework in which urban policies are developed plays a crucial role, weakening the capacity to go beyond immediate gains and results. At the same time, the necessity of finding sustainable ways to implement these strategies is undeniable; a possible suggestion could be to work through progressive stages in the adaptation process, not aiming at carrying out all the strategies at once, but rather setting smaller steps to achieve, as part of a wider approach.

Finally, architects, urban planners, and practitioners have great responsibility towards the development of resilient cities, coming up with sustainable strategies, aspiring to the creation of constantly new and dynamic spatial experiences. The recognition of their role within urban development discussions is, therefore, fundamental: designers, who care and are knowledgeable about these issues, need to be involved in the conversation by municipalities and decision-makers, contributing with their expertise to the creation of a positive legacy for our cities for the future.



Open Seminar

Exhibition's Posters (28th May - 4th June 2018)

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