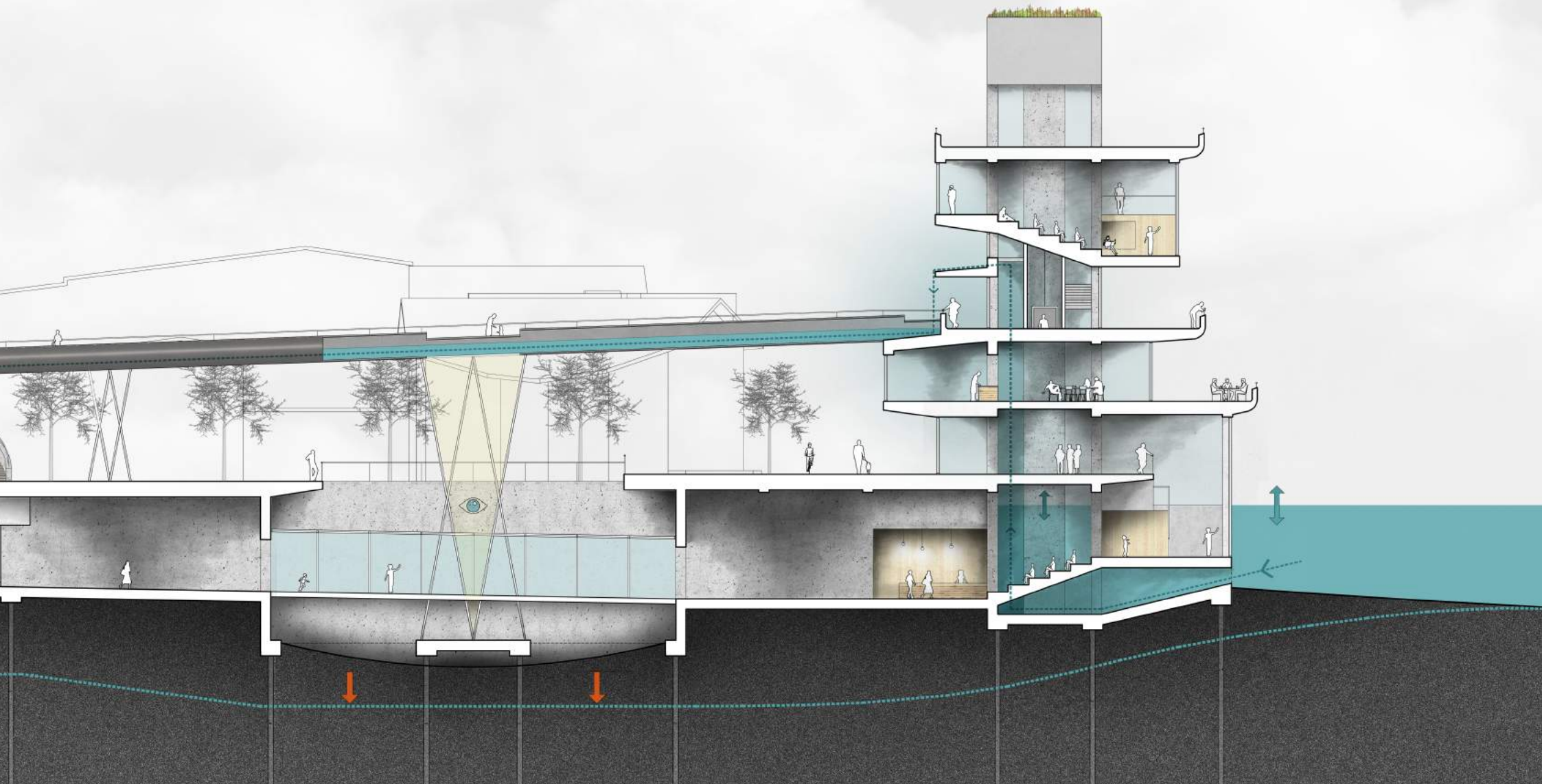
ELEVATORN 2.0

Architecture that amplify and mitigate the risk of land subsidence and sea level rise

A master´s thesis by Jens Andersson
Uddevalla, Sweden, spring 2018

Chalmers School of Architecture
Department of Architecture & Civil Engineering
Architecture and Planning Beyond Sustainability, MPDSD

Examiner: Emilio da Cruz Brandao
Supervisor: Joaquim Tarrasó



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Master's thesis at Chalmers School of Architecture
Department of Architecture & Civil Engineering
Master program Architecture and Planning Beyond Sustainability, MPDSD
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Examiner: Emilio da Cruz Brandao
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CHALMERS
UNIVERSITY OF TECHNOLOGY

STUDENT BACKGROUND

Jens Andersson was born and raised in Uddevalla, on the Swedish west coast. Since upper secondary school has he studied engineering at Chalmers University of Technology (2007-2010) and practice as a designer of prefab concrete elements (2007-2013). However, he wanted to be involved earlier in the building process and he lacked the creative and visionary part of his work life. Then he decided to follow his childhood dream of becoming an architect. He did his Bachelor of Architecture in Umeå (2013-2016) before he returned to Chalmers and started the master program Architecture and Planning Beyond Sustainability (2016-2018).

"For me is the essence of architecture to reveal the hidden potentials of a given environment. The combination of site specific architecture and system thinking approach has characterized my previous projects. Site specific architecture can help people feel the sense of where they are in space and time. By increasing the understanding of the place, makes people value it more and therefore caring for it better. An environment cared for will be more enjoyed, which hopefully can increase the sense of belonging and pride among the local community. This system thinking approach can also be used to mobilize existing resources and create synergy effects, where bi-products from one actor is always a nutrient for someone else. I believe that site specific architecture and system thinking approach has the potential to involve and inspire people to live in a more efficient, resilient and sustainable way. This master´s thesis represents an opportunity for me to explore these topics in my hometown Uddevalla, where I belong."

Jens Andersson

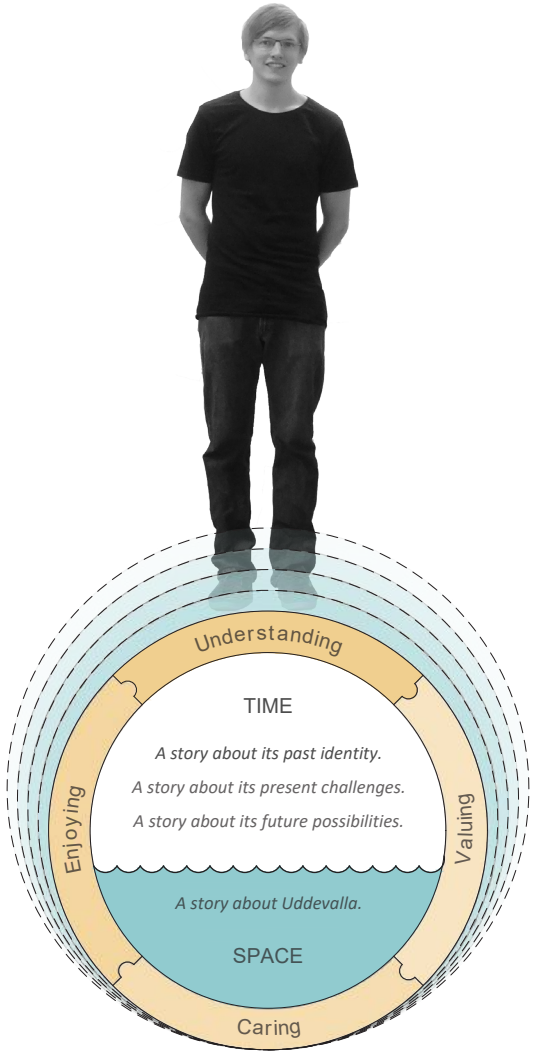


Figure 1. Architectural approach. Author's own copyright.

ACKNOWLEDGEMENTS

This Master´s thesis would not have been possible without support and help along the way. A special thank to...

...my supervisor Joaquim Tarrasó for your support and guidance during my periods of hope and despair.

...my examiner Emilio Brandao for your engagament and valuable inputs.

...my nearest friends and family who always supported me when I needed it the most.

I dedicate this work to you all.

Educational background

Master of Science in Architecture (2016-2018)
Architecture and Planning Beyond Sustainability
Chalmers University of Technology, Göteborg

Bachelor of Fine Arts (2013-2016)
Architecture
UMA School of Architecture, Umeå

Bachelor of Science in Engineering (2007-2010)
Building engineering
Chalmers University of Technology, Göteborg

Work experiences

Internship (2016-2018) & Employment (2018-)
Architecture
Contekton Arkitekter Fyrstad AB, Vänersborg

Internship (2007-2010) & Employment (2010-2013)
Precast concrete designer
Kynningsrud Prefab AB, Uddevalla

ABSTRACT

This master thesis tries to add another mindset to the discussion of flood protection strategies through an integrated approach that is not only dealing with sea level rise, but also land subsidence or falling land levels. The purpose is to demonstrate how to live in more symbiosis with these landscape dynamics and thereby question the human history of controlling and disturbing natural processes. Land subsidence and sea level rise are increasing the risk of flooding and causing more environmental damages every year. However, people rarely see or experience these environmental changes on site, nor understand the reason why they are happening and how they can be prevented. So, how can architecture amplify and mitigate the risk of land subsidence and sea level rise?

The Swedish west coast city of Uddevalla has suffered from repetitive floods ever since the industrial revolution, when the city started to expand onto its shallow river delta floodplain. The river delta was filled-up with dredged river sediments by means of a temporary building called "Elevatorn 1.0". This land reclamation helped the trading city of Uddevalla to grow, but it also reduced the city´s flood capacity and discharged its ground water table. Consequently, most parts of the filled-up river delta are compressing and therefore sinking. Because of its poor geotechnical conditions are large parts of the riverfront even closed for public use. At the same time is the dynamic river level rising much due to the global warming process that also began during the industrial revolution. Consequently, Uddevalla has become the forbidden river city.

Literature studies of the past helps to inform and anchor the future design proposal. Since Elevatorn 1.0 helped to reduce the waterbody in Uddevalla does "Elevatorn 2.0" re-make space for water and re-connect people with the natural water cycle. Unlike Elevatorn 1.0 is Elevatorn 2.0 a multifunctional building that complements the municipal flood protection strategies, while also offering public spaces for the local community. However, Elevatorn 2.0 serves mainly as an architectural exhibition that spatially and pedagogically tries to express the consequences of the disturbed water cycle and showcase the opportunities of a re-balanced water cycle in future. The design proposal is a combination of architecture, landscaping and engineering that amplifies and mitigates the dynamic changes of land and water by artificially stimulating the natural water cycle.

Instead of being a destructive force could water become an element embedded in the dynamic landscape, creating new urban qualities and achieving a re-balanced water cycle. Elevatorn 2.0 tries to turn the problems of sea level rise and land subsidence into spatial opportunities, which can motivate people to discover and conserve their local environment and cultural history.

TABLE OF CONTENT

INTRODUCTION

Describes the aim, purpose and framework of the thesis

1.0

BACKGROUND

Water is in our soul and stimulates our senses. Humanity has for a long time been attracted to convenient sources of water. Access to water was fundamental to the transition from nomadic cultures to human settlers and most settlements were founded along rivers, by lakes or by the sea. People were dependent on the water quality since they used it, lived with it and consequently respect it. However, since the industrial revolution has the old wisdom about living with water been replaced by a short-term profit demand of human greed. To whatever costs has human arrogance ever since tried to control Mother earth, rather than to learn from her. Contrary to the past, has our natural heritage of water been exploited, mistreated and contaminated. Consequently, the natural water cycle has been disturbed by means of human impact and human life has increasingly lost their strong relationship to water (Barker & Coutts, 2015).

Global warming is increasing the amount of water in atmosphere due to the human impact of deforestation, land use changes and burning fossil fuels. Simultaneously is the water storage capacity in cities decreasing due to the urbanization processes of land reclamation and ground water extraction. An increasing urban population globally demands bigger cities that in turn leads to more impermeable surfaces and an increased drinking water demand. The infiltration rate is lowered and the groundwater table drops, which leads to falling land levels (land subsidence) in especially coastal cities that are built on soft soils. Land subsidence and sea level rise are increasing the risk of flooding and causing more damages every year on buildings and infrastructures (Deltares, 2015). However, people rarely see or experience these environmental changes on site, nor understand the reason why they are happening and how they can be prevented (Angelöw, Jonsson 1994).

PURPOSE

Water is going to be a burning issue as urban densification and climate change will change the way we live. To conquer the increased flooding risk are often flood protections relied primarily on artificial flood defences that may be overtopped due to a sinking land and underestimated flood levels. This thesis will rather demonstrate how to live with the increased flooding risk in a more interactive and non-defensive way. Instead of getting water out of the city as quickly as possible could we keep it and use it as an element of attraction, where people want to go and visit (Barker & Coutts, 2015). This thesis explores the possibility of reducing the vulnerability of land subsidence and sea level rise through architecture that can turn these challenges into spatial opportunities. The intention is to demonstrate the advantages to live in more symbiosis with the natural water cycle and thereby question the history of human arrogance of controlling and disturbing natural processes.

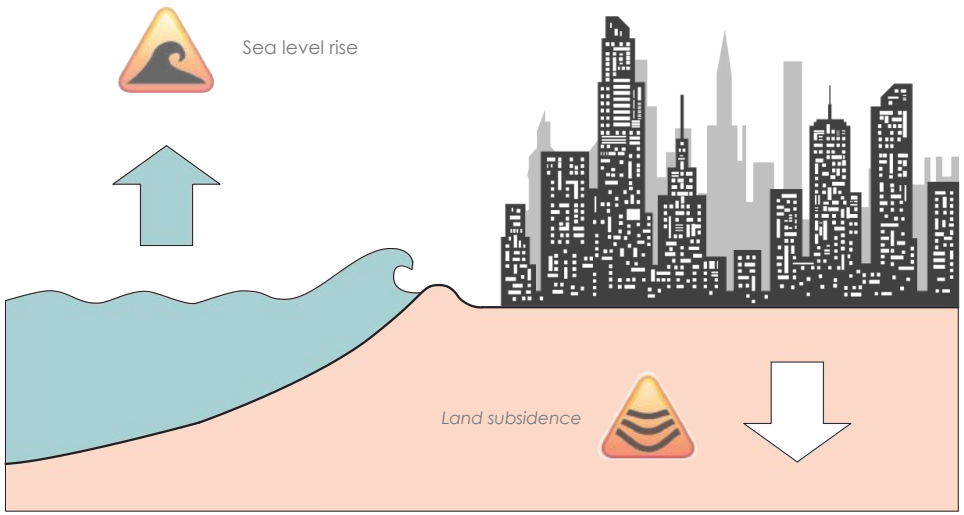
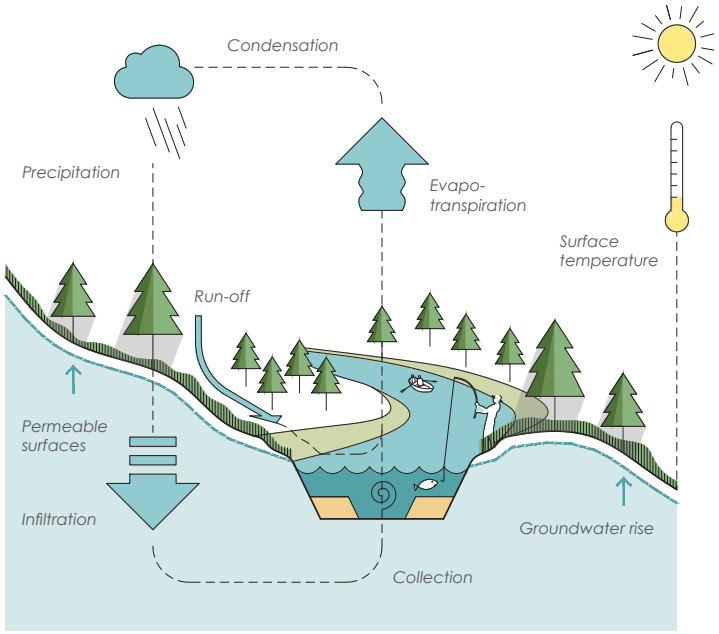


Figure 2. Sea level rise and land subsidence. Author's own copyright.

Figure 3. Re-balance water cycle. Author's own copyright.

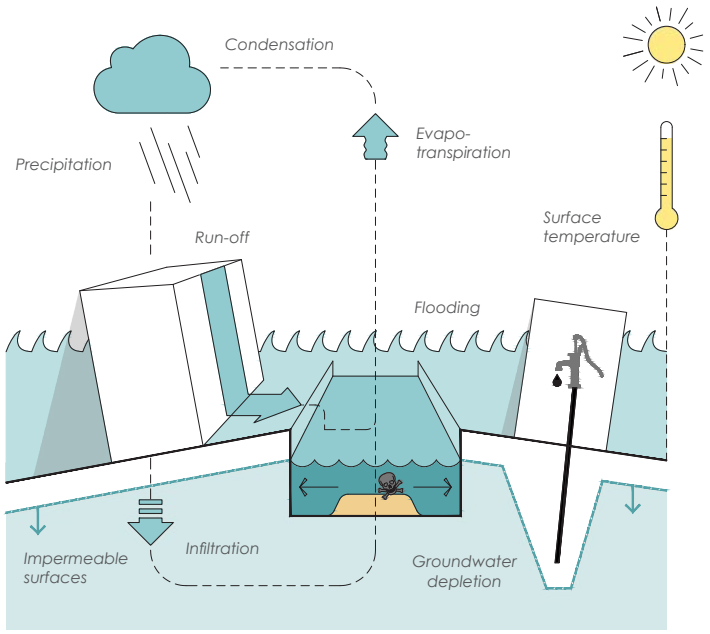
Balanced water cycle



Balanced water cycle in natural rivers

Re-balance water cycle

Disturbed water cycle

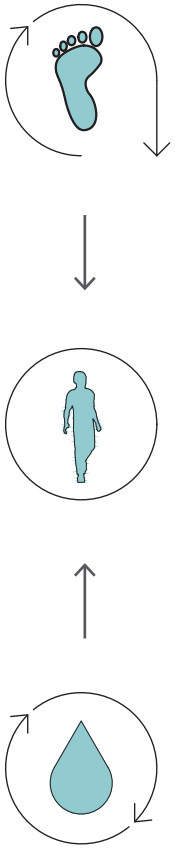


Disturbed water cycle in urban rivers

Re-connect people to a re-balanced water cycle

AIM

This thesis aims to explore how an architectural typology can help to re-balance the water cycle, to mitigate the flooding risk and also provide environmental gains. The thesis tries to create a stronger emotional connection to the nature of a particular place. Both the research and design have an informative agenda with three common objectives:



Enlighten the cultural history behind the locally disturbed water cycle

Offer a spatial experience of the cultural history and the re-balanced water cycle

Increase the knowledge of how to maintain the re-balanced water cycle

THESIS QUESTION

How can architecture amplify and mitigate the risk of land subsidence and sea level rise?

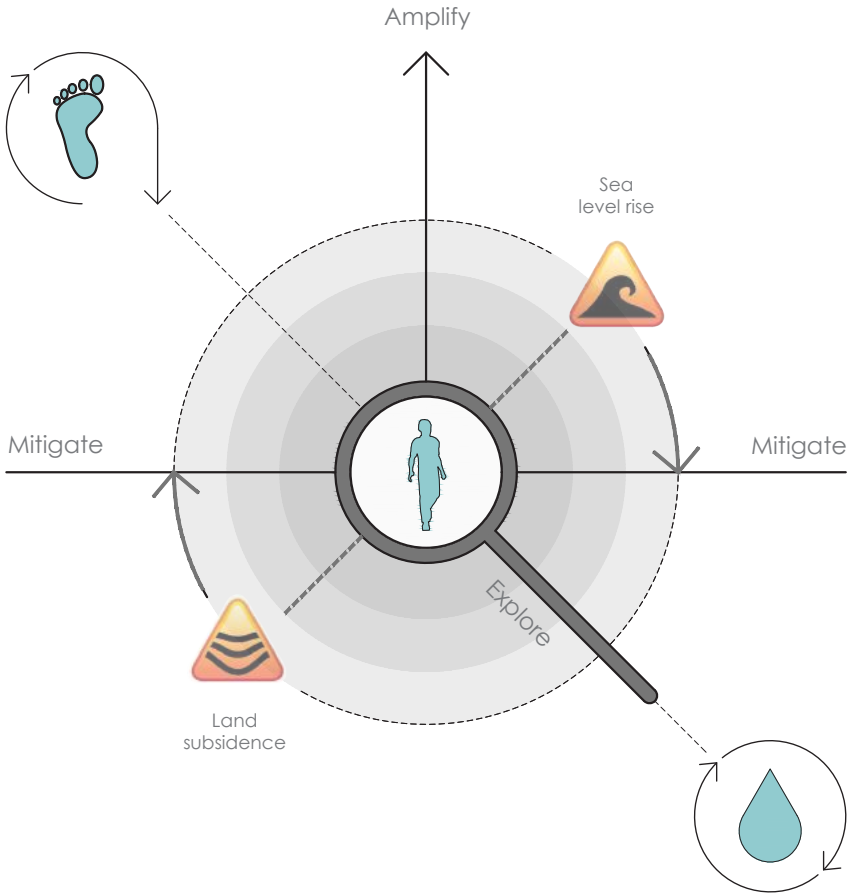


Figure 4. Thesis aim. Author's own copyright.

METHOD

The method is based on a historical research that enlightens the local uniqueness of a particular place, while the design tries to fill it with something meaningful. Literature studies of the past have helped to inform and anchor the future proposal. In this way has the project a Research by Design approach where the research is contextualized through design, while the design is conceptualized through research. It has been an iterative process of constant reflection and evaluation to make sure that the design becomes a clear part of the research and the other way around.

"He who does not know his past cannot make the best of his present and future, for it is from the past that we learn"

Zayed bin Sultan Al Nahyan

(Motivate Publishing, 2018)

"Those who cannot remember the past are condemned to repeat it"

George Santayana

(Santayana, 1905)

The design process is based on an analysis of the cultural history behind the locally disturbed water cycle.

The design proposal is structured like the historical timeline of the research, where visitors experience the cultural history and re-balanced water cycle spatially and simultaneously.

The research findings are transferred into spatial design principles to re-balance the water cycle.

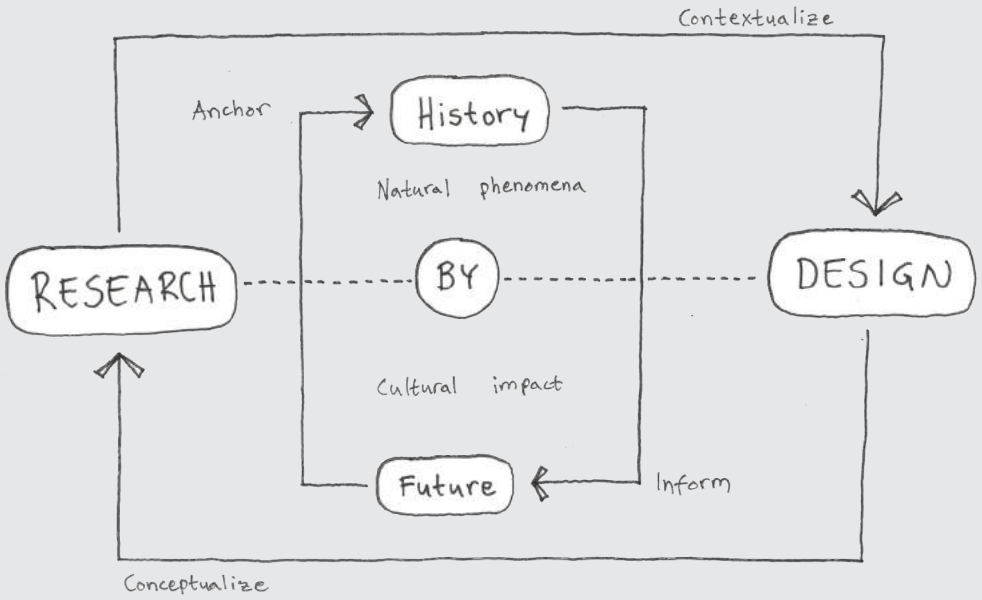


Figure 5. Research by design approach. Author's own copyright.

DELIMITATION

This thesis investigates how the interface between architecture, landscape and engineering can mitigate floods by providing more space for water in our cities. The focus is to explore the opportunity of combining natural and artificial systems to create a more inhabitable and resilient environment. From a historical research are evidences of a locally disturbed water cycle re-interpreted into future opportunities. The research findings are turned into an architectural exhibition with focus on a spatial and pedagogical experience of the local history and the re-balanced water cycle.

Even though the project applies an integrated approach are interdisciplinary collaborations and community participation excluded in the project. Existing knowledge from different disciplines is instead merged into new knowledge, in order to open up an interdisciplinary discussion in future.

In general are non-defensive principles of flood mitigation and flood adaptation explored in favour for the defensive approach of flood protection. However, the building design is flood resistance and static to amplify and express the dynamic changes of land and water. The design focus on the conceptual level of a public building, rather than on its construction and adjacent landscaping.

No focus *More focus*

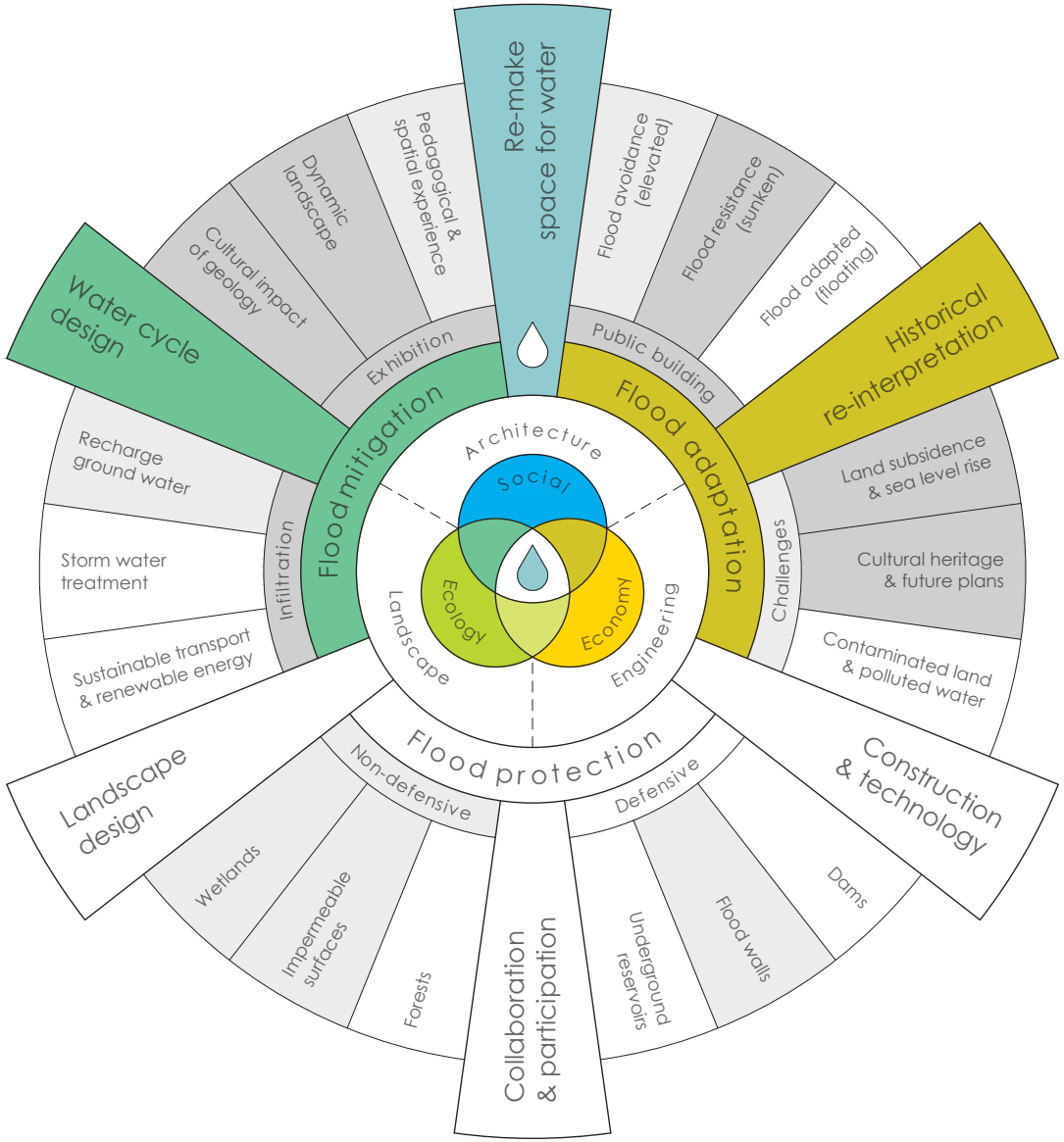


Figure 6. Delimitation chart. Author's own copyright.

THEORY

Make Past...
The literature study is based on a historical research about the cultural processes behind the forbidden city of Uddevalla (Nordlund, 1983; Hasselmo, 1980; Bohusläns museum, 2018; Bohusläns hembygdsförening, 1981; Kristiansson, 1936; Klasson, 2008, 2011, 2012). These local history is combined with more generic literature about cultural impact on the natural water cycle (Alexandersson, 1979; Alley, Reilly, Franke, 1999; Cengiz, 2013; UN-HABITAT, 2014).

...Present...
In order to describe the current situation has facts and future predictions about sea level rise and land subsidence been analysed both locally (Vestøl et al., 2016; Klimatanpassningsportalen, 2017; Fredgren, 2016; WSP, 2016; SMHI, 2018) and globally (IPCC, 2013 & IPPC, 2014).

... in our Future
Municipal documents have also been studied to position the design proposal in relation to the future city expansion and flood protection plans in Uddevalla (Uddevalla kommun, 2016; WSP, 2016). The design intention and proposal are based on the findings found in the research of the past, present and future conditions.

READING INSTRUCTIONS

This thesis is divided into the 5 chapters below, where the research and design are structured according to the same historical timeline. The timeline is in turn divided into four periods of cultural driving forces behind the forbidden city of Uddevalla (see Figure 7).

1.0 INTRODUCTION

Describes the aim, purpose and framework of the thesis

2.0 RESEARCH

Investigates the cultural history behind the sinking land and rising water in Uddevalla

3.0 INTENTION

Defines the design intention from the research findings in terms of concept, vision, strategies and site location.

4.0 DESIGN

The thesis result works as an architectural exhibition and community space that amplify and mitigate the forbidden city phenomena in Uddevalla

5.0 REFLECTION

Reflects upon the thesis topic and concludes with an answer to the research question

1.0 INTRODUCTION

Figure 7. Reading instructions. Author's own copyright.

2.0 RESEARCH

3.0 INTENTION

4.0 DESIGN

5.0 REFLECTION

2.1 **DEFORESTATION**

Disturbed the local soil infiltration

2.2 **LAND RECLAMATION**

Sinking land because of a reduced waterbody

2.3 GLOBAL WARMING

Increasing the amount of water in atmosphere

2.4 WATER DEPLETION

Lowering the ground water table in earth

Findings

Findings

Findings

Findings

4.1 **THE INFILTRATOR**

Infiltrating water and people underground

4.2 **THE SUBSIDENCER**

Expressing sinking archaeological layers

4.3 **THE AQUEDUCT**

Bridge inbetween sinking land and elevated water

4.4 **THE ELEVATOR**

Re-directing water and expressing the dynamic sea level

Past

Present

Future

RESEARCH

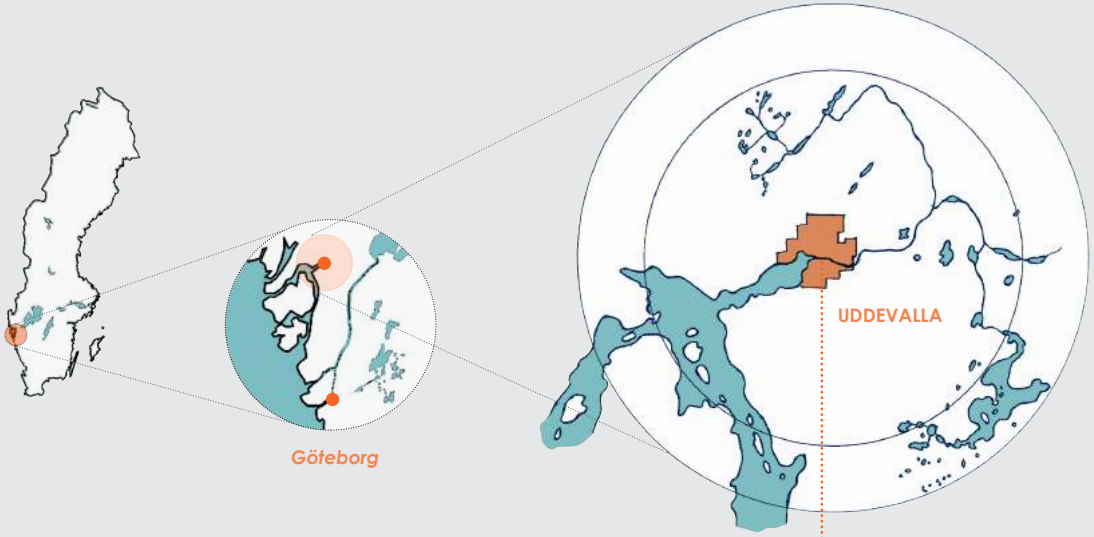
Investigates the cultural history behind the sinking land and rising water in Uddevalla

2.0

PRESENT CONTEXT

Uddevalla is both a municipality and city that is located on the Swedish west coast. The city is situated in a low-lying valley, where the fjord Byfjorden intersects with the river Bäveån. Uddevalla has suffered from repetitive floods since the industrial revolution, when the city started to expand onto its river delta land. Worst scenario is during western storms and heavy rainfalls, when water from the fjord is pushed into the city river that is also filled up by surface water. The past water storage capacity has been drained by cultural impact and most parts of the filled-up river delta is compressing and therefore sinking. Because of its poor geotechnical conditions are large parts of the riverfront even closed for public use. Uddevalla has become the forbidden city and it needs to allow more space for water in future, as the river delta did in the past.

Figure 8. Research context. Author's own copyright.



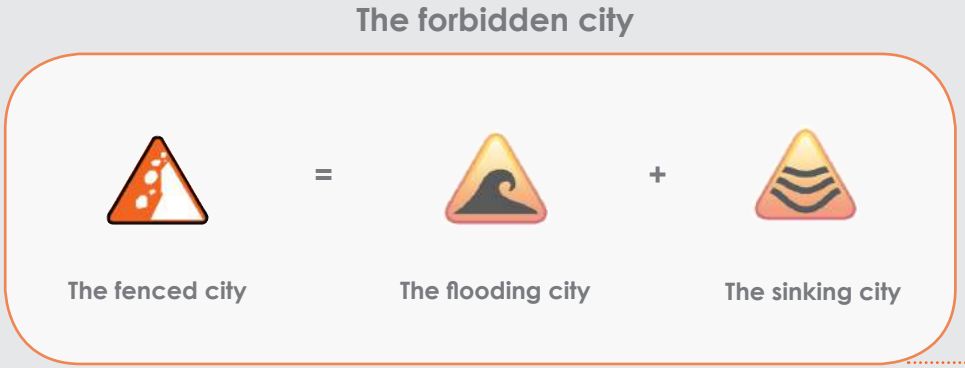


Figure 10. The forbidden city. Author's own copyright.

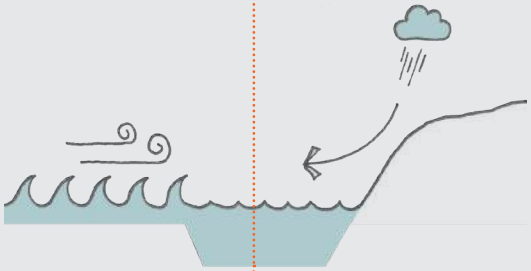


Figure 9. The valley city. Author's own copyright.

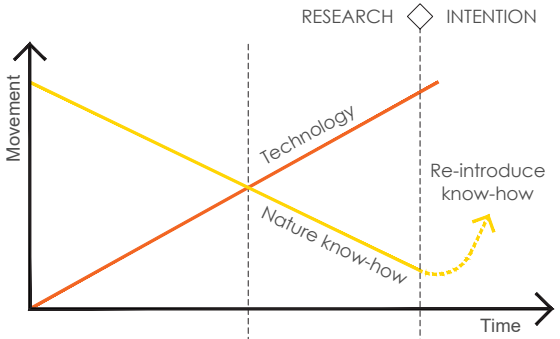
HISTORICAL CONTEXT

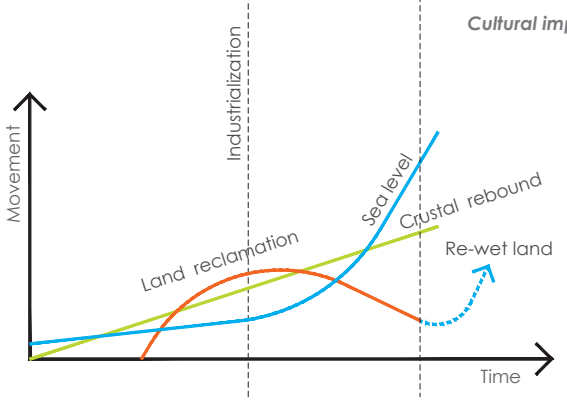
Figure 11. Historical research. Author's own copyright.

Past: Nature know-how
Natural flood protection
River delta exploitation

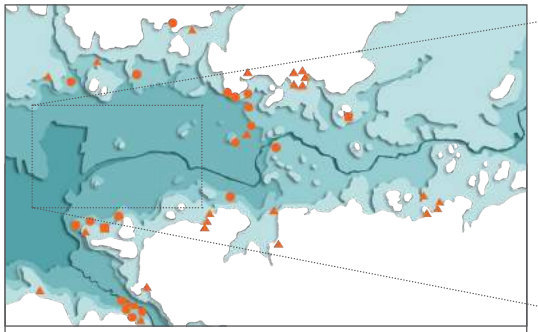
Present: Sinking river delta city
Rising water level
Repetitive urban floods

Future: Re-introduce know-how
Re-make space for water

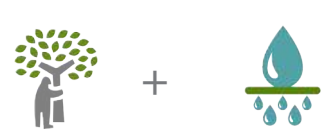




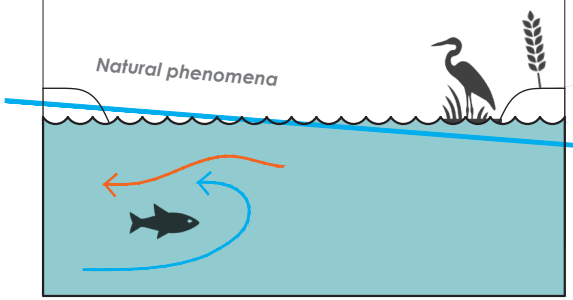
Ancient: First people
9000 BC - 4000 BC



Human settlements along the shoreline



Human nature + *Natural infiltration*

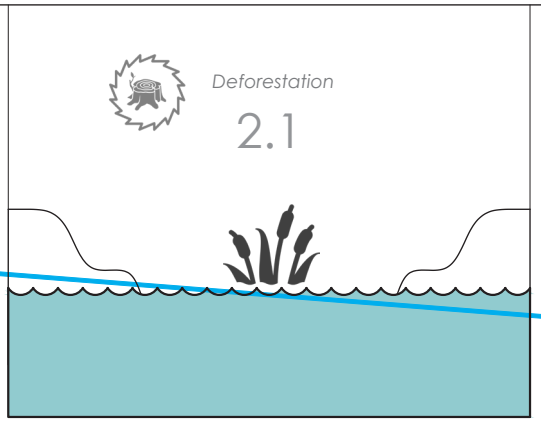


Nutrient land and water attracted the first people

Medieval: Trading city
1400 AC - 1500 AC

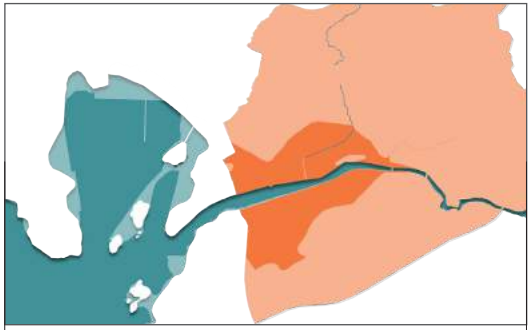
Market ····· River delta ····· City

Sailing ship *Trade* *Horse wagon*



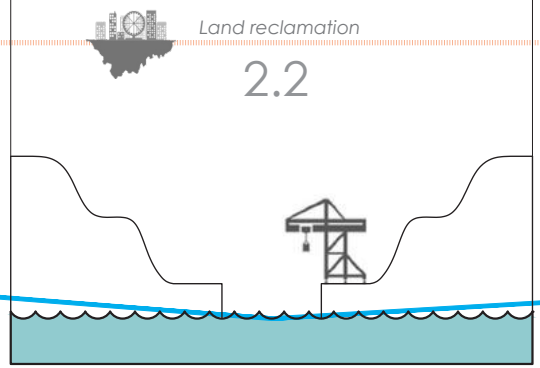
River delta as war and flood protection

Industrial: Harbour city
1850 - 1950 AC



Harbour ····· City

Steam ship Trade Steam train



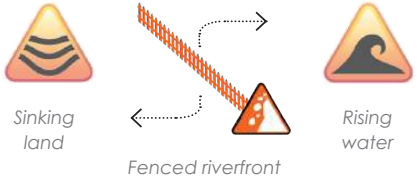
Land reclamation

2.2

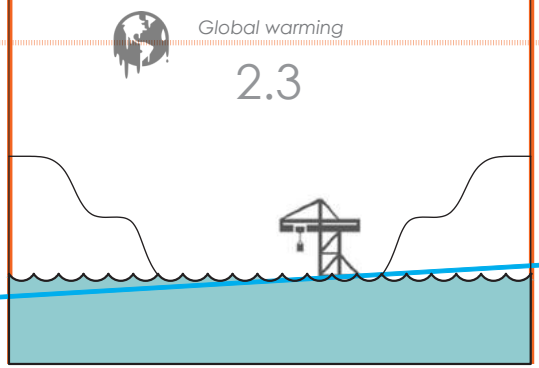
Harbour in city

Present: Forbidden city
2018 AC

Harbour ····· City



Sinking land Fenced riverfront Rising water



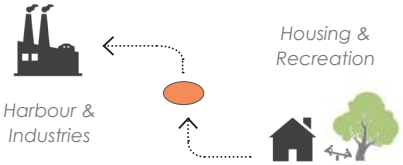
Global warming

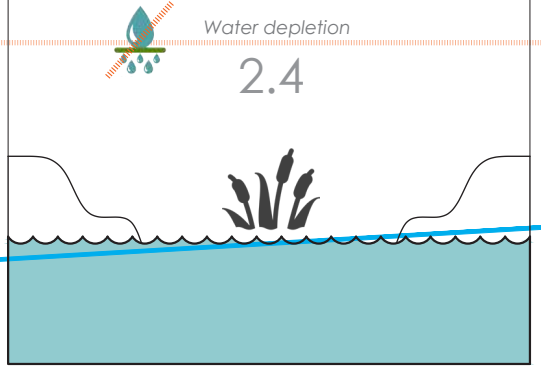
2.3

Repetetive flooding

Future: Waterfront city
2050 AC

Harbour ····· Waterfront city ····· Old City



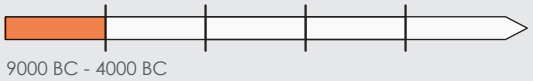


Water depletion

2.4

Allow more space for water

2.1 DEFORESTATION



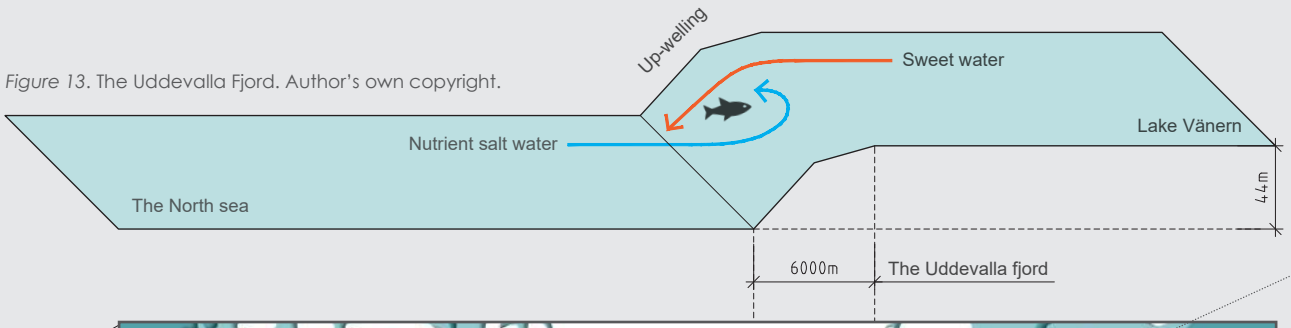
2.1.1 ANCIENT: FIRST PEOPLE

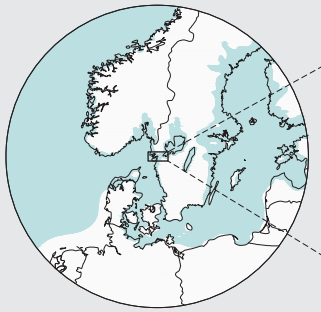
Scandinavia was covered by ice in over 100000 years which pushed down its topography. Around 18000 BC did the ice began to melt away, due to a warmer climate. Since the ice disappeared has the land been raised naturally, due to a crustal rebound response to the previous ice pressure. This vertical movement of land has since then increased more than the sea level of melted water in Uddevalla (SGU, 2011).

By means of the uplifting land was an archipelago in Uddevalla transformed into a fjord, which unified the lake Vänern with the North Sea. Through the fjord was sweet water flowed from the lake to the sea, while nutrient salt water welled-up from the bottom and created a nutritious environment (SGU, 2011). The fjord became narrower and more windy, until it was closed in 7500 BC (Bohusläns hembygdsförbund, 1981).

The lake Vänern is about 44 meters above todays sea level (Länsstyrelsen, 2017). In ancient time was at least this height difference of flowing water roaring through a distance of 6000 meters, where Uddevalla is located today (Bohusläns hembygdsförbund, 1981). Today´s modest river Bäveån has got its name from the powerful and roaring sound of its predecessor. The basic meaning of "Bäve" is namely "to shake" (Nordlund, 1983).

Figure 13. The Uddevalla Fjord. Author's own copyright.





9000 - 7500 BC

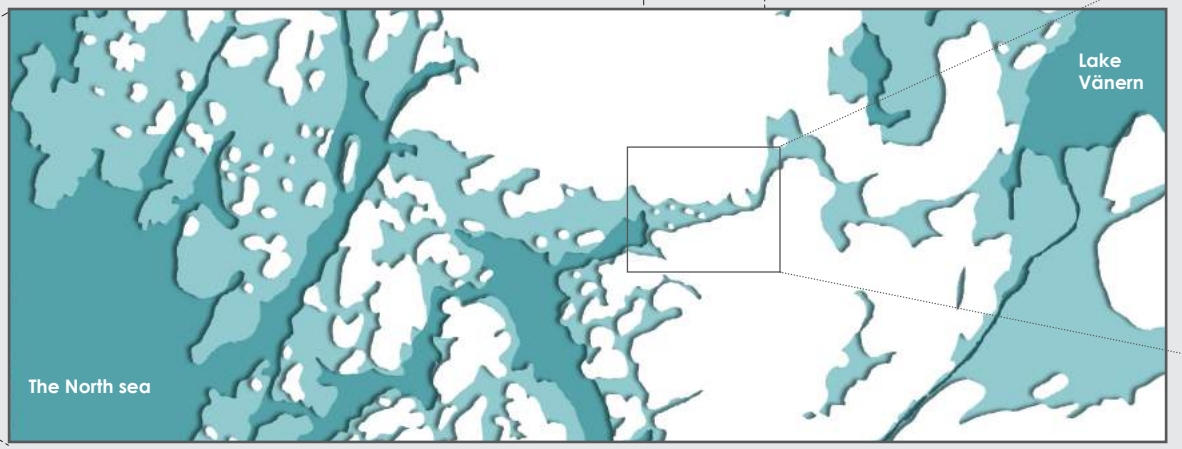
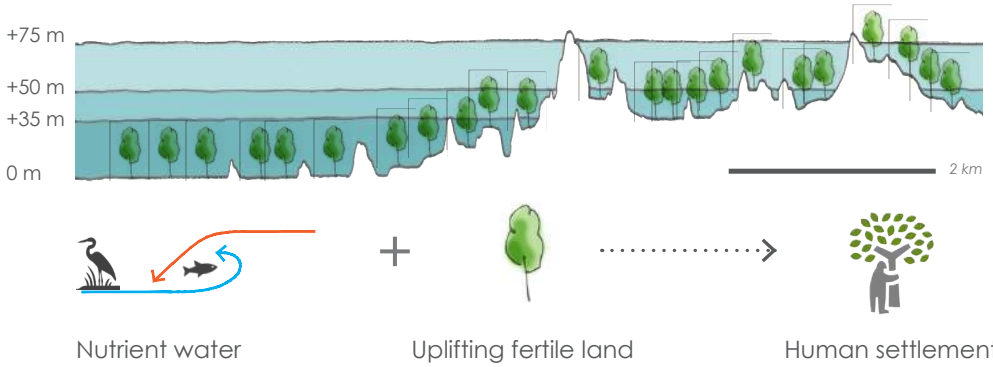


Figure 12. The coastline 60-65 m above current sea level (Bohusläns hembygdsförbund, *1981*). Adapted with permission.

Figure 15. Sea level change and valley topography. Author's own copyright.



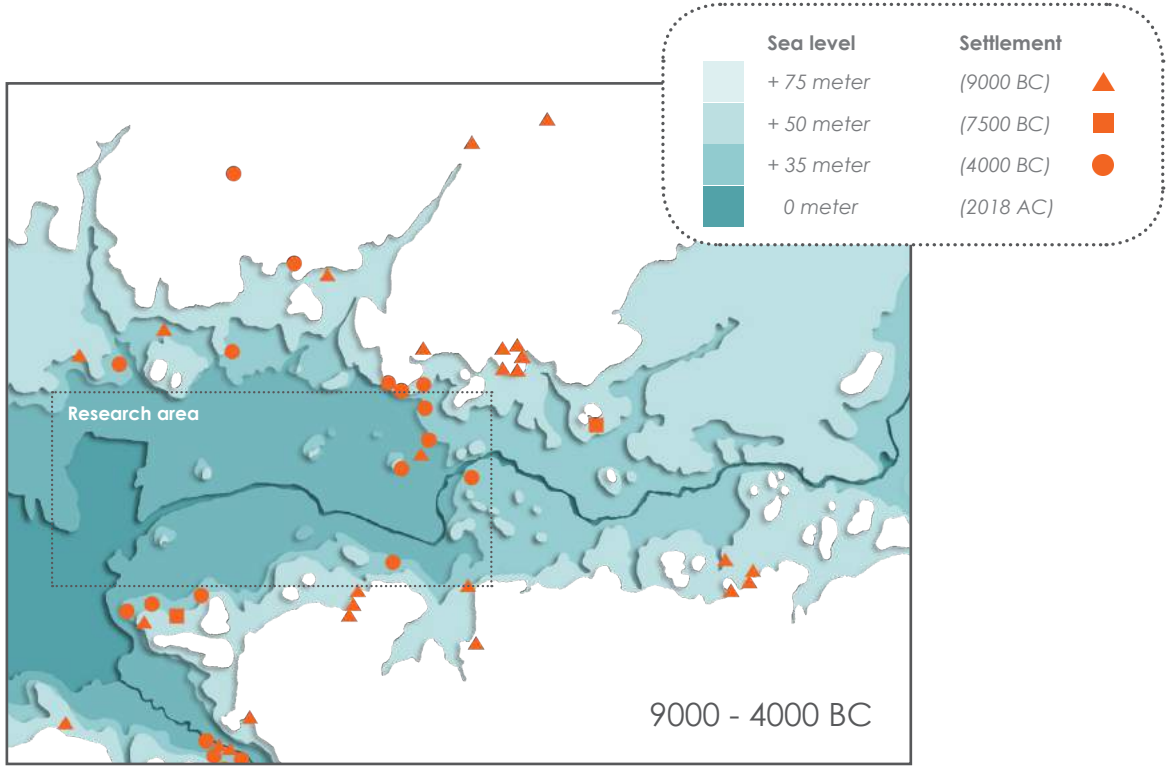
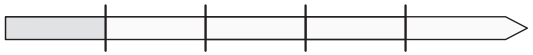


Figure 14. Stone age settlement and shoreline change (Bohusläns hembygdsförbund, 1981). Adapted with permission.



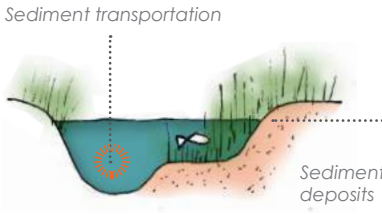
Human - nature in symbiosis

The first people in Uddevalla (around 9000 BC) were attracted to its nutritious land and water environment. Hunger, wear, fear and sorrow certainly came to these people. However, they had an inherited knowledge of how to live in symbiosis with the environment, without drastically changing its natural processes. In the late stone age (around 4000 BC) came warmer times due to natural climate change. The fjord of Uddevalla was closed and the old fertile sea bed became suitable for agriculture and noble deciduous trees, such as oak. Instead of moving after food could people settle and grow their own food (Nordlund, 1983).

The first people in Uddevalla lived in symbiosis with the nutrient environment without drastically changing its natural processes, which has not been the case later in history.

River characteristics

When the fjord was closed by the uplifting land did it transformed into the river Bäveån that flowed in three different ways through the valley landscape of oak trees:



1. The mountain river flows fast because of the mountain slope and it does more erosion or carving than it deposits (Alexandersson, 1979).

2. The meandering river flows slow and has reduced its erosive and transporting power of sediments and nutrients. Its outer curves are deepest due to higher water velocity and erosive power, while the swirling water masses on the edges break down sediment into mineral rich sand. The river cleaning and furnishing itself with an uneven depth of fertile margins where plants and fishes can flourish. (Alexandersson, 1979).

3. The river delta accumulated the remaining sediments and nutrients from the river and was periodically flooded (Cengiz, 2013). By time did the deposits formed a shallow flood plain area with a deeper continuation towards the currents in the fjord (Uddevalla kommun, 2002).

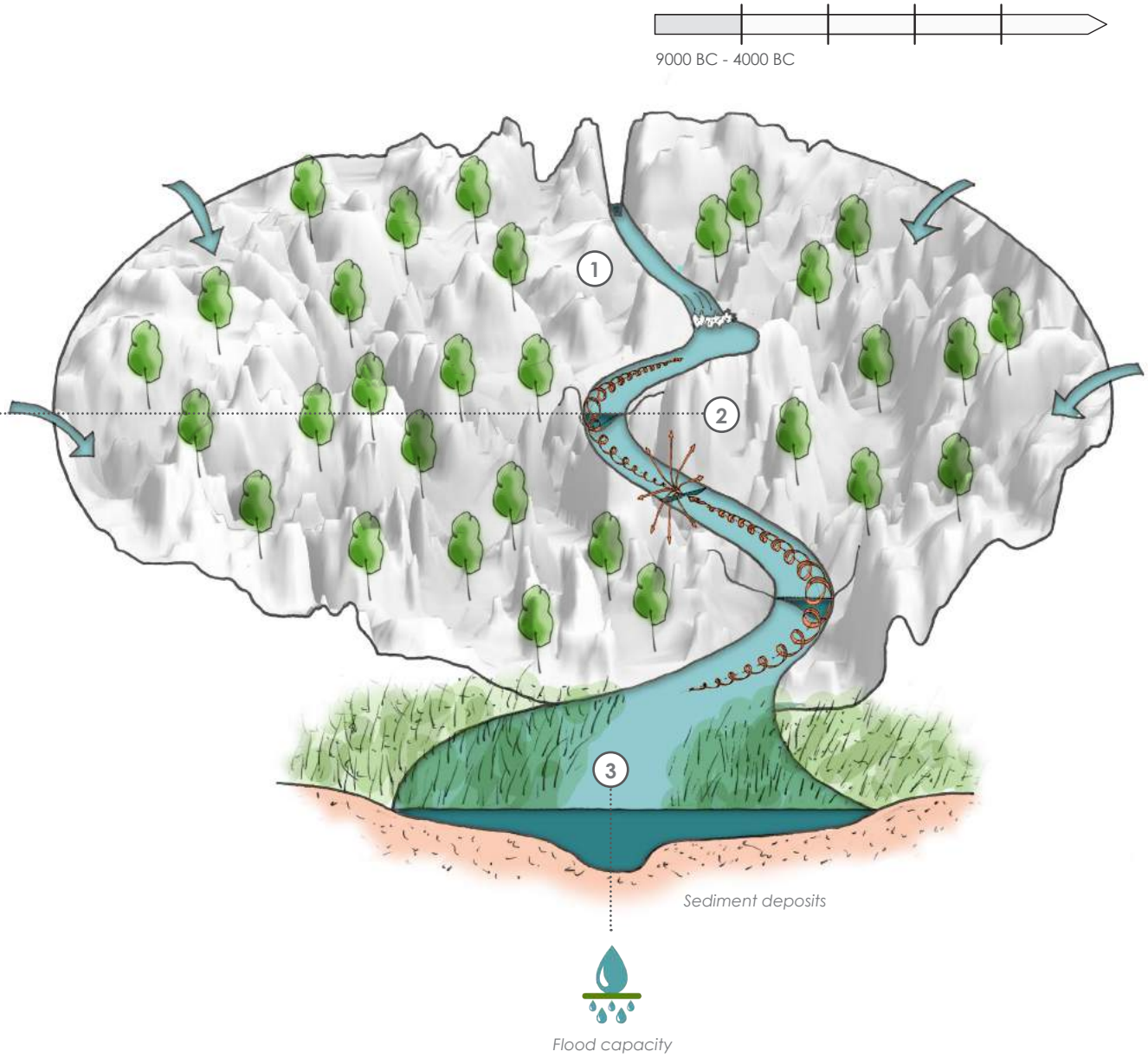
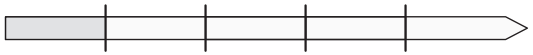


Figure 16. The oak tree valley and river delta of Uddevalla. Author's own copyright.



9000 BC - 4000 BC

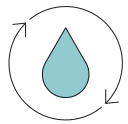
River delta function

Floods are natural outcomes of river ecology, why it is important to be ready for floods. The natural characteristics of river delta areas work together in storing and conveying floodwaters, protecting water quality, preventing erosion and sustaining rich habitats of fish and wildlife. The table to the left demonstrates all the important resources and functions that the river delta had in Uddevalla, before people started to disturb its natural purpose (Cengiz, 2013). These functions are prioritized throughout the investigation according to the thesis objectives below.

Natural resources and functions of river delta

- More focus
- Less focus
- No focus

Water resources	***Natural Flood & Erosion Control***	***- Provide flood storage & conveyance*** - Reduce flood velocities ***- Reduce peak floods*** - Reduce sedimentation
	Water Quality Maintenance	***- Filter nutrients & impurities from runoff*** - Process organic wastes - Moderate temperature fluctuations
	Groundwater Recharge	***- Improve infiltration & aquifer recharge*** - Reduce the frequency & duration of low surface flows - Support high rate of plant growth
Biological resources	***Biological productivity***	- Support high rate of plant growth - Maintain biodiversity - Sustain the integrity of ecosystems
	Fish & Wildlife habitats	- Provide breeding & feeding grounds - Create and improve waterfowl habitat - Protect habitats of rare & endangered species
Social resources	***Harvests of Wild & Cultivated Products***	- Improve agricultural lands - Provide sites for aquaculture - Restore & improve forest lands
	Areas for Scientific Study & Outdoor Education	***- Support cultural resources (historical & archeological sites)*** - Provide opportunities for environmental studies
	Recreational Opportunities	***- Provide areas for active & passive usage*** ***- Provide open spaces*** ***- Provide aesthetic pleasure***



Focus areas vs Thesis objectives

Increase the knowledge of how to maintain the re-balanced water cycle

Offer a spatial experience of the cultural history and the re-balanced water cycle

Enlighten the cultural history behind the locally disturbed water cycle

Figure 17. Natural resources and functions of floodplain. (Cengiz, 2013). Adapted with permission.

2.1.2 MEDIEVAL: TRADING CITY

Uddevalla has throughout history served as a focal point for trade, due to its location between inland and sea. The deep penetrating sea bay Byfjorden, served as the shortest route to reach land or sea for many people in the region. However, Uddevalla has also suffered from many battles. In the past was this region important for Norway, Sweden and Denmark in order to control the coastline´s fairway. In Uddevalla was forestry and agricultural products from inland exchanged with diverse products from the coastal population. People from inland came with horse wagons while sailing ship came from the coast (Hasselmo, 1980).

People learned how to use wind, wheels and horses to rationalize their transportation system, without releasing greenhouse gases to the atmosphere.

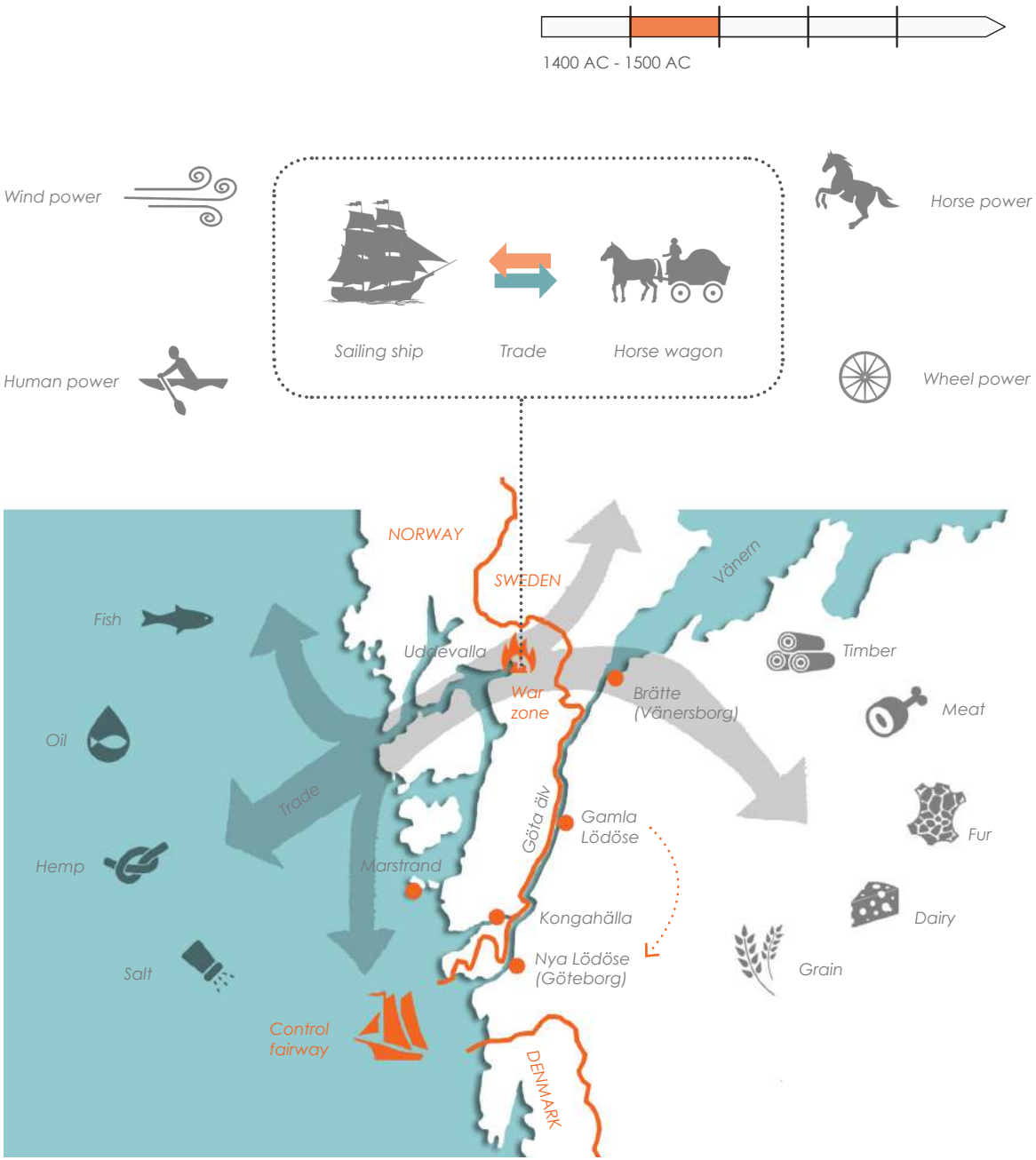


Figure 18. The geographical and political context between 12th-17th century. (Hasselmo, 1980). Adapted with permission.

River farm & fjord market

The city of Uddevalla has two precursors, a farm at the river Bäveån´s last waterfall (Strömbergsfallet) and a market in the fjord (Byfjorden). The water was deep enough for big ships to reach the market, but simultaneously exposed and hard to defend in times of war. On the contrary, the farm was well integrated in the surrounding landscape and well protected from floods and warships by the shallow river delta area (Nordlund, 1983).

River city & fjord harbour

In 1498 had the market grown so large that it regained city rights, but already in 1501 was it burnt down in a war. Therefore was the city moved into the more protected farm location (Bohusläns museum, 2018). Here at the river outlet did the inhabitants had proximity to sweet and salt water which gave them both salmon and herring. However, the river Bäveån gain its real importance first when the inhabitants learned to make use of the powerful river (Hasselmo, 1980). Several water powered sawmills were installed along the river in order to export refined oak trees that covered the uplifting fertile land around Uddevalla (Bohusläns museum, 2018). The river gave the place nutrition and life, but the river delta eventually became an inefficient border for the trading activities. Traded goods were inefficiently transferred between the river city and fjord harbour by people in rowing boats (Uddevalla kommun, 2002).

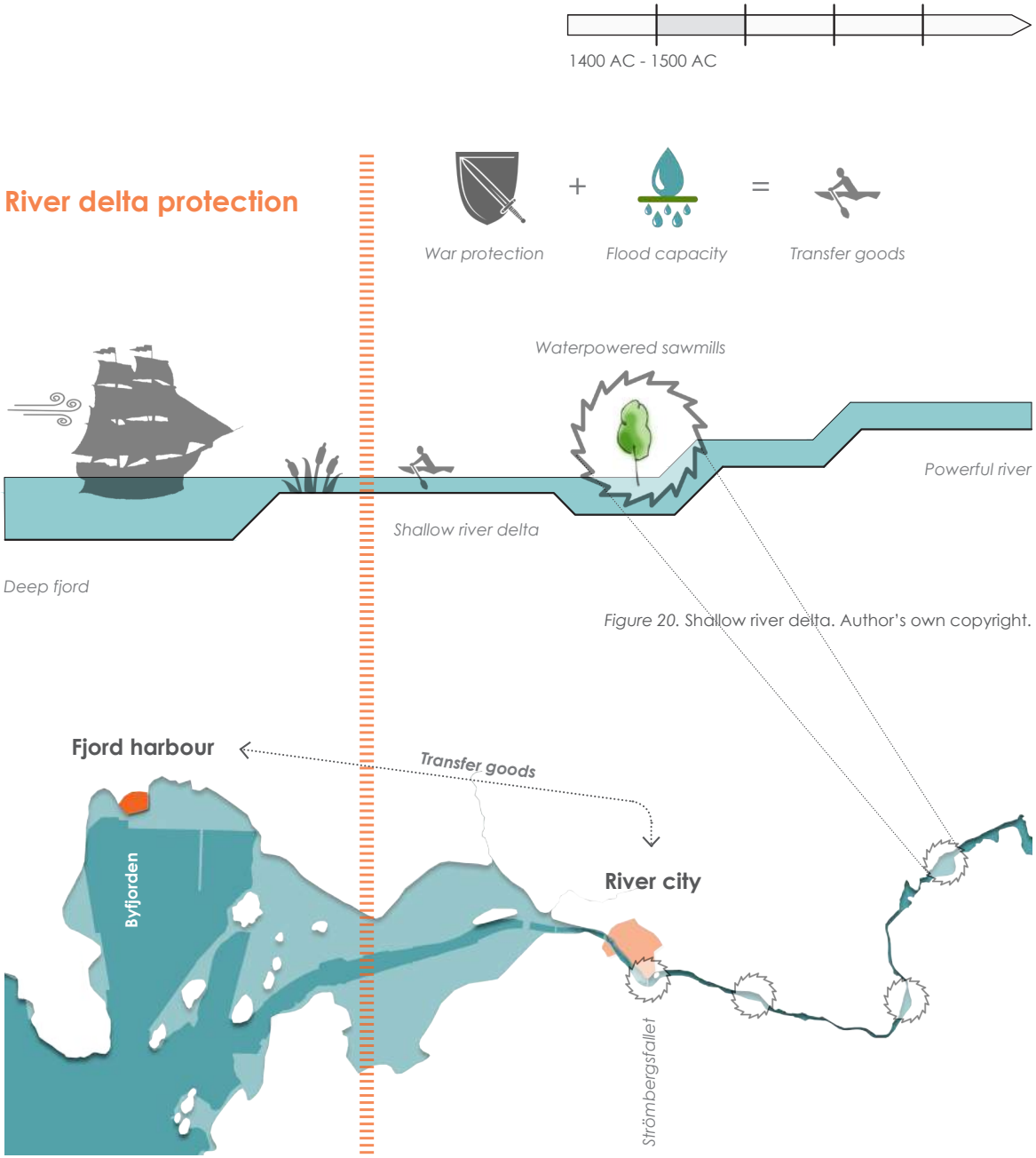
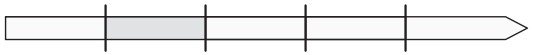


Figure 20. Shallow river delta. Author's own copyright.

Figure 19. Flood and war protected river delta. (Kristiansson, 1953). Adapted with permission.



Balanced water cycle

The hydrological cycle describes the natural circulation of water between heaven and earth, where the forests form a vital link between them. In the shade of trees is the forest soil cooler than the rain water, which promotes infiltration. The water is stored in the ground until some of it will be released through land and water evaporation and plant transpiration. Then does the water vapor condensates and it rains again. This natural harmony has gradually been disturbed by human impact (Alexandersson, 1979).

Transportation boundary
Over-sedimented river delta

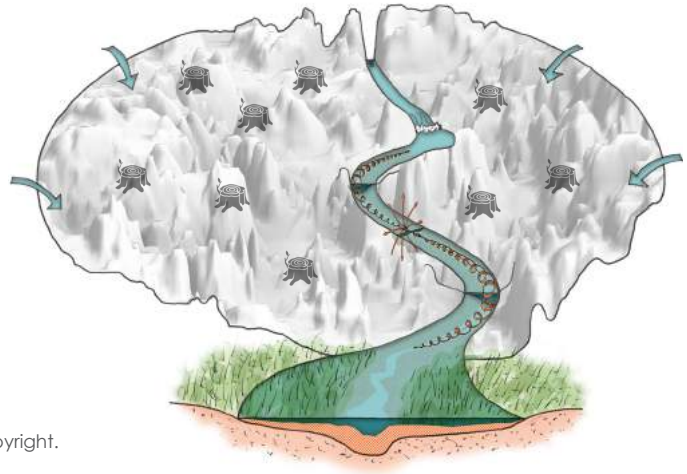
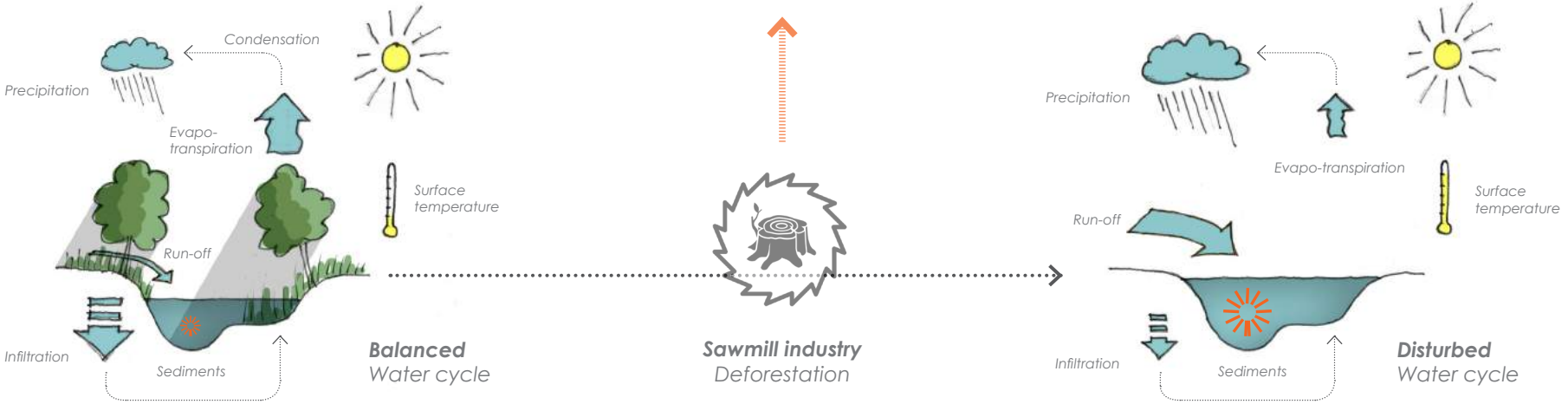


Figure 21. River delta as a transportation. Author's own copyright.

Disturbed water cycle

The export of oak timber led to the city´s first economic growth. However, it also led to a deforestation that disturbed the local soil infiltration. Surface water entered the river far quicker than before. The amount of water increased which gave the river a higher velocity and erosive power. Without the shade of trees was the slow flowing river quickly heated up. The erosive power was reduced while the deposits of sediment increased in the river outlet (Alexandersson, 1979). The over-sedimented river delta reduced its flooding capacity and became a transportation boundary, which increased the problem of transporting goods between the river city and the fjord harbour (Uddevalla kommun, 2002).



2.1.3 FINDINGS

The stone age people in Uddevalla lived in symbiosis with the environment without drastically changing its natural processes. During the medieval period came the sawmill industry, which gave the city´s first economic growth. However, the human greed eventually led to deforestation that worsen the boundary effect of the river delta. The flooding capacity reduced and the trading activities were disturbed, which in the long run led to less economic benefits. In contrary, this thesis demonstrates a long-term perspective that both can re-establish a stronger human-nature relationship and strengthen the local economy.

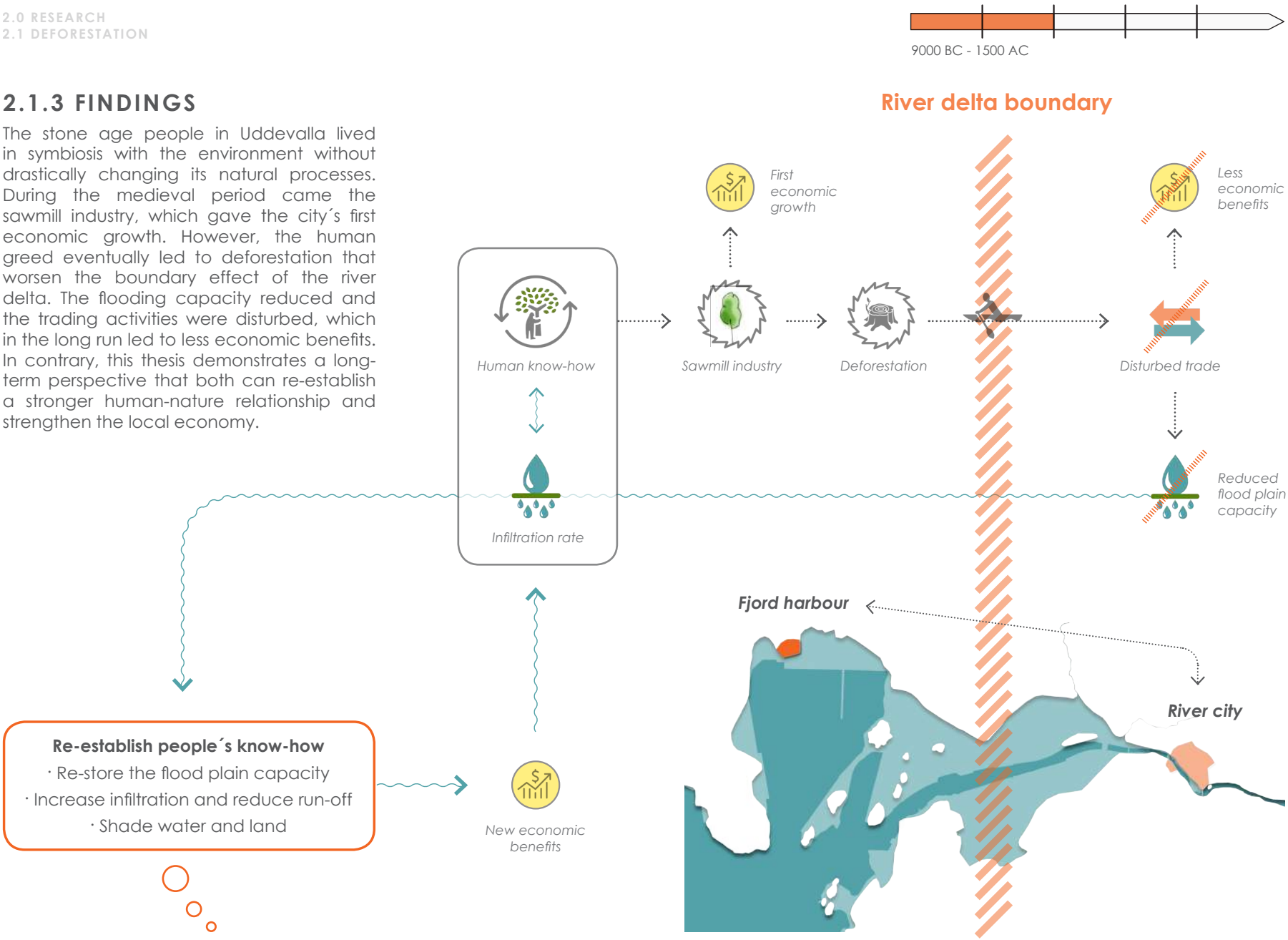
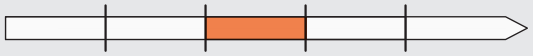


Figure 22. Re-establish people´s know-how. Author's own copyright.

2.2 LAND RECLAMATION



2.2.1 INDUSTRIAL: HARBOUR CITY

During the 18th century did Uddevalla had a glory period due to its export of wood, iron, corn and herring. In that time was it the third most important trading city in Sweden after Göteborg and Stockholm (Bohusläns museum, 2018). The river delta boundary was therefore a hot topic back then. In 1769 was the wetland passage so curvy, narrow and filled-up that barely a small empty boat could float between the city and harbour. The wetland passage was therefore deepening for the first time in 1841 by means of a horse-driven dredger (Kristiansson, 1936).

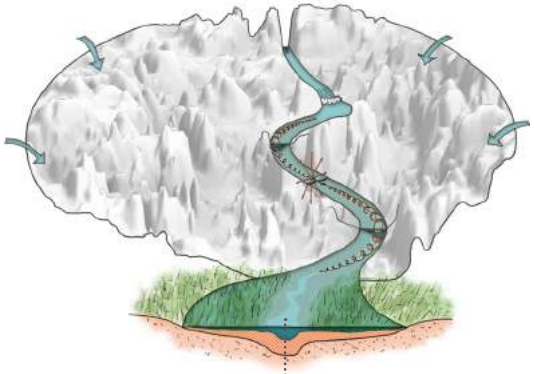
In the 1850s did the industrial revolution began in Uddevalla. The wetland passage was once again deepened and straightened in 1849, but with a steam dredger instead (Nordlund, 1983). In 1894 did Uddevalla invest in a new dredger system, including a special building typology with its foundation partly on land and in water. The building was called "Elevatorn", which facilitated the land reclamation process in Uddevalla. It was used to fill-up large parts of the shallow river delta, which allowed to move the harbour into the city (Klasson, 2012).

Figure 23. Elevatorn 1.0 in Uddevalla: Photo unknown.

Elevatorn 1.0

Dredged sediments were collected and transported on flatboats to the temporary position of Elevatorn. By means of a conveyer were the sediments transported up into the building and flushed through slightly inclined gutters, until the sediments were deposit on the river delta far from the river. The gutters were rotated in order to fill-up other areas of the river delta. In 1908 was large parts of the northern wetland filled-up and the building was disassembled and moved to the river´s southern side (Klasson, 2012).

In 1932 was the southern wetland filled-up. Then became Elevatorn useless because the river delta areas closer to the river could be filled-up without the building´s function. In the end did Elevatorn became an attraction point for play and ghost stories before it was demolished in 1934 (Klasson, 2012).



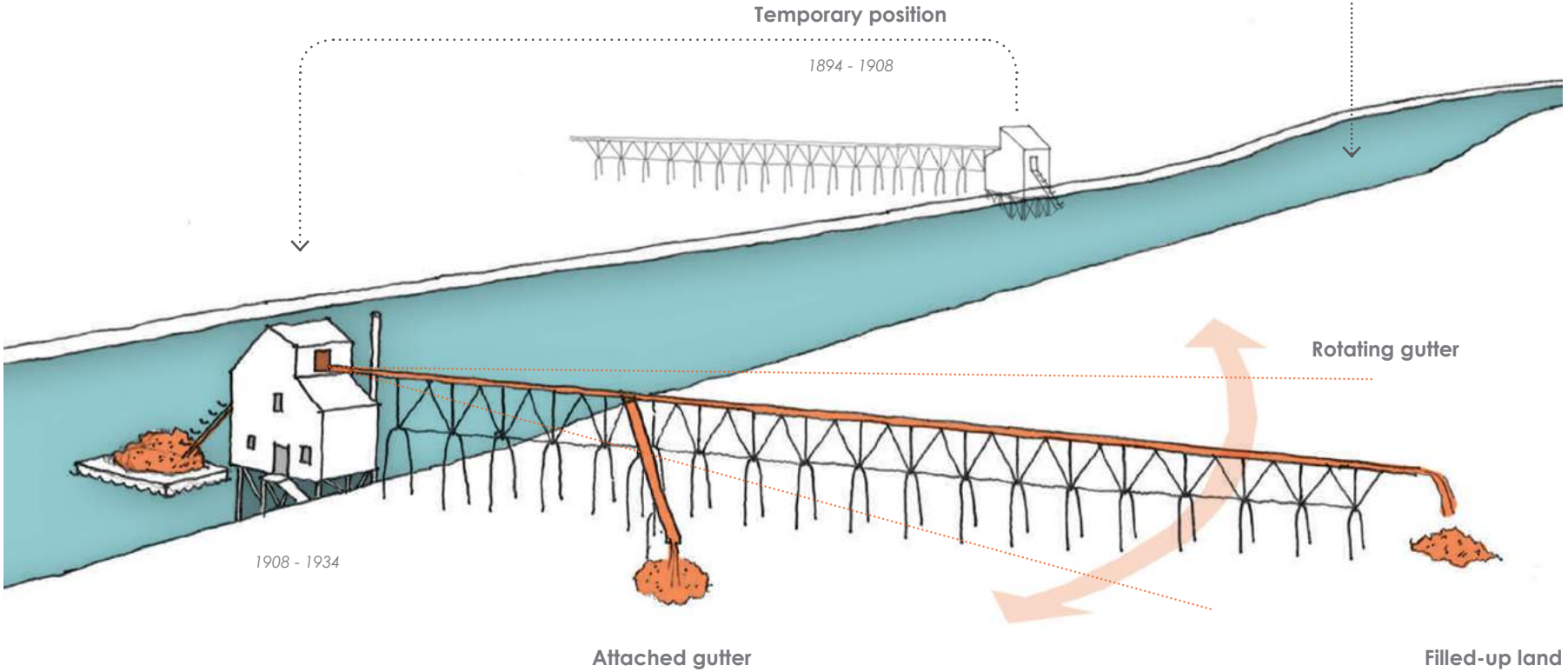
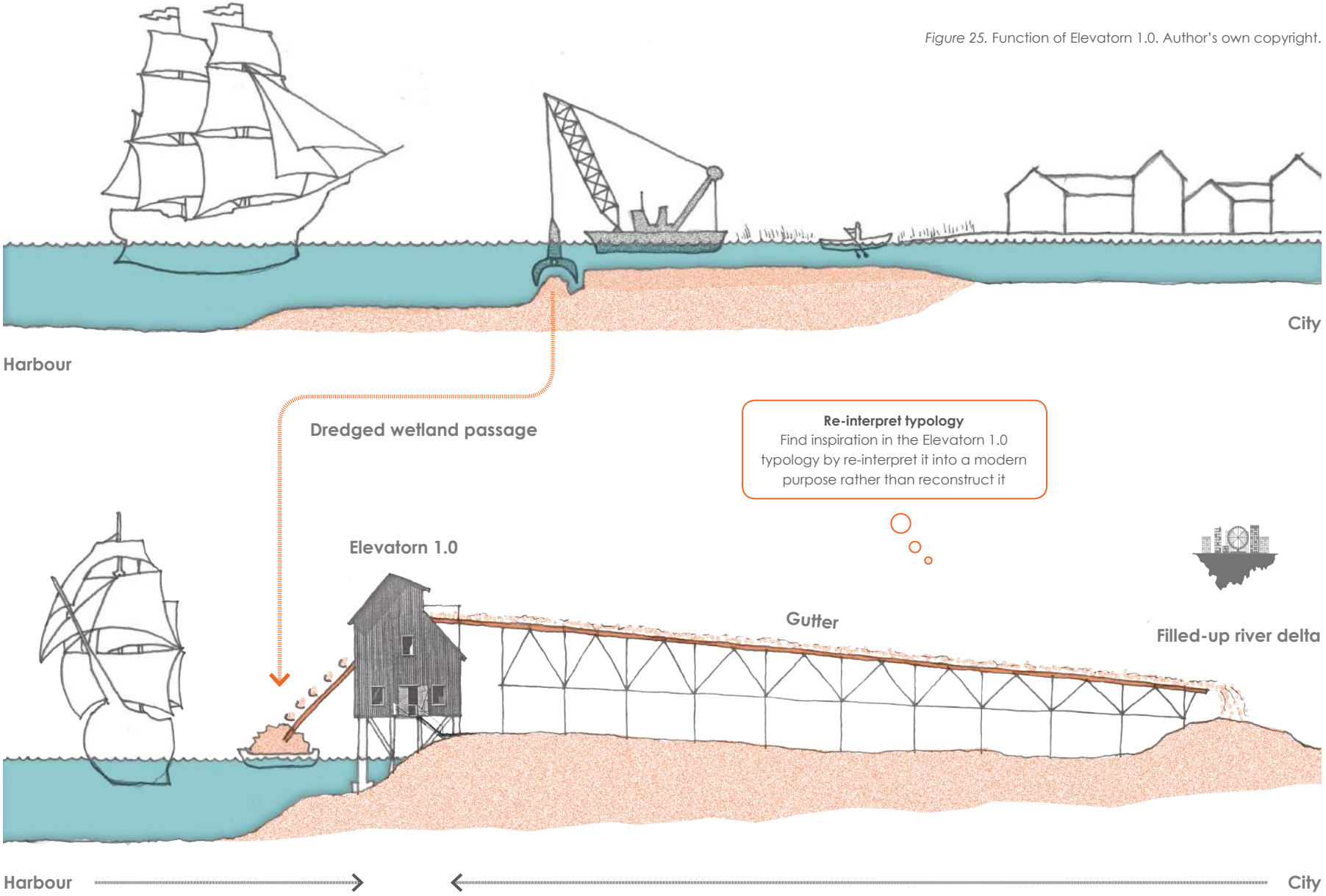


Figure 24. The temporary position of Elevatorn 1.0. Author's own copyright.

1850 AC - 1950 AC

Figure 25. Function of Elevatorn 1.0. Author's own copyright.



The industrial revolution

The industrial revolution came to revolutionize the way people and goods move on land and water. In Uddevalla did the dredged river and the filled-up river delta made it possible to move the harbour into the city. This move contributed to an economic and spatial growth of the city. Infrastructures for steam boats and steam trains were established for transhipment in the city harbour. Industries emerged along the river Bäveån with different production such as cotton spinning, weaving, carpentry, matches, mechanics and shipbuilding. The industrial harbour city of Uddevalla attracted more and more people that looked for jobs (Bohusläns museum, 2018). However, the industrial revolution marked a major turning point in Earth's ecology and humans' relationship with their environment (McLamb, 2011).

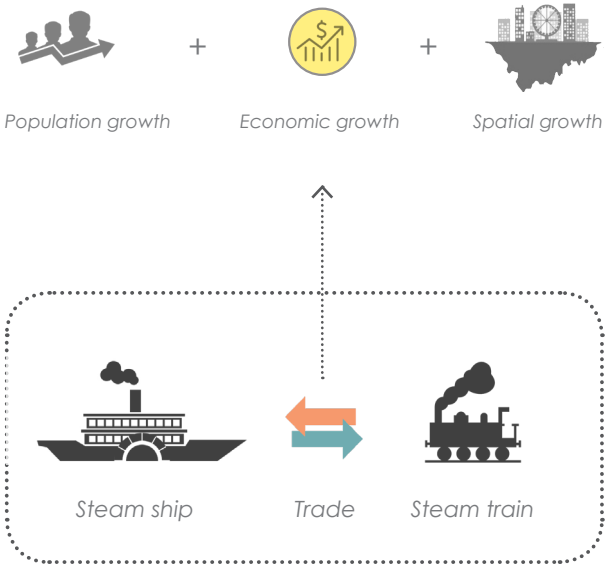
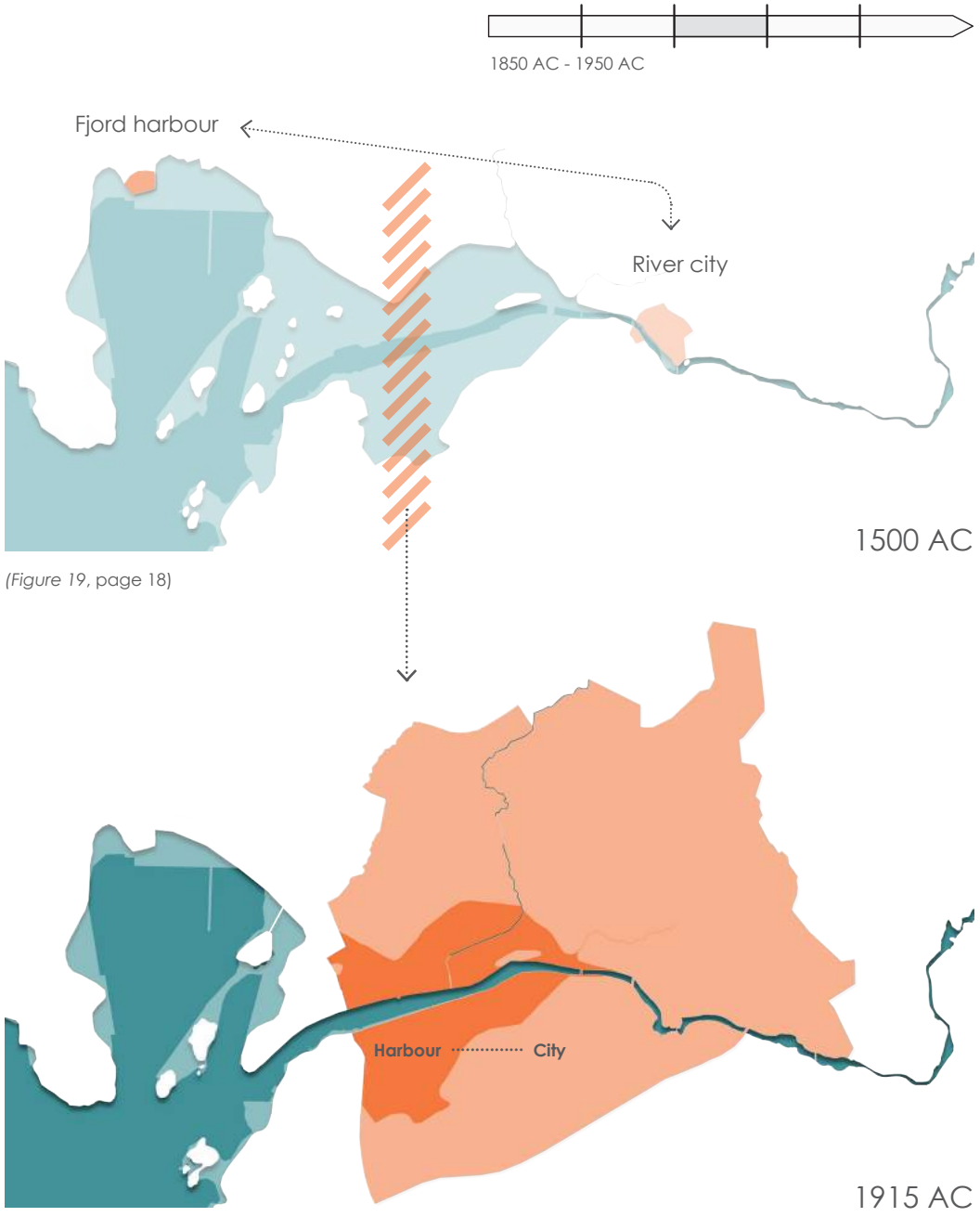
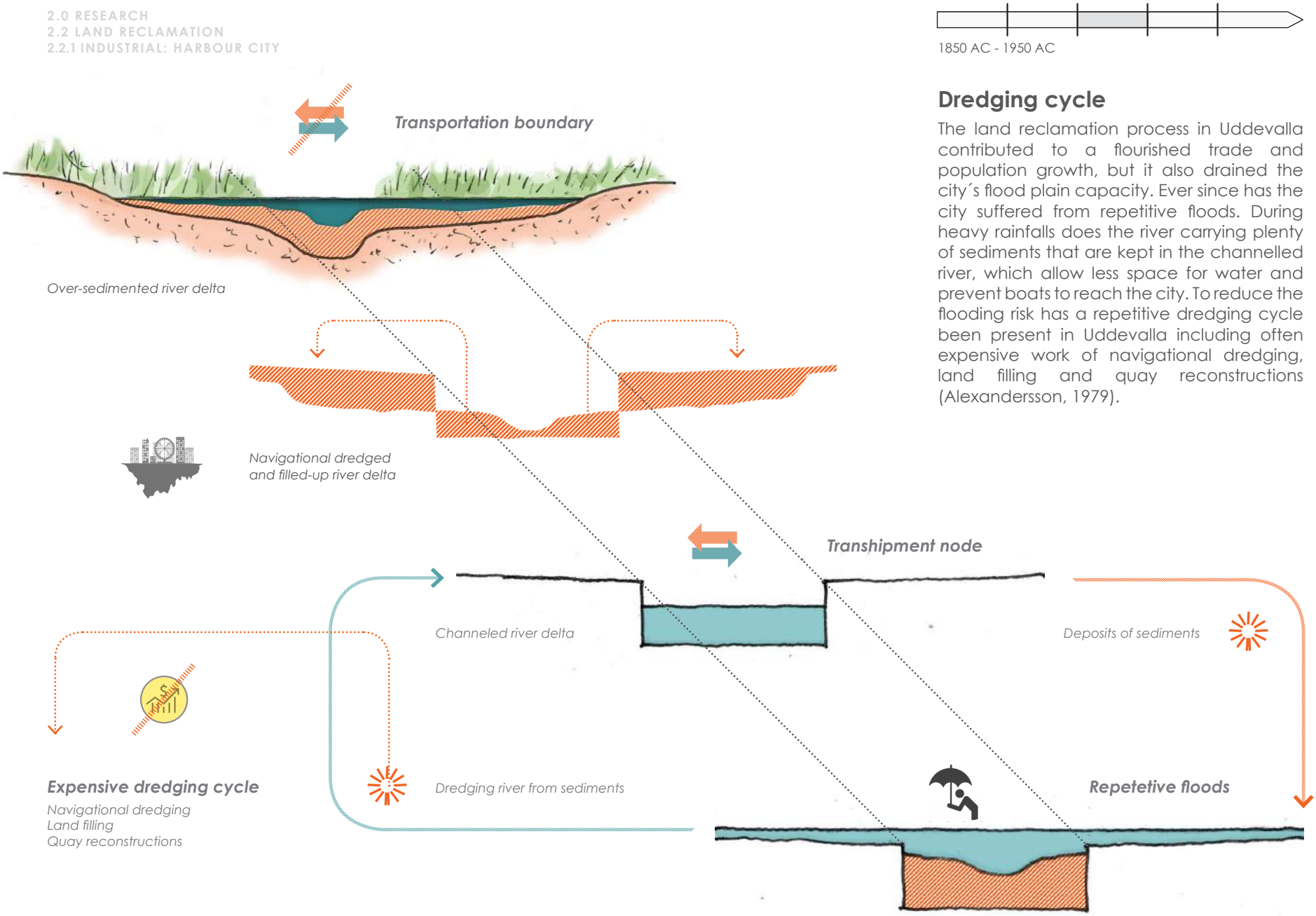


Figure 27. Harbour city. Author's own copyright.



(Figure 19, page 18)

Figure 26. Expanded harbour city. (Berne, 1915). Adapted with permission.



Dredging cycle

The land reclamation process in Uddevalla contributed to a flourished trade and population growth, but it also drained the city´s flood plain capacity. Ever since has the city suffered from repetitive floods. During heavy rainfalls does the river carrying plenty of sediments that are kept in the channelled river, which allow less space for water and prevent boats to reach the city. To reduce the flooding risk has a repetitive dredging cycle been present in Uddevalla including often expensive work of navigational dredging, land filling and quay reconstructions (Alexandersson, 1979).

Figure 28. Dredging cycle of the river Bäveån in Uddevalla. Author's own copyright.

2.2.2 PRESENT: FORBIDDEN CITY

Since the industrial revolution has Uddevalla expanded towards all directions and the harbour has been moved further out to the fjord, much due to the shipyard industry (Uddevallavarvet 1947-1984) (Bohusläns museum, 2018). However, most parts of the filled-up river delta are compressing and therefore sinking, because of the urbanization processes of land reclamation and ground-water depletion (Fredgren, 2016). Because of its poor geotechnical conditions are large parts of the riverfront even fenced and closed for public use. At the same time is the global sea level rising, much due to the global warming process that began during the industrial revolution (IPCC, 2013). Uddevalla has become the forbidden city that is suffering from land subsidence and repetitive flooding.

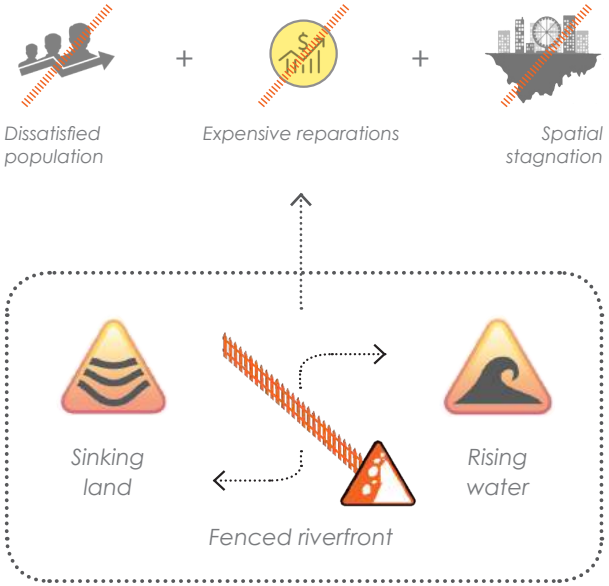


Figure 30. The forbidden city. Author's own copyright.

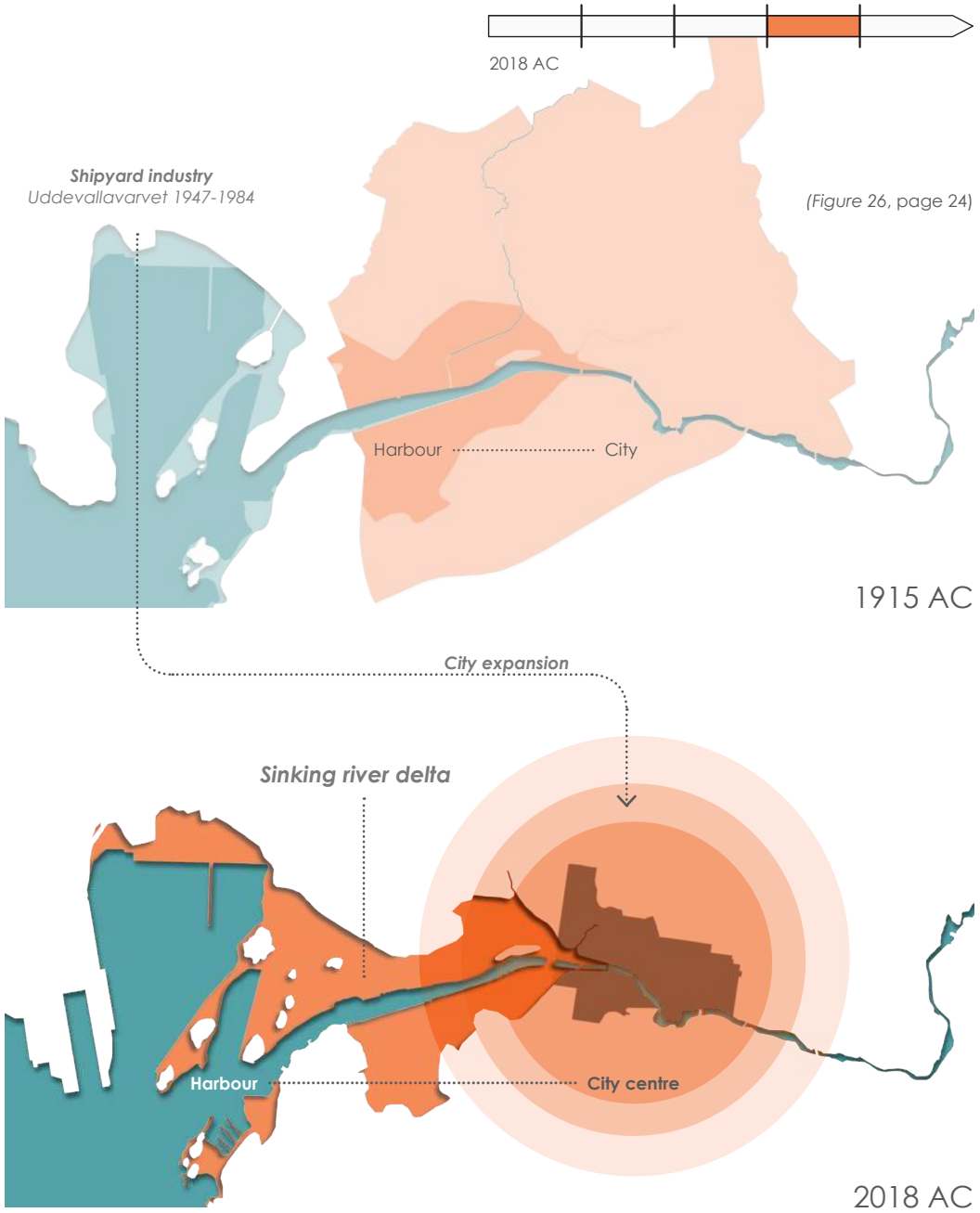
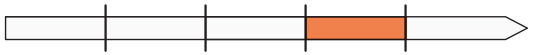


Figure 29. Sinking river delta 2018. Author's own copyright.



2018 AC

2.2.3 FINDINGS

In the past did the river Bäveån served as a connector and artery in Uddevalla, by giving nutrition and life to the place. However, by human impact of land reclamation has it over time developed from an important public space of transhipment into a mental and physical barrier of today. The city has literally turned its back towards the river, since the riverfront has a limited public access.

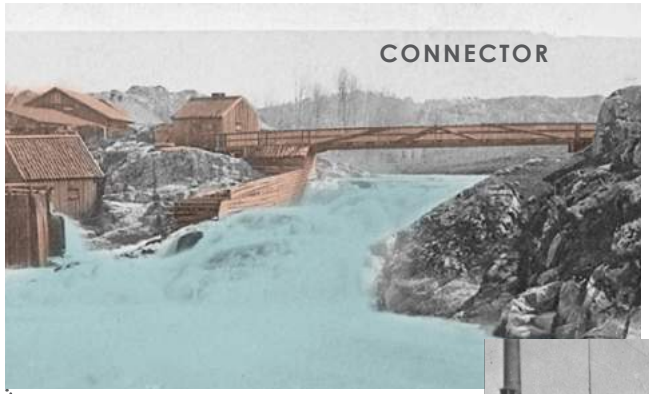


Figure 31. Sawmill at Strömberget (Rydholm, 1867 - 1874). CC PDM. Adapted with permission.

Figure 32. Harbour city flooding in 1923. CC BY-NC-ND.

2.1 Deforestation

2.2 Land reclamation

2.3 Global warming

2.4 Water depletion

The forbidden city

Uddevalla as a forbidden city consist of three parts; the flooding, sinking and fenced city.

Figure 33. Fenced riverfront. (Edwartz, 2017). Reprinted with permission.

2018 AC

The flooding city

Uddevalla has turned its back towards the river because of the repetitive flooding that occur due to sea level rise and land subsidence.

Figure 34. The flooding city: 10 January 2015. (Nilsson, 2015). Adapted with permission.

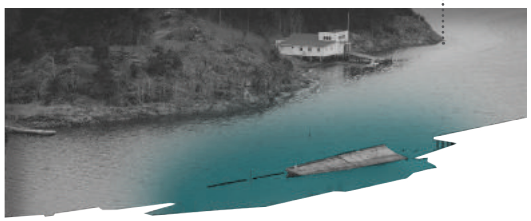


Figure 37. Collapsed riverfront. Author's own copyright.

The fenced city

Figure 36. The fenced city. Author's own copyright.

- *Regenerate the riverfront as a human realm*
- *Restore the flood capacity of the river delta*
- *Inform the history behind the forbidden city*

The sinking city

Since the buildings rest on poled foundations is the sinking ground making ramps steeper and stairs are hanging in the air.

Figure 35. The sinking city. Author's own copyright.

In 2008 did a 100-meter long part of Uddevalla´s quay collapsed into the river Bäveån (Klasson, 2011). In 2016 did the municipality decided to close large parts of Uddevalla´s riverfront for public use, which are also expecting to collapse at any minute (Uddevalla kommun, 2018).

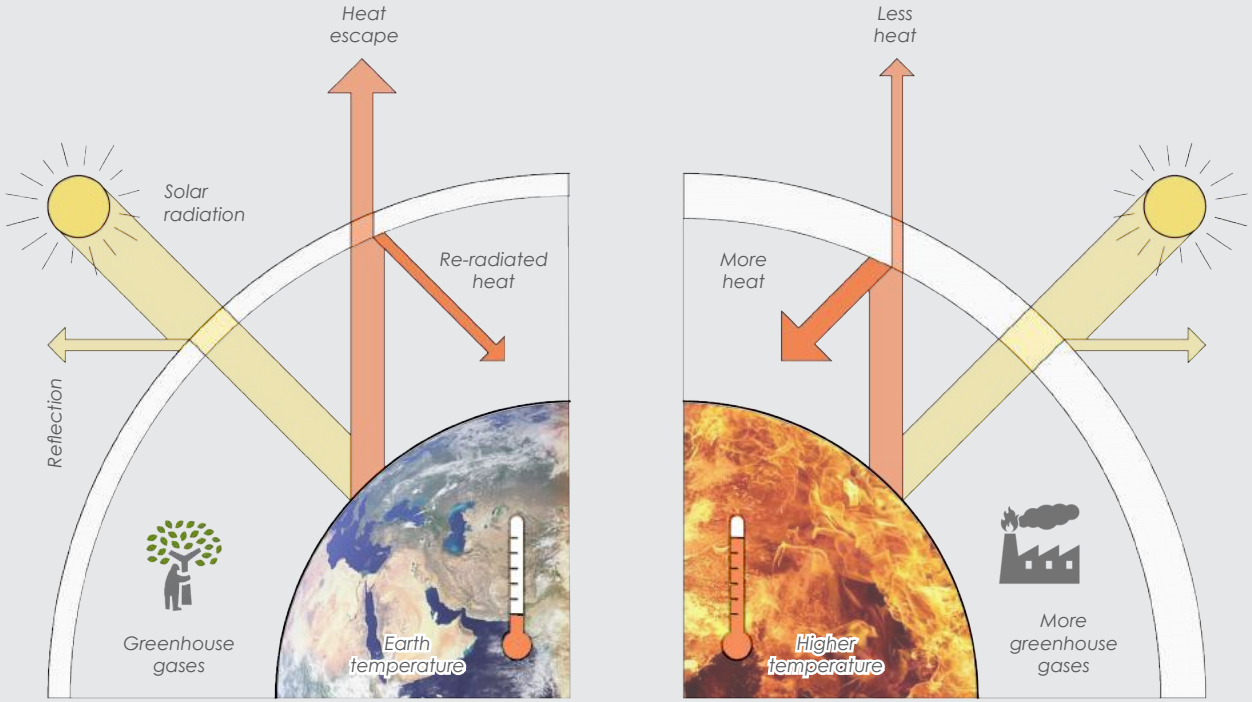
Climate change

Climate Change is one of the most significant challenges that we are facing globally. The causes of climate change are mainly human-driven, which means that we are deteriorating the conditions for all life to exist on earth (IPCC, 2013).

Since the industrial revolution have human greenhouse gas emissions influenced the climate more than the natural changes in solar energy, volcanic eruptions, and greenhouse gas (GHG) concentrations (IPCC, 2013).

Human greenhouse gas emissions derive primarily from the energy consumption of fossil fuels (80 % of carbon dioxide emissions), but also from deforestation and other depletion of biological systems (20 % of carbon dioxide emissions) (Bokalders & Block, 2014). The greenhouse gases form a layer around the Earth, which retains essential sunlight heat inside the planet's atmosphere. However, the increasing amount of greenhouse gas emissions have resulted in a global warming effect where even more sunlight heat is retained. Consequently, global warming has led to a warmer and wetter climate in Sweden that will continue to affect Uddevalla in the future (Berglöv et al., 2015).

Figure 38. Consequences of global warming. Author's own copyright.



Natural greenhouse effect

Disrupted greenhouse effect by human global warming

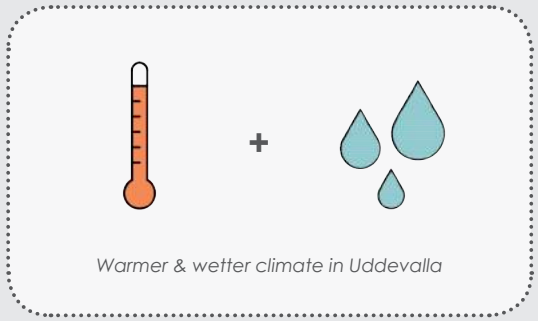
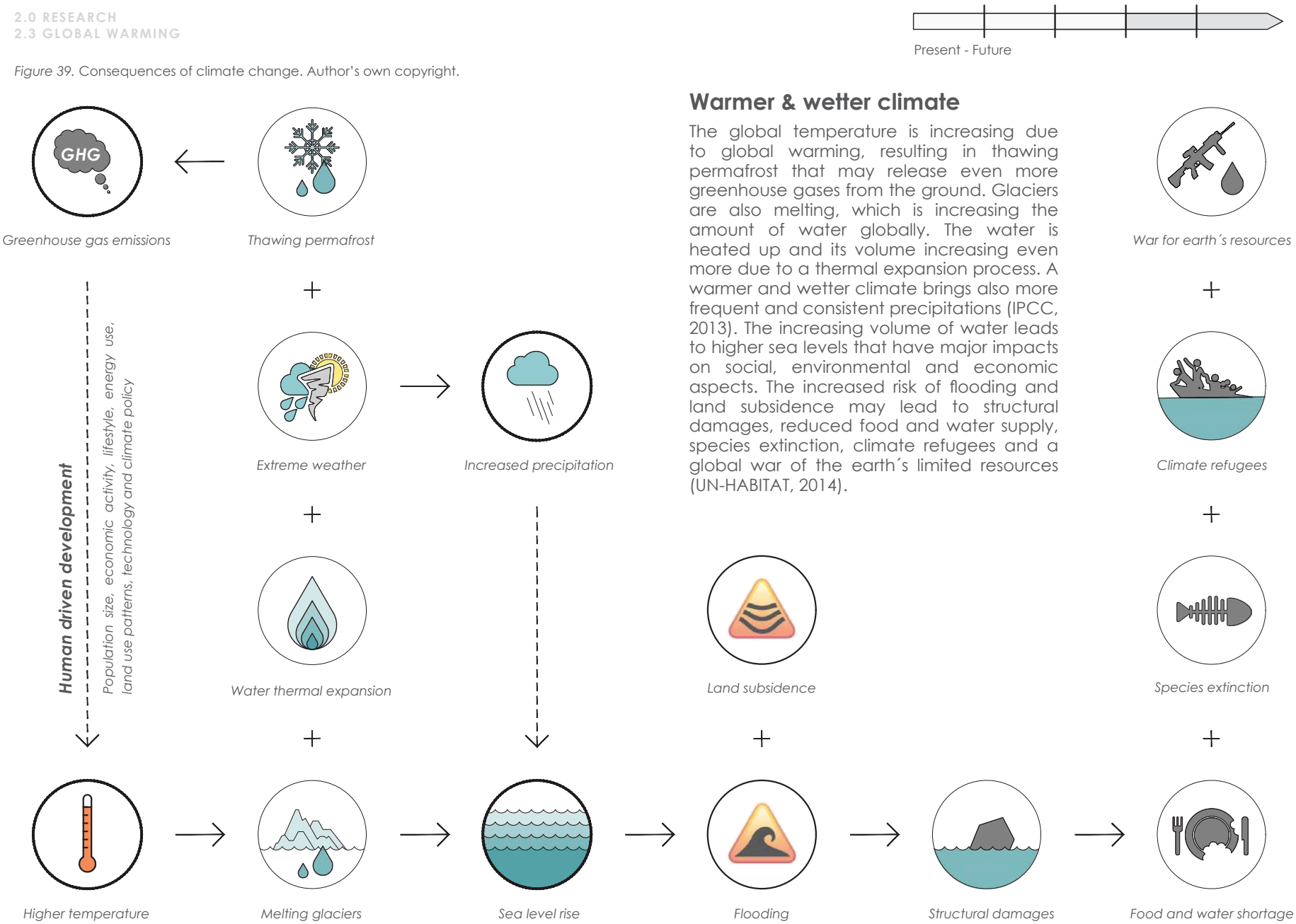
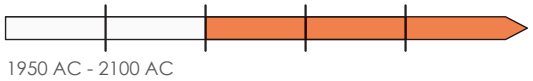


Figure 39. Consequences of climate change. Author's own copyright.



Warmer & wetter climate

The global temperature is increasing due to global warming, resulting in thawing permafrost that may release even more greenhouse gases from the ground. Glaciers are also melting, which is increasing the amount of water globally. The water is heated up and its volume increasing even more due to a thermal expansion process. A warmer and wetter climate brings also more frequent and consistent precipitations (IPCC, 2013). The increasing volume of water leads to higher sea levels that have major impacts on social, environmental and economic aspects. The increased risk of flooding and land subsidence may lead to structural damages, reduced food and water supply, species extinction, climate refugees and a global war of the earth´s limited resources (UN-HABITAT, 2014).



2.3.1 CLIMATE DATA

The following diagrams are demonstrating historical observations and future projections of the warmer and wetter climate. The Representative Concentration Pathways (RCPs) represent four different climate projections, which depends on how much greenhouse gases that are emitted in the future (IPPC, 2014):

RCP 2.6 *peak around 2010-2020, then decline*

RCP 4.5 *peak around 2040, then decline*

RCP 6 *peak around 2080, then decline*

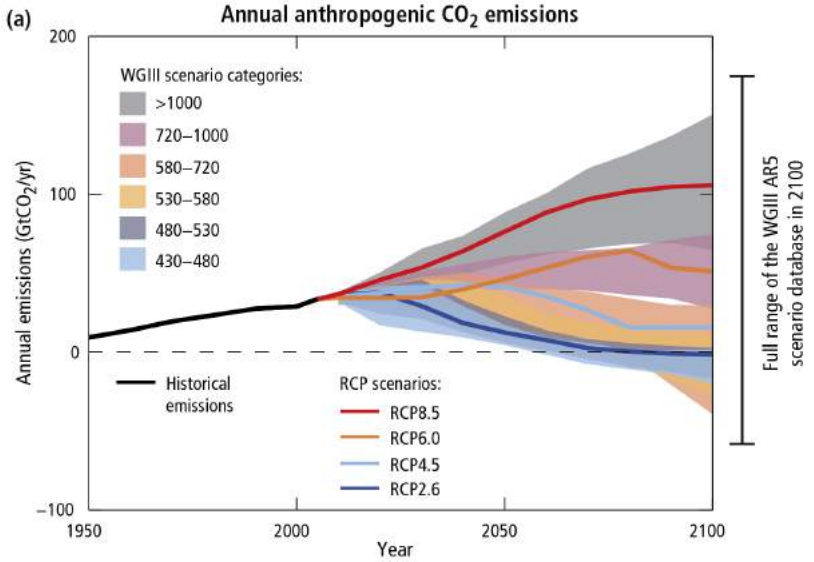
RCP 8.5 *continue to rise throughout the 21st century*

Greenhouse gas emissions

Higher temperature

Global temperature change

The global temperature is increasing much due to human greenhouse gas emissions of especially carbon dioxide (CO2) (IPPC, 2014).



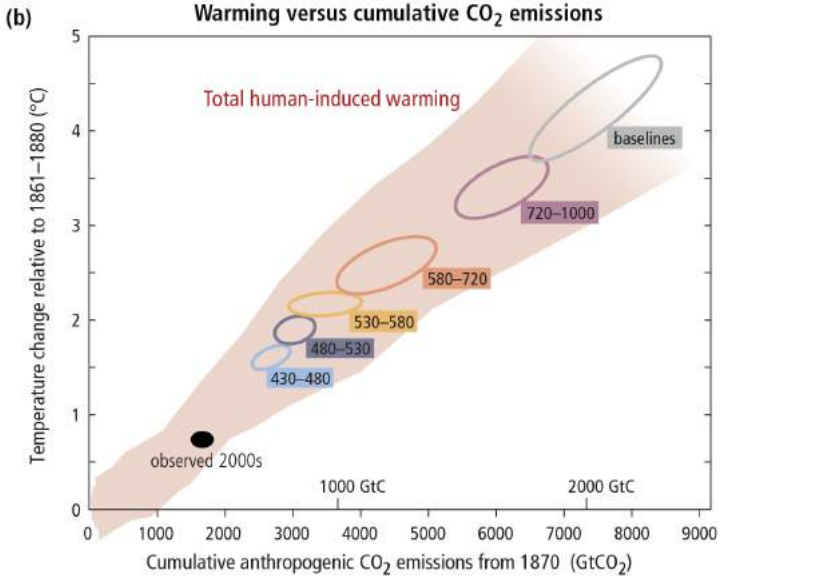


Figure 40
Figure SPM.5 from IPCC (2014). Climate Change 2014: Synthesis Report. Reprinted with permission.

(a) Annual anthropogenic CO2 emissions

(b) Warming versus cumulative CO2 emissions

Regional temperature change

In Region Västra Götaland was the yearly average temperature about 6°C, between 1961-1990. Observations and future projections show a gradually warmer climate. In the end of the 21th century will the regional temperature be up to 5°C warmer compared to the period of 1961-1990 (Berglöv et al., 2015).

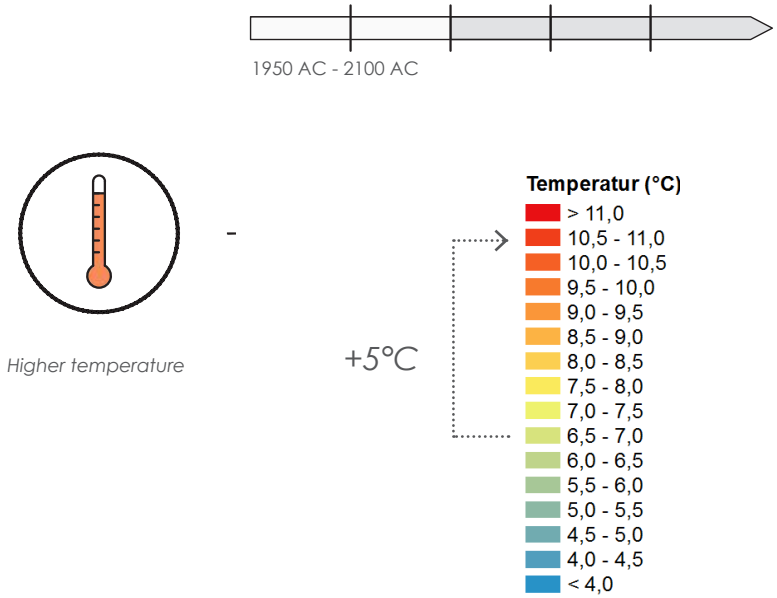
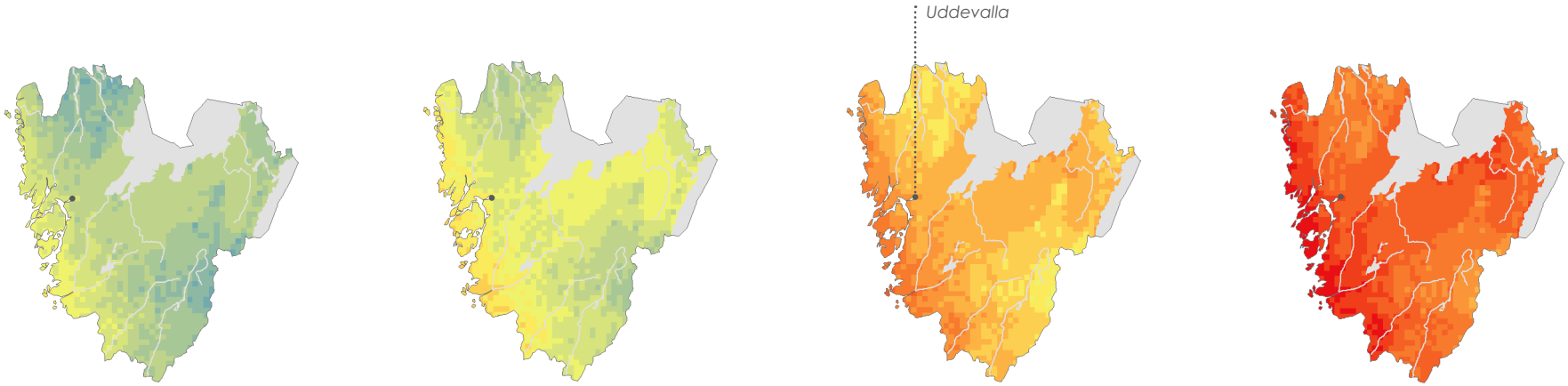


Figure 41. Average temperature change in Region Västra Götaland. (Berglöv et al., 2015). Adapted with permission.



1961-1990
Observed

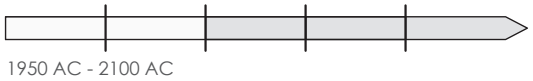
1991-2013
Observed

2069-2098
RCP 4.5 scenario

2069-2098
RCP 8.5 scenario

Regional precipitation change

A warmer climate means higher evaporation and faster water circulation, which gives more precipitation. Observations and future projections confirms larger amounts of rain in the future climate. The yearly average precipitation in Region Västra Götaland is expecting to increase up to 25 %, compared to the period of 1961-1990. Rainfalls will especially increase during winter time, when an increase of 40% can be expected in the end of the 21th century (Berglöv et al., 2015).

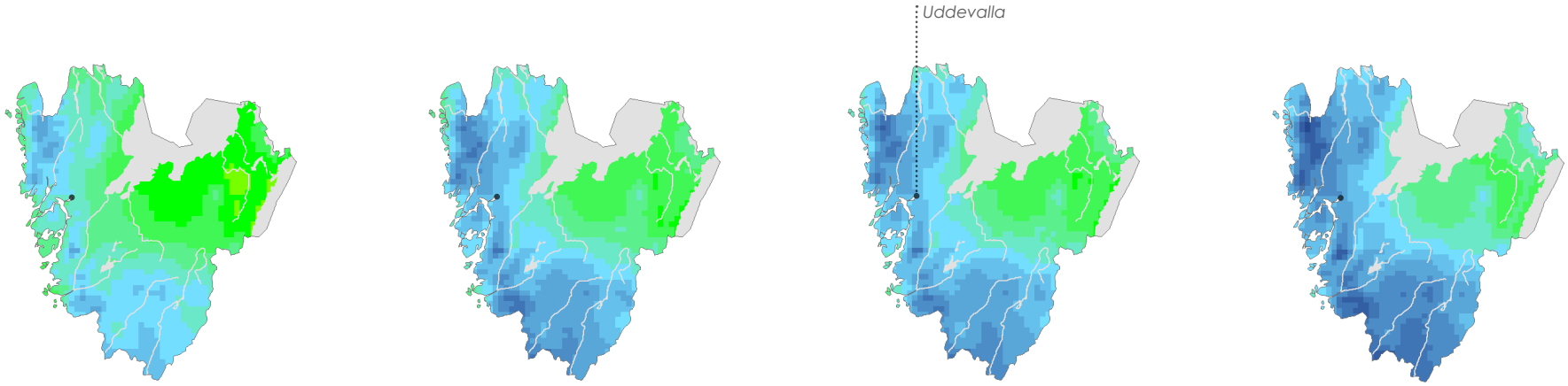


Increased precipitation

+25 %

Nederbörd (mm)
- > 1500
- 1425 - 1500
- 1350 - 1425
- 1275 - 1350
- 1200 - 1275
- 1125 - 1200
- 1050 - 1125
- 975 - 1050
- 900 - 975
- 825 - 900
- 750 - 825
- 675 - 750
- 600 - 675
- 525 - 600
- 450 - 525
- < 450

Figure 42. Average precipitation change in Region Västra Götaland. (Berglöv et al., 2015). Adapted with permission.



1961-1990
Observed

1991-2013
Observed

2069-2098
RCP 4.5 scenario

2069-2098
RCP 8.5 scenario

National sea level rise

During the latest 100 years has the sea level in Sweden increased with approximately 16 cm (SMHI, 2018), which is expecting to continue raising according to future projections (IPCC, 2013). The sea level is currently rising with 3 mm/year (SMHI, 2018) and in Uddevalla is the land uplifting with 3.5 mm/year (Vestøl et al., 2016). In future is the relative sea level (actual sea level rise - uplifting ground) expecting to increase with 60-70 cm (Klimatanpassningsportalen, 2017). However, this projection does not take the river delta in Uddevalla into consideration that is currently sinking between 0-35 mm/year (Fredgren, 2016).

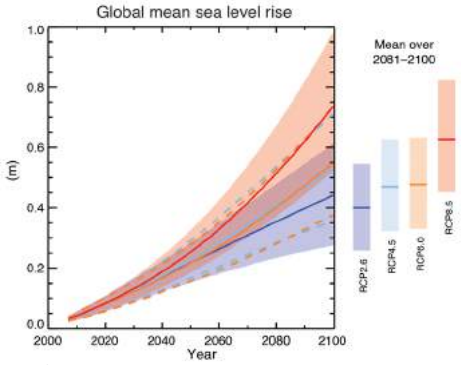


Figure 44. Projected range of global mean sea level rise. Figure SPM.9 from IPCC (2013). Reprinted with permission.

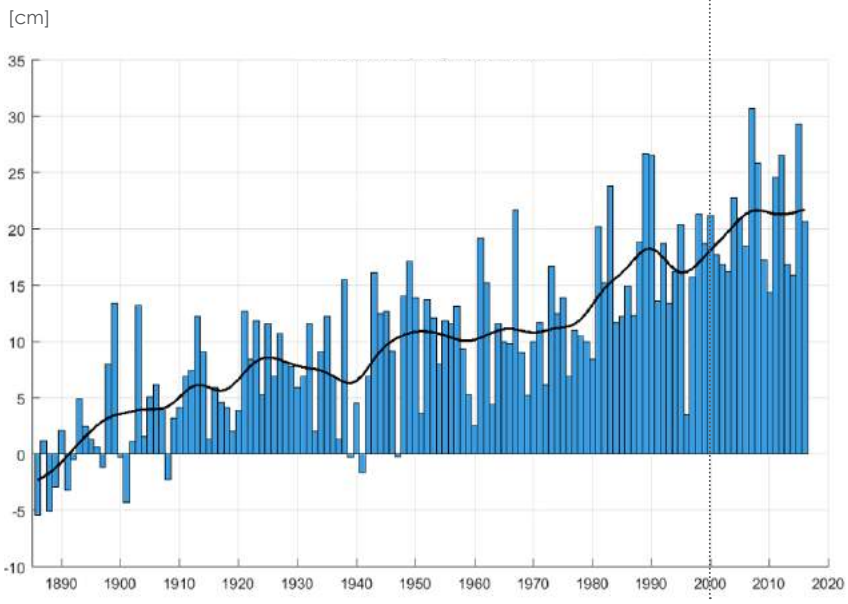


Figure 43. Sea level rise in Sweden, between 1886-2016. (SMHI, 2010). Printed with permission.

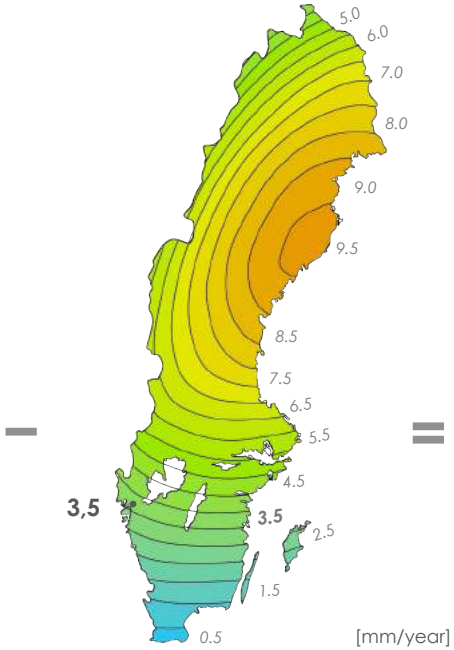


Figure 45. Postglacial land uplift. (Vestøl et al., 2016). Adapted with permission.

Sea level rise

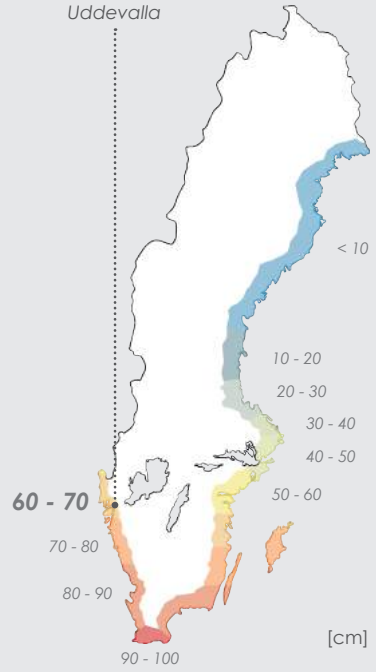
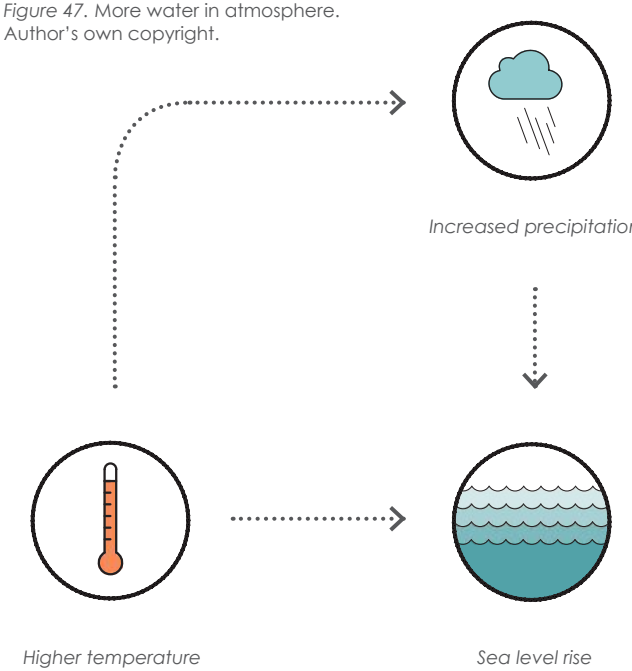


Figure 46. Relative sea level rise in 2100. (Klimatanpassningsportalen, 2017). Adapted with permission.

2.3.2 FINDINGS

Global warming is leading to more precipitation and higher sea levels. Therefore does coastal cities need to make more space for water in the future. Uddevalla has been affected by repetitive floods ever since the river delta was filled-up. The worst scenario is during western storms and heavy rainfalls, when water from the fjord is pushed into the city river that is also filled up by surface water. Of that reason can three main spaces be identified to prevent the city from flooding in the future. At first could strategies be applied in the fjord to prevent the increasing sea level from reaching the city. Then could also water storage strategies in the mountains reduce the run-off water towards the city. However, this thesis is focusing on how to provide more space for water in the valley city itself, as the river delta did in the past.

Figure 47. More water in atmosphere. Author's own copyright.



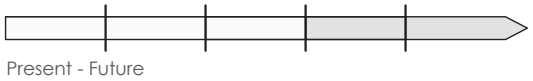


Figure 49. More space for water. Author's own copyright.

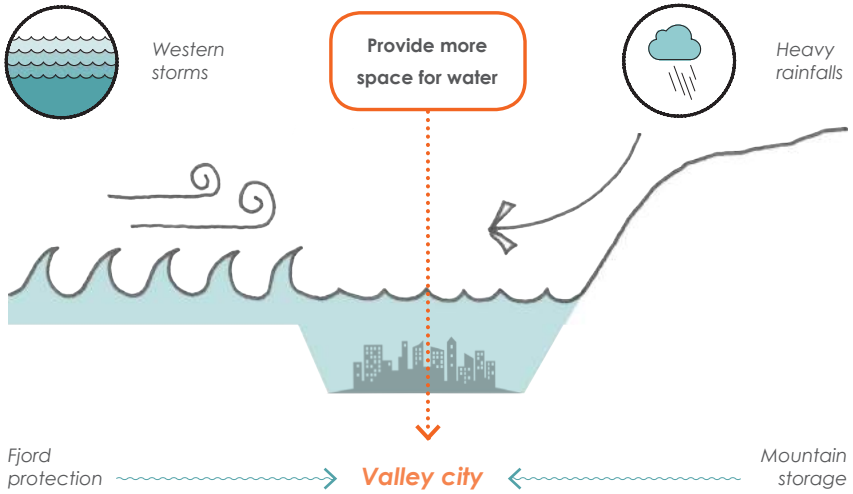


Figure 48. Flood scenario in Uddevalla, 2.7 m above todays sea level. (Dahllöf, 2007). Printed with permission.

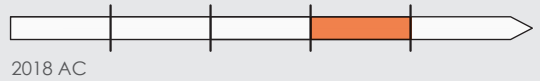
2.4 WATER DEPLETION

Rising water & sinking land

The river level in Uddevalla is currently rising with approximately 3 mm/year (SMHI, 2018), while the land is uplifting with 3.5 mm/year (Vestøl et al., 2016). Simultaneously are most parts of the filled-up river delta in Uddevalla sinking up to 35 mm/year (Fredgren, 2016). Despite that the sedimented river works as a counter-weight for the straight quays is the sinking process accelerating by the weight of urban development and the land itself. Because of the vast area of filled-up river delta and its deepness of clay is the old river delta expecting to sink even faster in the future. The consequence is that the river cannot be dredged from sediments, the riverfront cannot further be loaded with goods and the flood protection in future has to adapt to both an increased water level and a sinking land (WSP, 2016).

Reduced subsurface support

The depletion of ground-water is the major factor behind the sinking river delta in Uddevalla. Water extraction from wells contributes to the discharged water table, but it is not the main reason because the city is mainly using surface water for irrigation and drinking water (Klasson, 2008). Instead, it mainly depends on impermeable surfaces and underground drainage pipes that has reduced the water infiltration rate and thereby lowered the ground-water table. When the ground-water table drops is the subsurface support reduced and the soft soil is compressing and therefore sinking (Alley, Reilly, Franke, 1999).



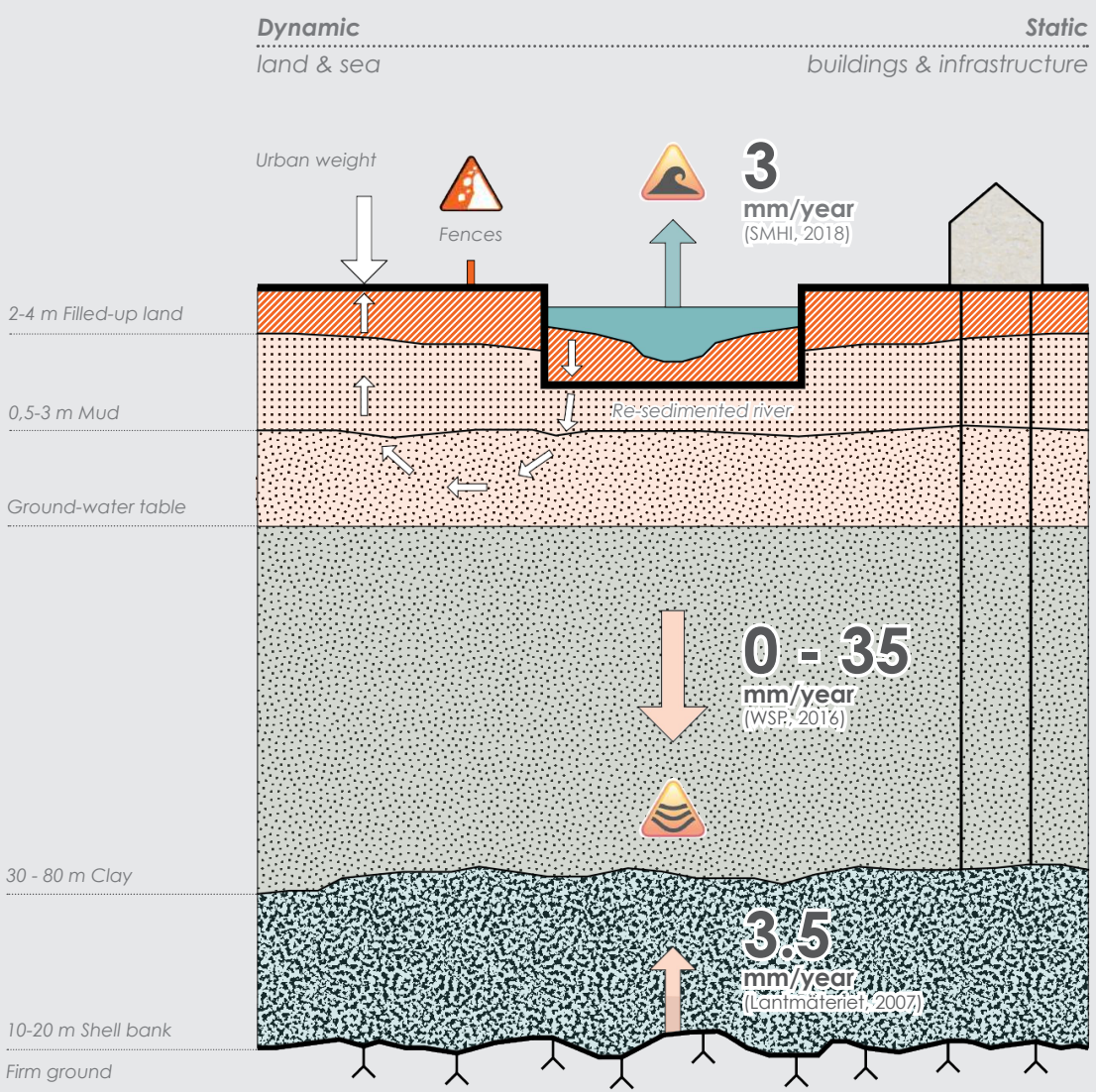
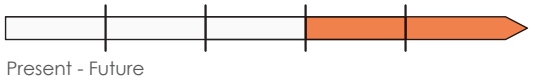


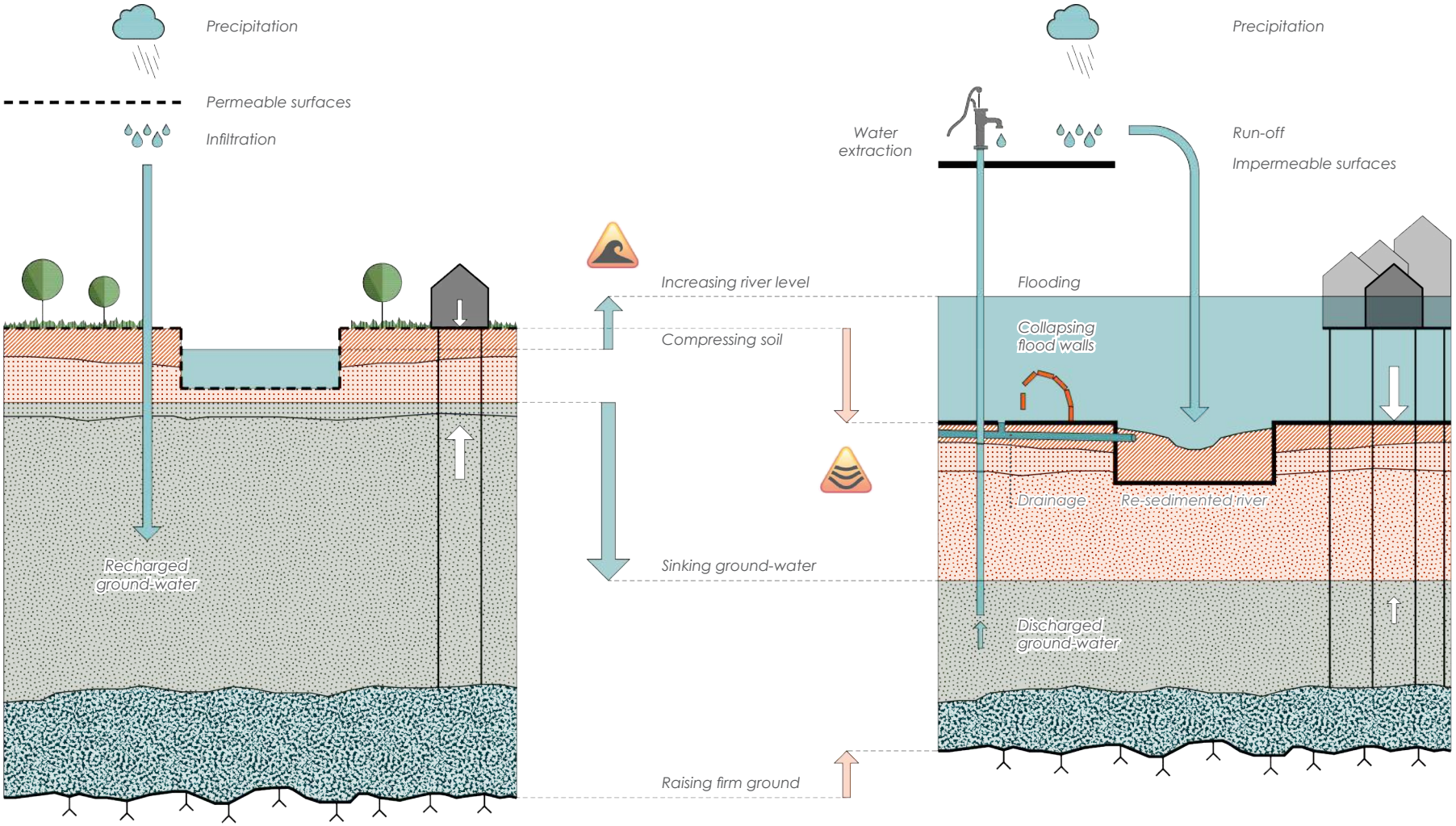
Figure 50. Vertical land and water movements. Author's own copyright.



Early urbanization
Land reclamation

Ongoing processes
Global warming
&
Water depletion

Future densification
City expansion



Ground-water preassure higher than urban weight

Figure 51. Dynamic river delta landscape. Author's own copyright.

Ground-water preassure lower than urban weight

2.4.1 FUTURE: WATERFRONT CITY

The municipality is planning to re-locate the harbour in the fjord to make space for mainly housing and recreational areas on the sinking river delta. The plan is that a spatial growth of the city can offer riverfront spaces that attracts residents and tourists to Uddevalla, which in turn will generate economic growth (Uddevalla kommun, 2016). However, the waterfront expansion risks to increase the urban pressure on the river delta that in turn will sink even faster in the future.

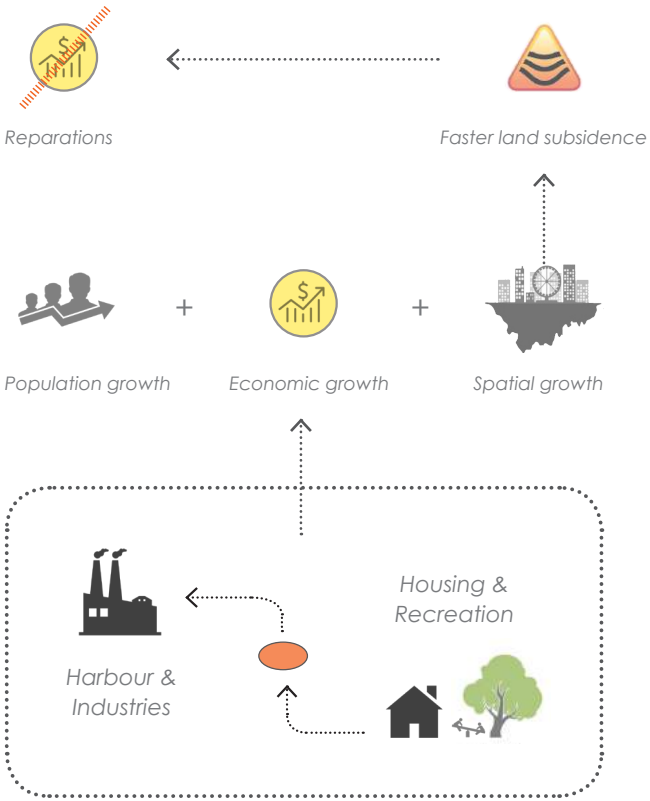
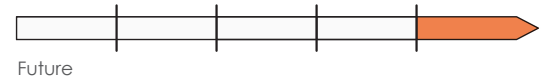
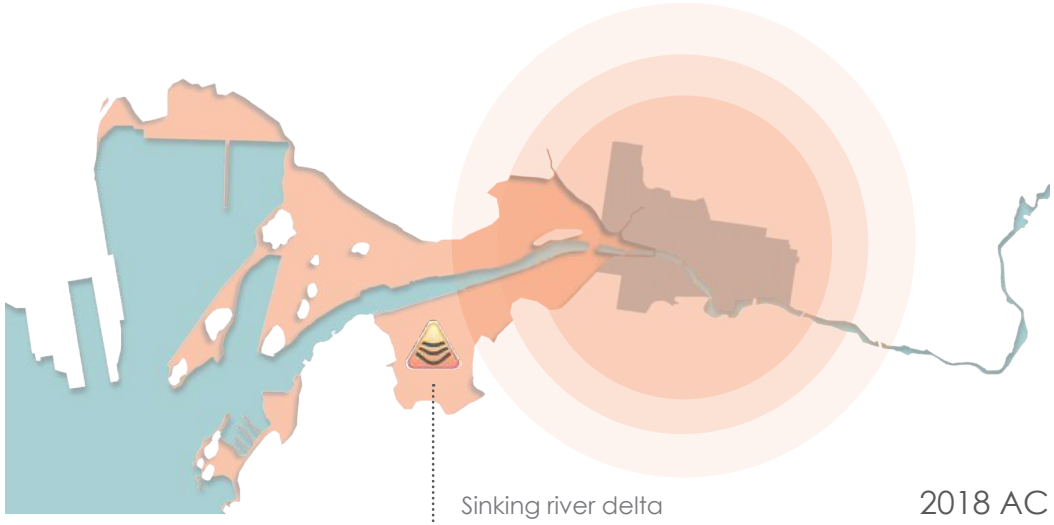


Figure 53. The waterfront city. Author's own copyright.





(Figure 29, page 26)

Waterfront expansion

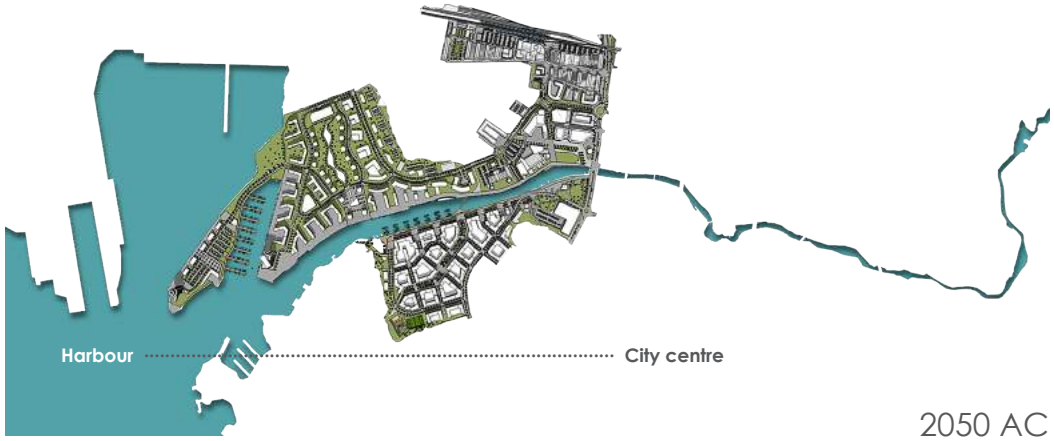
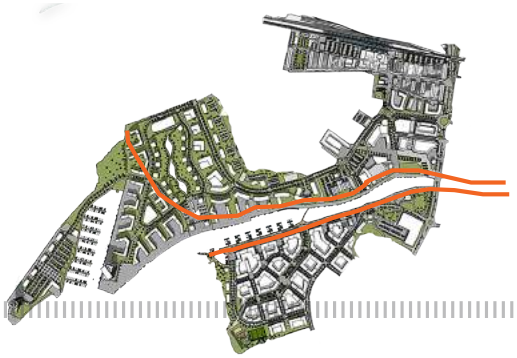


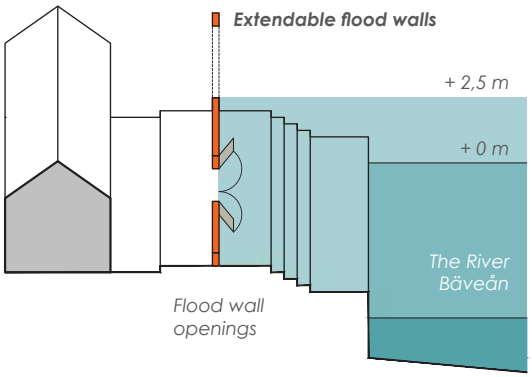
Figure 52. Future waterfront expansion. (Uddevalla kommun, 2016). Adapted with permission.

Planned flood protection

The waterfront expansion will be protected mainly by flood defensive walls along the river, but the municipality also suggests several flood reservoirs above and beneath the river delta. The planned flood wall is extendable, but it will first be terraced up to 2,5 m above the normal river level of today. It will also have openings that can be closed during floods, to make the riverfront accessible every other day (Uddevalla kommun, 2016).



The waterfront city



Flood strategies

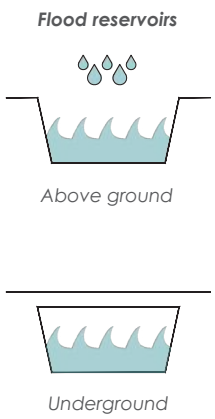
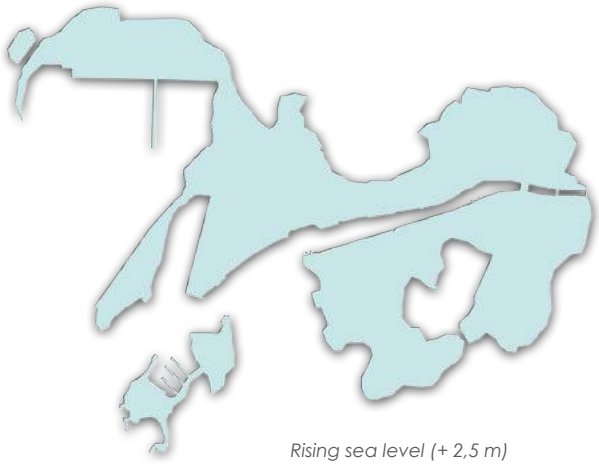


Figure 54. Static flood protection in a dynamic landscape. Author's own copyright.

The flooding city



Rising sea level (+ 2,5 m)

Rising sea level

Sinking river delta

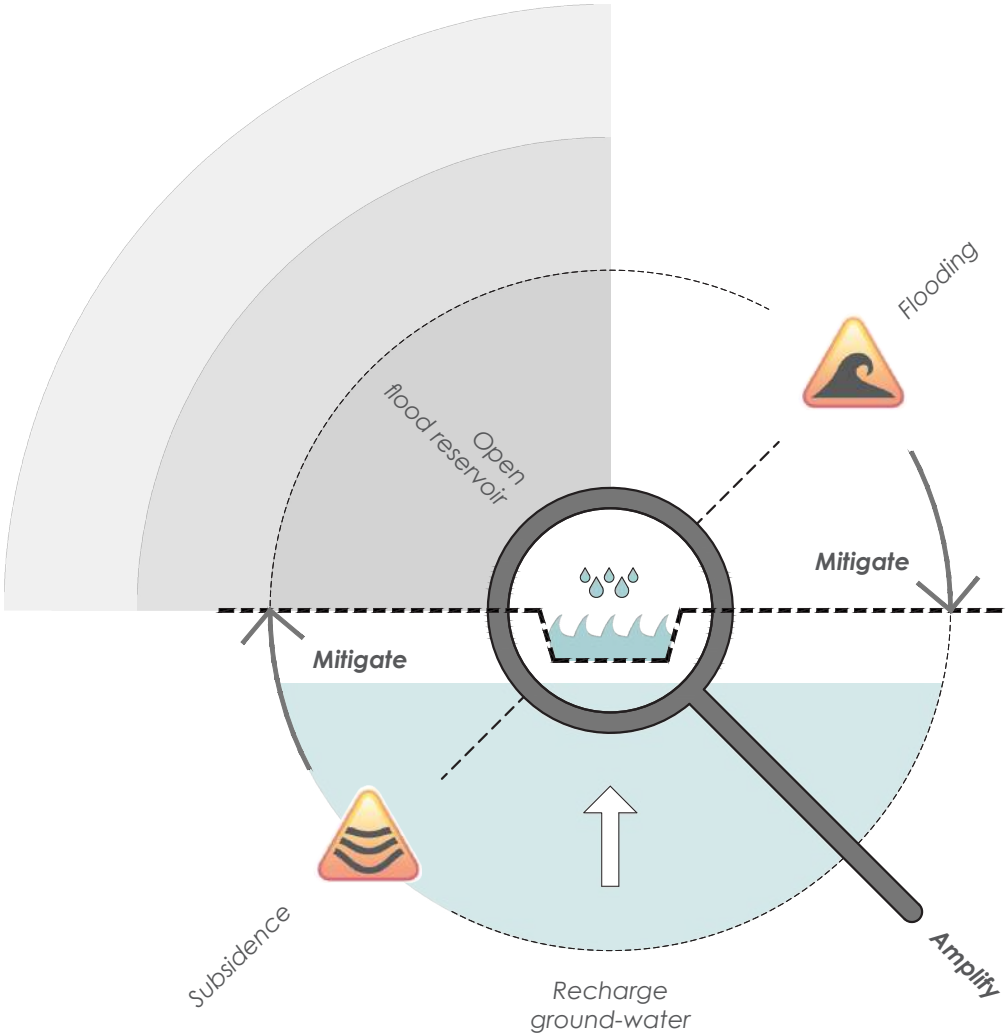
The sinking city

2.4.2 FINDINGS

The municipal flood protection plan is mainly focused on how to protect the future waterfront city from an increasing sea level, by means of static flood defensive walls. This master thesis suggests a complement to the municipal flood defensive strategy that both can mitigate flooding and land subsidence. The municipal strategy of open flood reservoirs will be further investigated, as a re-interpretation of the previous river delta flood storage capacity. By storing flood water and recharging the ground water table can open flood reservoirs contribute to both a reduced land subsidence and flooding risk.

Open flood reservior
Reduce the effect of both land subsidence and flooding by recharging the ground-water table

Figure 55. Open flood reservoir. Author's own copyright.



SUMMARY

Findings

Uddevalla´s riverfront is fenced due to poor geotechnical condition, caused by the human impact on natural processes. Global warming is increasing the amount of water in atmosphere, while the urbanisation processes of land reclamation and water depletion have reduced the waterbody in the city. Uddevalla has become the forbidden city that is suffering from repetitive floods and land subsidence. The project tries to respond to the forbidden city phenomena by suggesting ways of turning these challenges into spatial opportunities. It tries to demonstrate a method of how to re-make space for water in the city and how to re-connect people with the natural water cycle. Instead of being a destructive force could water become an element embedded in the dynamic landscape, creating new urban qualities and achieving a re-balanced water cycle.

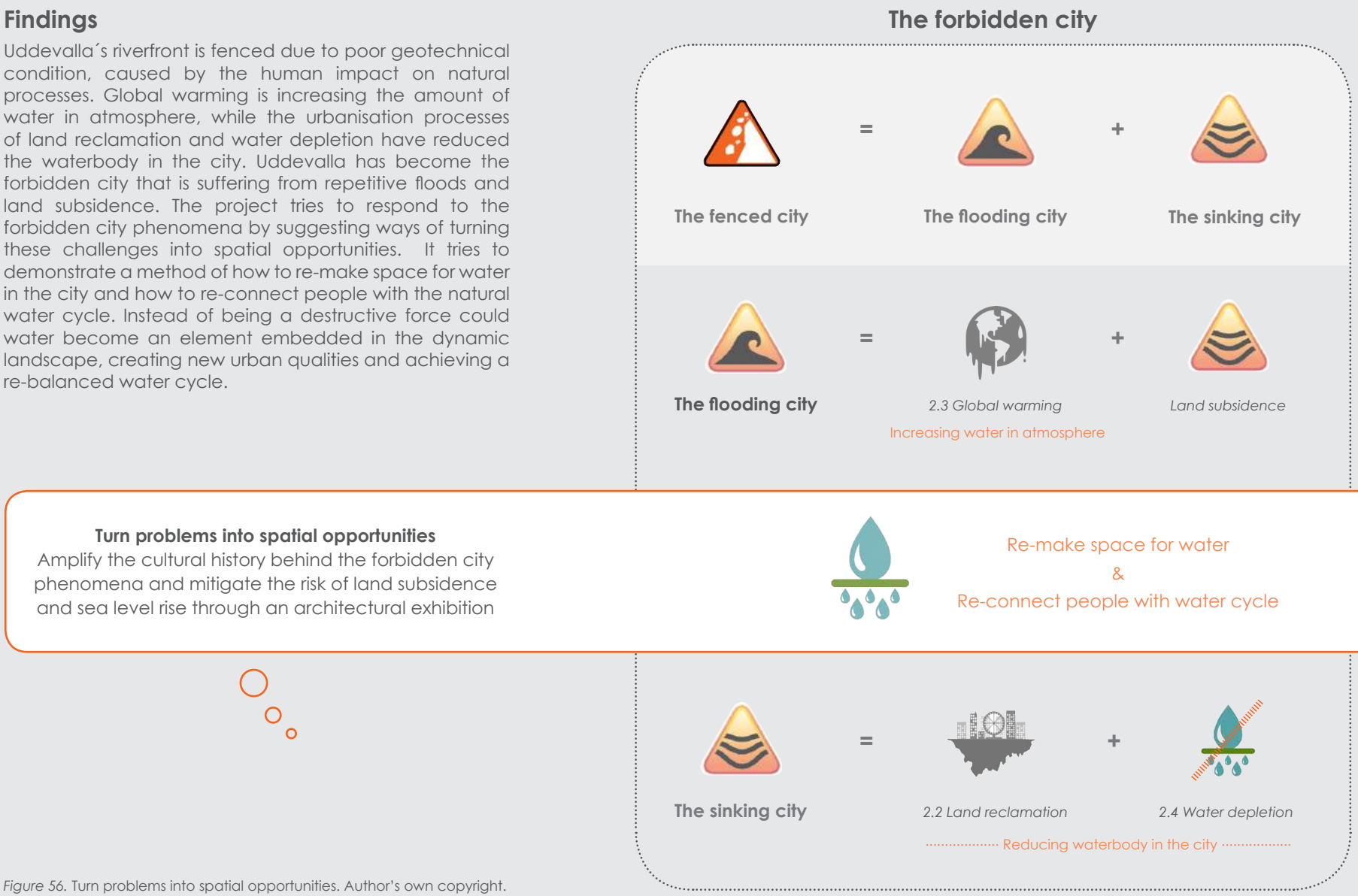


Figure 56. Turn problems into spatial opportunities. Author's own copyright.

Historical research

ANCIENT

The city of Uddevalla is situated in a low-lying valley on the Swedish west coast, where salt water from the deep fjord Byfjorden intersects with sweet water from the river Bäveån. Since the last ice age has the land around Uddevalla been raised faster than the water level, due to a crustal rebound response to the previous ice pressure. Between **9000 BC - 4000 BC** was the valley of Uddevalla a powerful fjord with a water level between 35-75 m above today. Nutrient salt water was upwelled from the bottom by means of the roaring sweet water from the higher altitude. The nutrient water and the uplifting fertile land attracted stone age people to Uddevalla that **lived in symbiosis with its natural processes** without drastically changing it.

MEDIEVAL

When the uplifting land closed the fjord did the valley became covered with oak trees and a **river delta was naturally formed** by its deposits of nutrients and sediments. This shallow area of water functioned as a natural **protection from wars and floods** in Uddevalla, which emerged as a **medieval city in 1498**. Uddevalla became a focal point for trade, due to its location between inland and sea. The river Bäveån gains its real importance first when the inhabitants learned to use water powered sawmills. The export of oak timber led to the city´s first economic growth. However, it also led to a **deforestation that disturbed the local soil infiltration**. The deforestation accelerated the river flow and increased the deposits of sediments in the river delta, which became a **transportation boundary** between the river city and the fjord harbour.

INDUSTRIAL

In the 18th century was the river delta passage so curvy, narrow and filled-up that barely a small empty boat could float between the city and harbour. In the beginning of the **industrial revolution** did the city started to fill up the river delta with dredged material from the wetland passage, in order to reduce the boundary effect. **Elevatorn 1.0** was a temporary building that was used to fill-up the river delta far from the river. The dredged material was collected and elevated up through the building and flushed out on an inclined gutter until it was deposit on the wetland far from the river. This land reclamation process allowed to **move the harbour activity into the city**, which in turn expanded towards the fjord.

PRESENT

Since the industrial revolution has the **amount of water increased globally** much due to the greenhouse gas emissions of human´s interventions. Simultaneously has the **water storage capacity been drained** in Uddevalla and most parts of the filled-up **delta land is compressing and therefore sinking** up to 35 mm/year. Because of the vast area of filled-up land and its deepness of clay is it expecting to sink even faster in the future. Since buildings rest on poled foundations is the sinking ground making ramps steeper and stairs are hanging in the air. Because of its poor geotechnical conditions are large parts of the **riverfront even closed for public use**. Uddevalla has become **the forbidden city** that is suffering from repetitive floods, especially during western storms and heavy rainfalls.

FUTURE

The municipality is planning to **re-locate the harbour in the fjord** to make space for mainly **housing and recreational areas**. This waterfront expansion will be protected mainly by a **flood defence** system of static walls, without any special consideration to the dynamic movements of land and water. This master thesis suggests a **complement to the municipal flood defensive strategy** that both can mitigate flooding and land subsidence. Since Elevatorn 1.0 contributed to a reduced waterbody is **Elevatorn 2.0** trying to **allow more space for water** in Uddevalla, as the river delta did in the past. By **storing flood water and recharging the ground water table** can Elevatorn 2.0 both reduce the land subsidence and prevent flooding in other areas. Furthermore, Elevatorn 2.0 is a characteristic building in a strategic location with a particular function that also can **strengthen the identity of place**, awake curiosity and put Uddevalla on the map in a broader context.

INTENTION

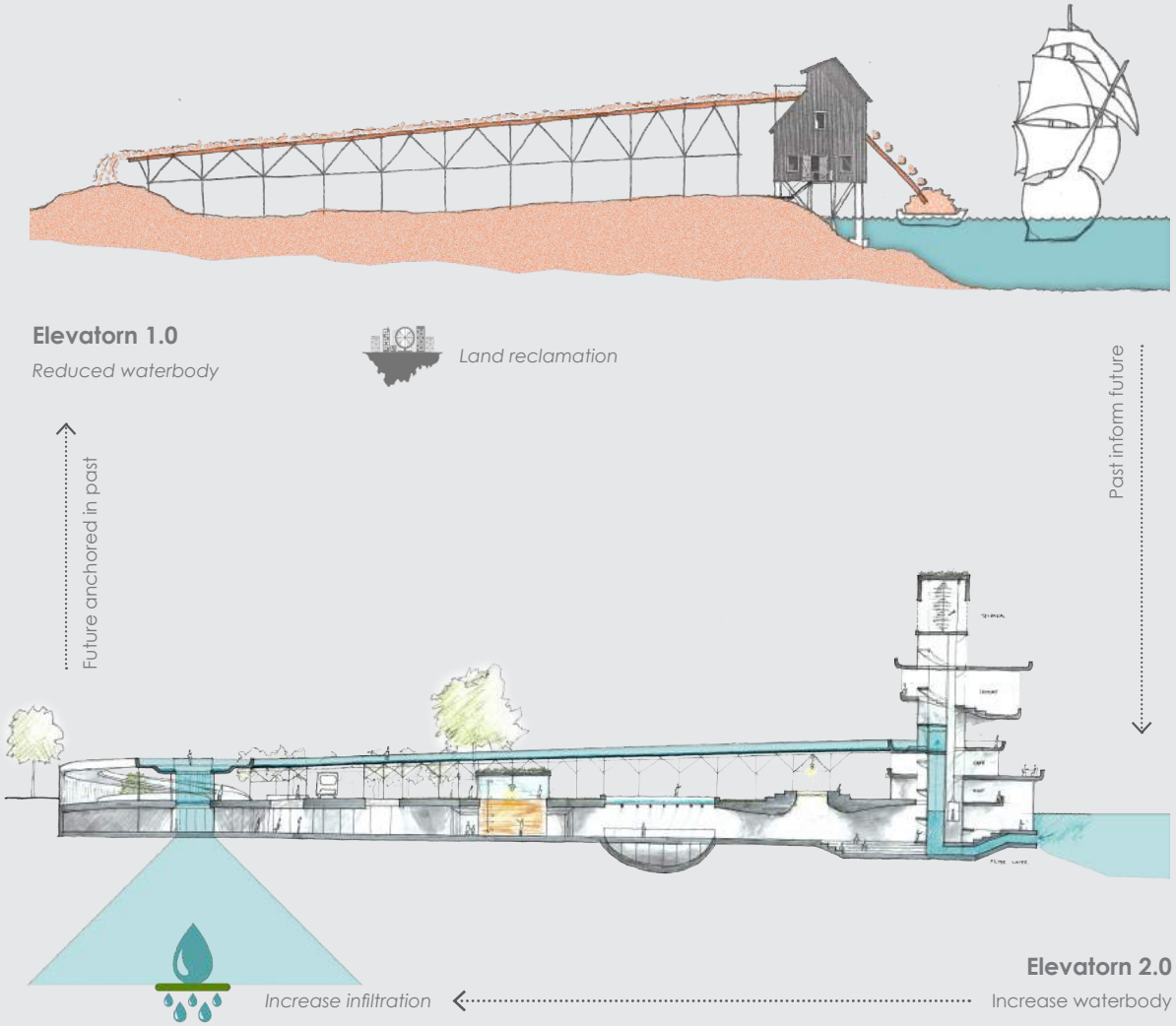
Defines the design intention from the research findings in terms of concept, vision, strategies and site location.

3.0

Elevatorn 2.0

Since Elevatorn 1.0 contributed to a reduced waterbody is Elevatorn 2.0 tries to re-make space for water in Uddevalla, as the river delta did in the past.

Figure 57. Elevatorn 1.0 vs. 2.0. Author's own copyright.



Urban naturrum

Naturum is a Swedish institution which informs visitors about animals, plants, geology and culture that have shaped the surrounding characteristics. Normally are naturum dedicated to natural reserves or national parks that are of great value for conservation and recreation (Naturvårdsverket, 2015). However, this thesis proposes an urban naturum that let visitors experience the water cycle through an architectural exhibition about the cultural impact behind the forbidden city phenomena in Uddevalla.

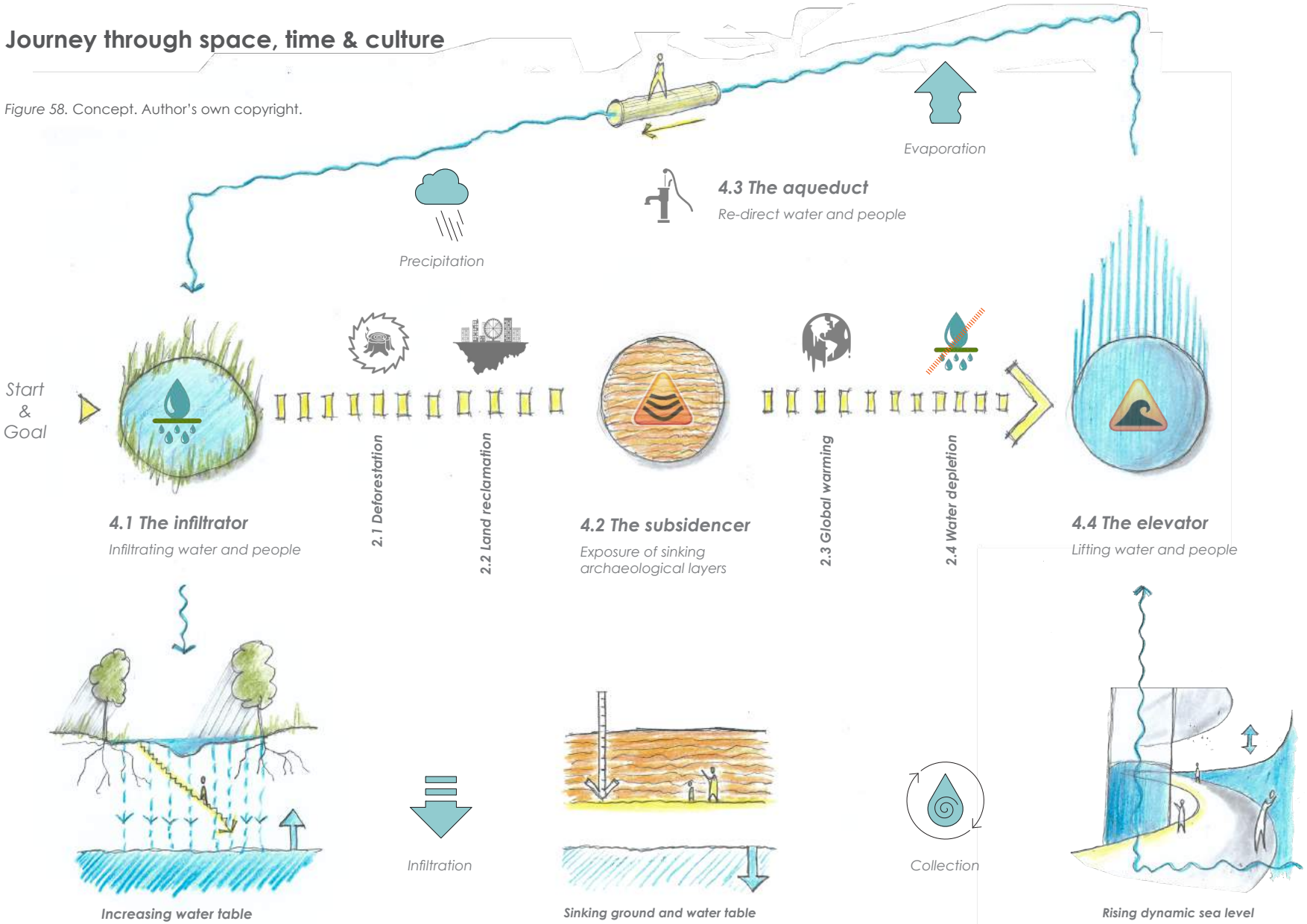
The project consists of three main parts that express the natural processes of infiltration, land subsidence and sea level rise. These parts are connected by an underground timeline axis that express the cultural impact of deforestation, land reclamation, global warming and water extraction. The last component is the elevated aqueduct that re-direct water and people from the river back to the infiltration park in the beginning, which is a re-interpretation of the previous flood storage capacity of the past river delta in Uddevalla. The sequence ends where it starts by infiltrating water and people into the shaded earth.

Urban
naturum®
Elevatorn 2.0 in Uddevalla

The Swedish Environmental Protection Agency (Naturvårdsverket) owns the right to the trademark naturum (Naturvårdsverket, 2015)

Journey through space, time & culture

Figure 58. Concept. Author's own copyright.



Integrating multiple objectives

The project demonstrates one way of re-balancing the water cycle and revealing the hidden story of a particular place. It combines architecture, engineering and landscaping to integrate as many social, economic and ecological concerns as possible. This type of multifunctionality can re-make space for water that brings wildlife to the old river delta, which in turn brings a sensorial experience to people. A sense of human-nature relationship can be re-established, which motivate visitors to make use of the old river delta in such a way that its values can be conserved. The urban naturum in Uddevalla has the potential to create an understanding of the need to live with natural processes in general and the water cycle in particular.

Re-infiltrate the river delta

The project tries to increase the infiltration rate on land, which both can mitigate land subsidence and sea level rise. An infiltration park will be established to naturally capture, store, infiltrate and treat storm water. This park will be allowed to flood to reduce the risk of flooding in other areas, as the river delta did in the past. Besides of controlling floods and maintaining water quality can the infiltration park bring wildlife habitat, reduce run-off, diminish erosion and provide access to recreation in an appealing learning environment. The infiltration park is as a cost-effective natural system that can reduce the need of expensive storm water infrastructure, most of which give high volumes of untreated water directly into the river.

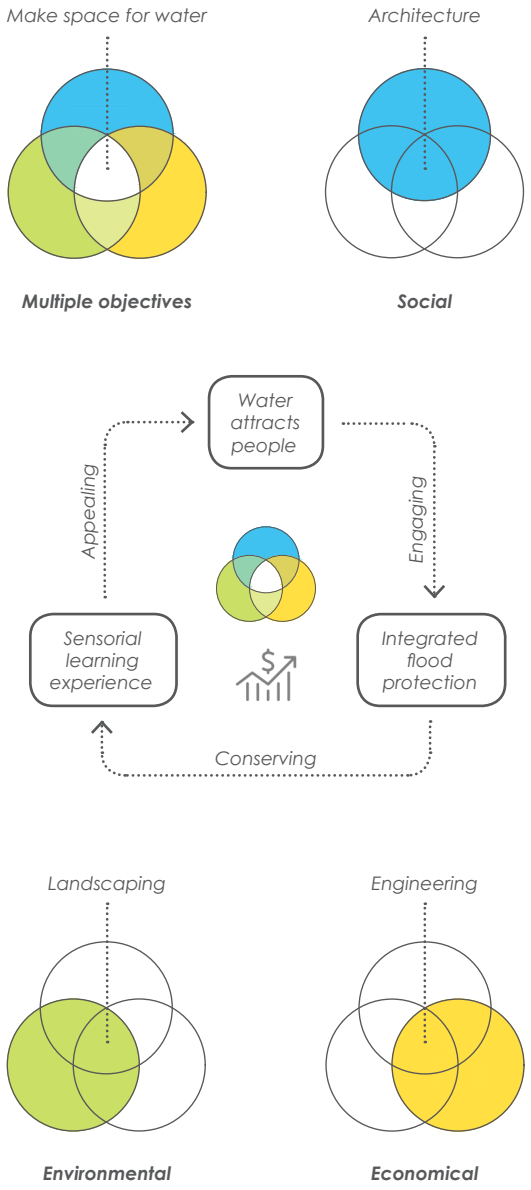


Figure 59. Vision. Author's own copyright.

Re-generate the riverfront

The project functions as an architectural exhibition that demonstrates the cultural reasons behind the forbidden city phenomena. It also attracts people by offering recreational opportunities and cultural events. Along the journey are visitors given opportunities to touch and interact with water in different stages, to encourage an appreciation for natural processes. Once these values are appreciated are the visitors becoming supporters for protecting and restoring the water cycle. Future solutions of urban challanges can further be discussed and evaluated at this place. This will provide a well-informed and more engaged community that is ready to turn problems into more sustainable opportunities.

Re-interpret the typology

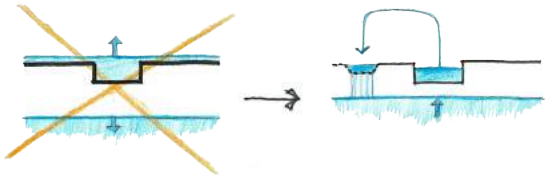
The project serves as a multi-purpose flood protection that can largely finance itself, compared with flood protection facilities with only one function that is used very rarely. Elevatorn 2.0 represents a re-interpretation of the Elevatorn 1.0 typology that moved dredged material onto the old river delta. The project does the opposite by re-directing water from the flooded river to the infiltration park. This infrastructure stimulates and re-make more space for the natural process of ground infiltration. Apart from a more resilient flood protection does Elevatorn 2.0 generate other economic benefits such as touristic attraction, improved water quality, reduced infrastructure costs, less structural damages and increased property values and tax base.

STRATEGIES

Figure 60. Strategies. Author's own copyright.

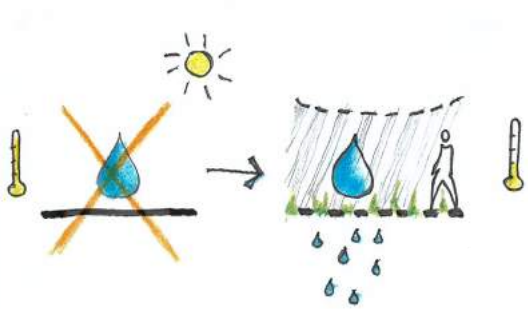
Strategy 1
The naturum emerges specifically from the site rather than being applied onto it (Naturvårdsverket, 2015)

Strategy 2
The naturum is both protecting and articulating the character of its surrounding (Naturvårdsverket, 2015)



Strategy 3
Re-direct storm water from the river to an infiltration park

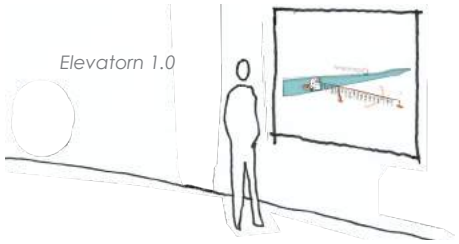
Strategy 4
Reveal natural phenomena through a sunken dry-proof building and elevated aqueduct



Strategy 5
Replace impermeable surfaces with shaded and permeable surfaces

Strategy 6
Static building amplifies and meassures the dynamic land and water movements

Strategy 7
Attract and direct people on a pedagogical journey along the water cycle



Strategy 8
The thesis research works as an informative support along the architectural exhibition

SITE

Sinking river delta

The site is situated where the river delta sinks at the most, 35 mm per year (Fredgren, 2016). It is located in the city center next to Bohusläns museum, which is one of the most visited region museums in Sweden (Post, 2014). The project works as an extension of today´s museum that could fund the project together with the municipality of Uddevalla.

The site consists of an abandonned street that is leading to the fenced riverfront. In the beginning of the street is a sunken parkland located. The purpose is to give a new meaning to the street and parkland that can help to re-balance the local water cycle.

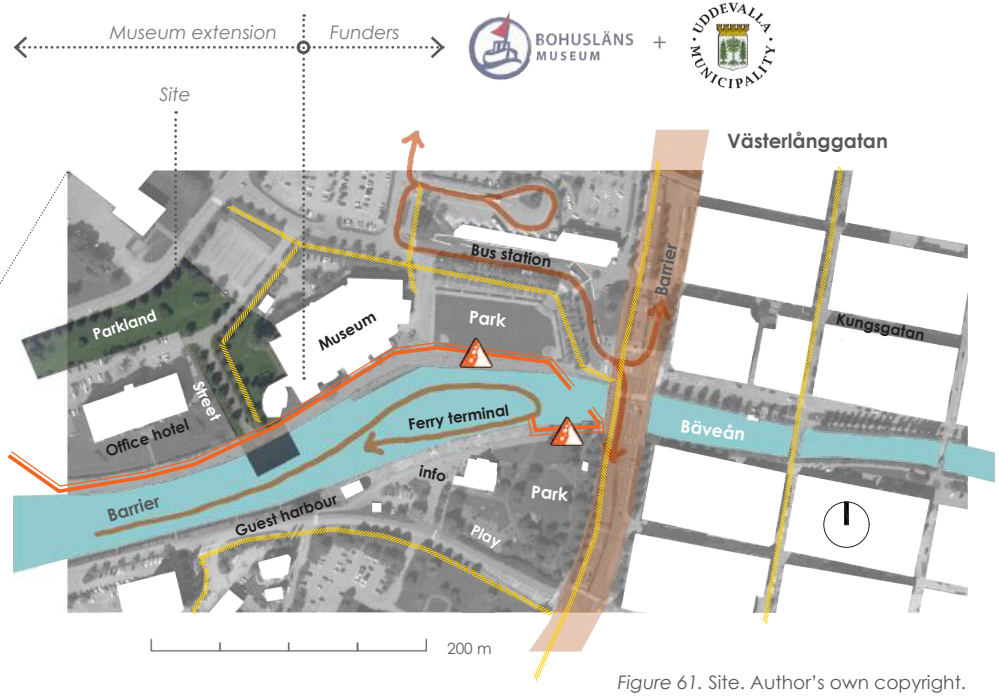


Figure 61. Site. Author's own copyright.

(Figure 29, page 26)

Sinking river delta

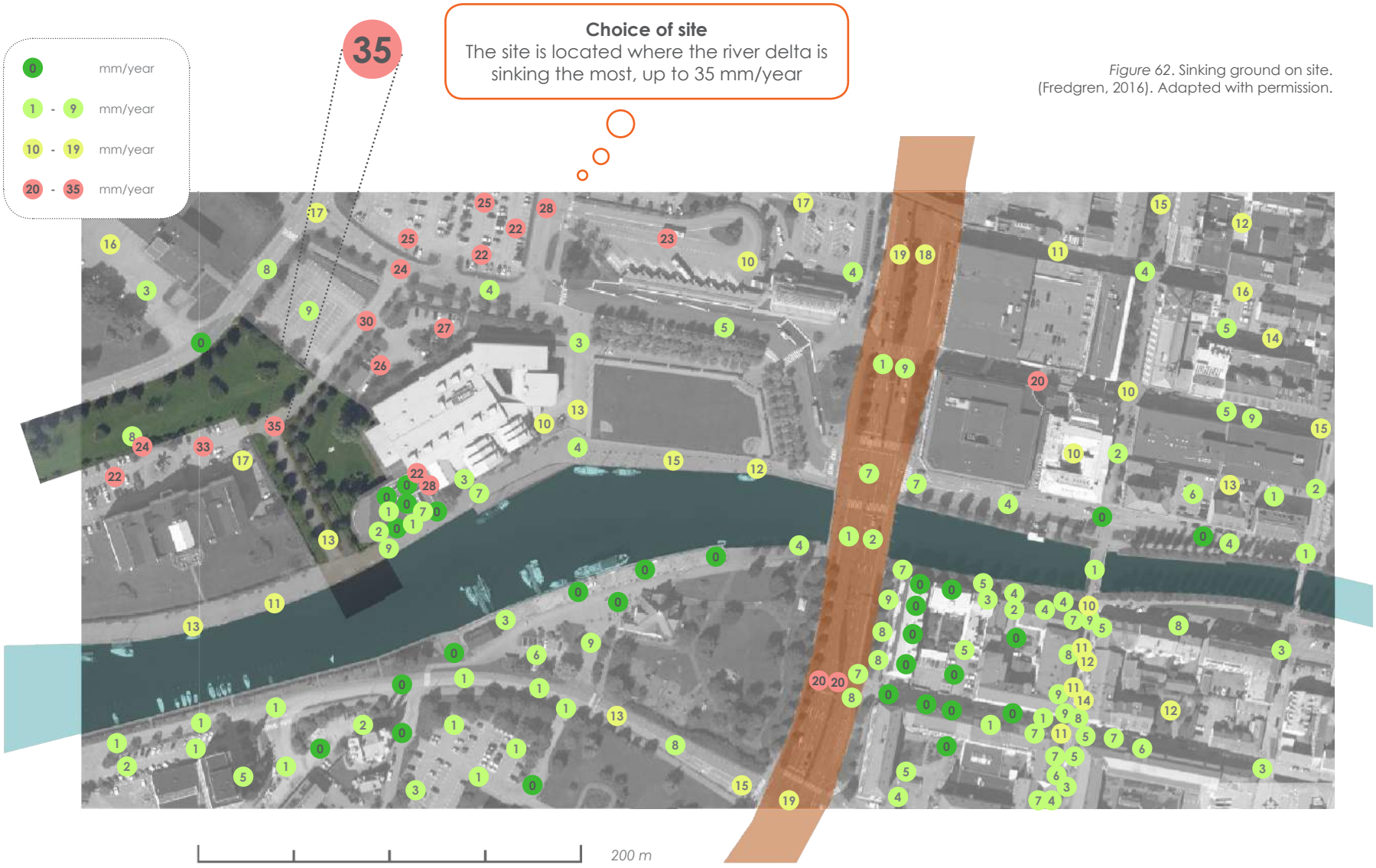
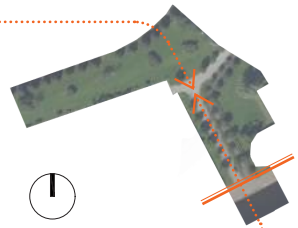
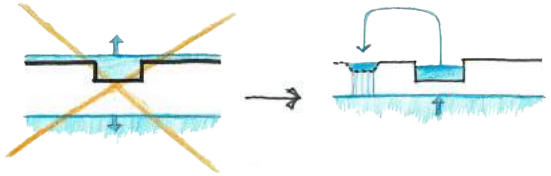


Figure 62. Sinking ground on site. (Fredgren, 2016). Adapted with permission.

Figure 63. Sunken parkland with existing water storage capacity. Author's own copyright.

Figure 64. Abandoned street towards the fenced riverfront. Author's own copyright.





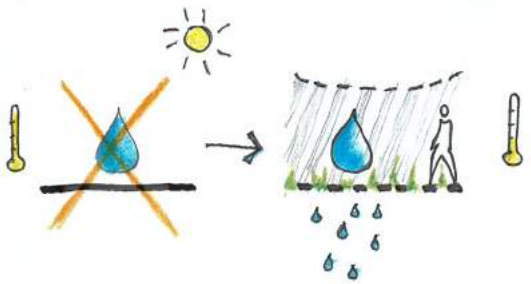
Strategy 3
Re-direct storm water from the river to an infiltration park

Sunken parkland ·····> ***Infiltration park***

Site strategies

The proposal is to transformed the sunken parkland into an infiltration park with more floodwater storage capacity, while the abandoned street is transformed into a green axis with mostly permeable surfaces.

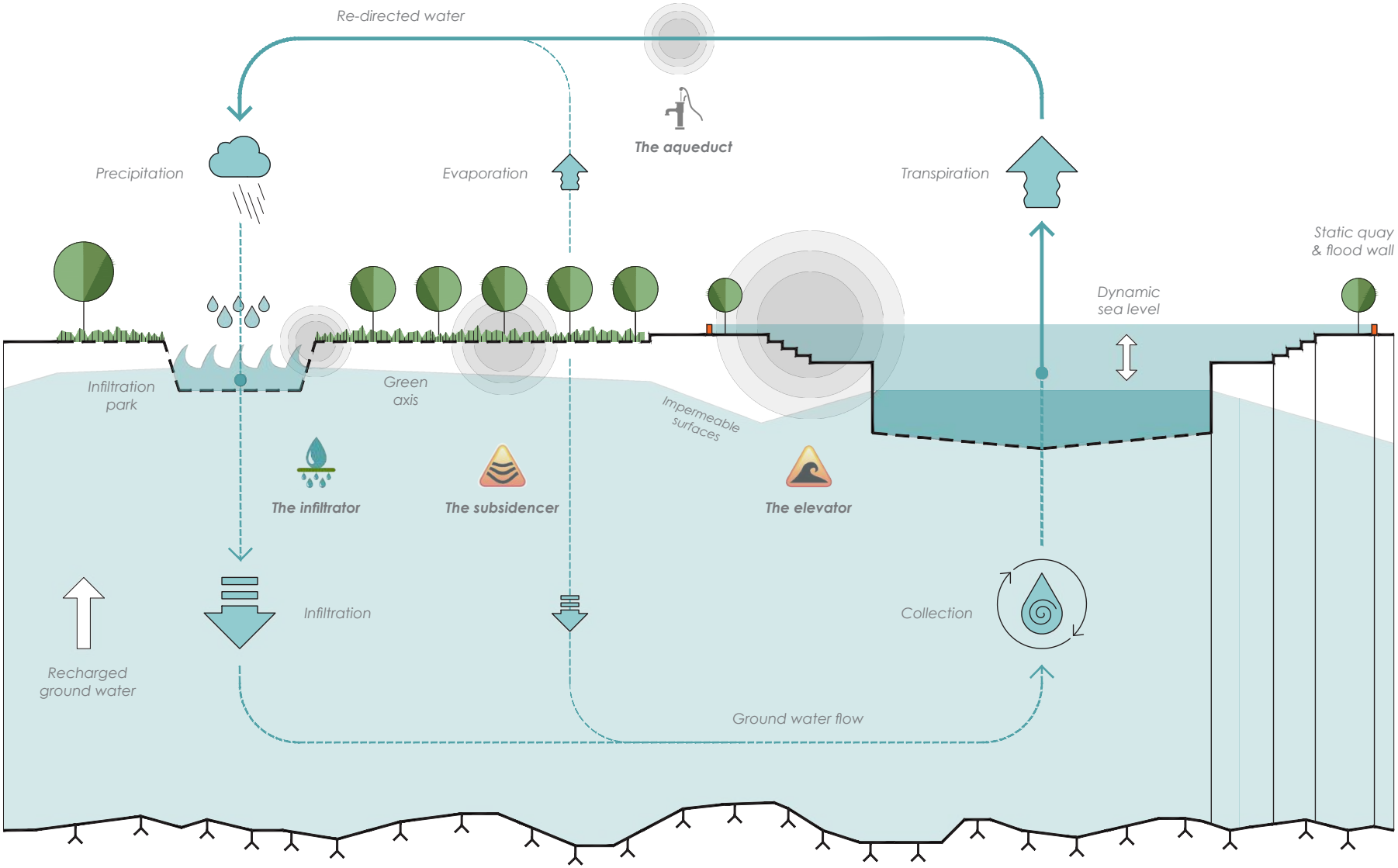
Abandoned street ·····> ***Green axis***



Strategy 5
Replace impermeable surfaces with shaded and permeable surfaces

Section diagram

Figure 65. Summary intention. Author's own copyright.



DESIGN

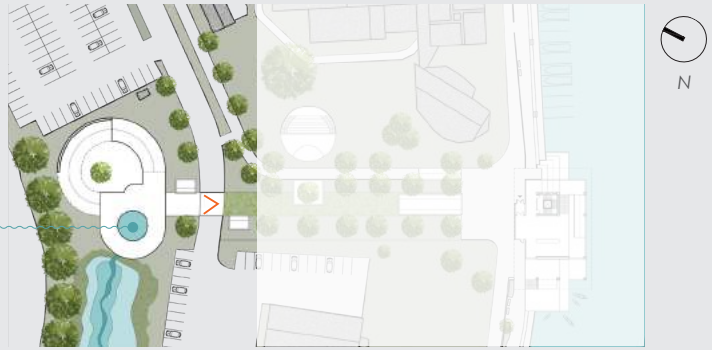
The thesis result works as an architectural exhibition and community space that amplify and mitigate the forbidden city phenomena in Uddevalla

4.0

4.1 THE INFILTRATOR

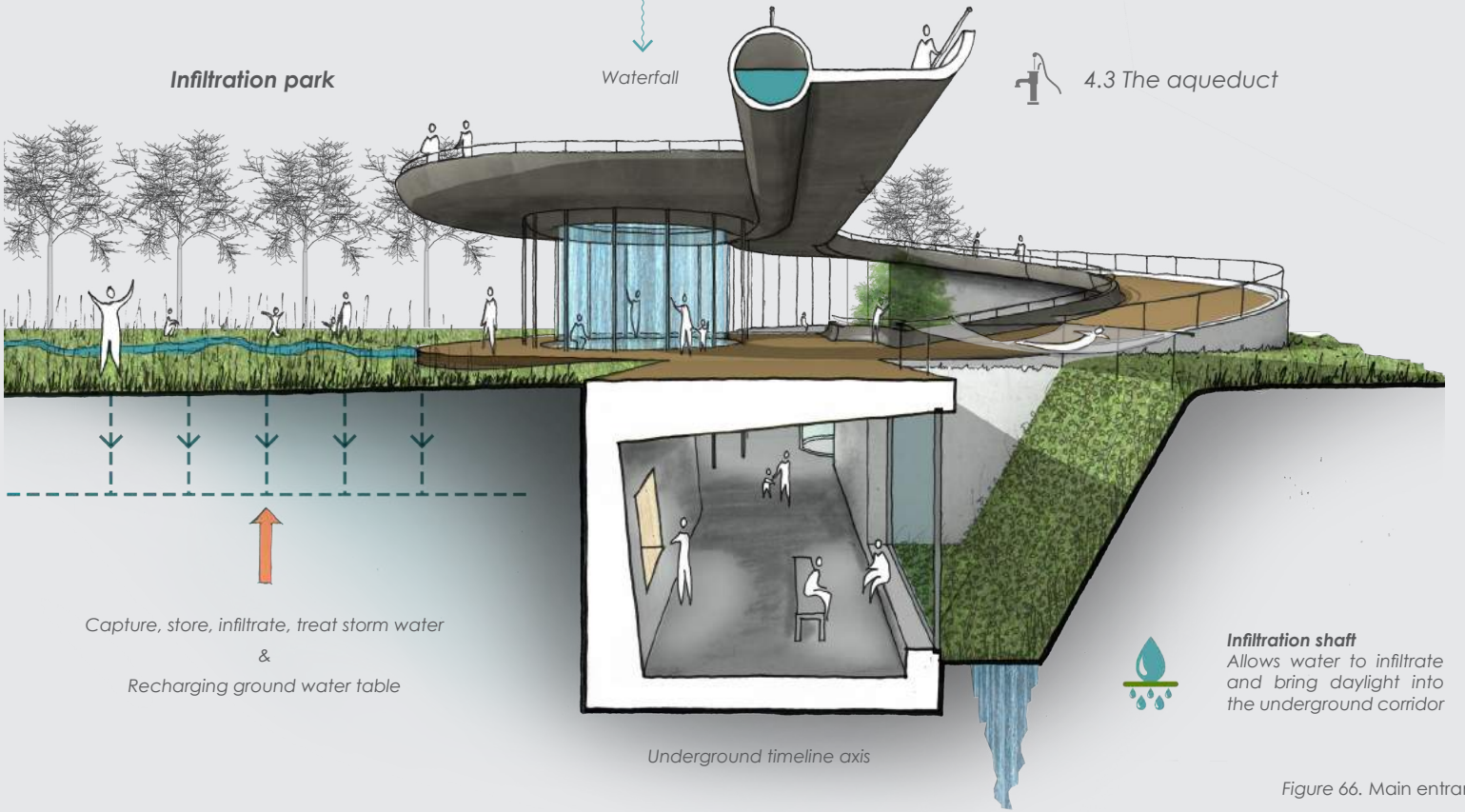
Main entrance

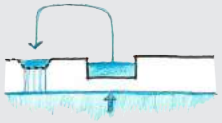
The infiltrator represents the start and goal of Elevatorn 2.0, where visitors actively can experience the infiltration process of water. A waterfall from the aqueduct is directing storm water from the river towards the infiltration park that naturally capture, store, infiltrate and treat the flood water. The infiltrator demonstrates a method of re-charging the ground water table that can be a useful education tool towards a more re-balanced water cycle.



Infiltration park

Orientation (Plan 0)





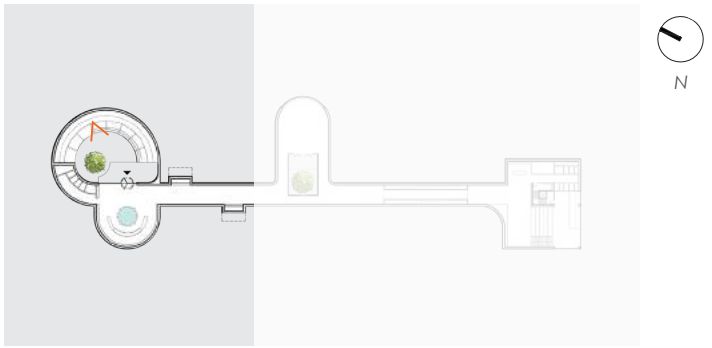
Strategy 3
Storm water is re-directed from the river to the infiltration park

Infiltration shaft
Allows water to infiltrate and bring daylight into the underground corridor

Figure 66. Main entrance. Author's own copyright.

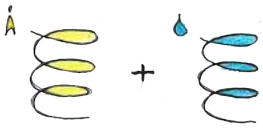
Entrance courtyard

The infiltrator directs both water and people underground. By following a continuous spiral ramp are visitors reaching the entrance courtyard, which is a public space that can host cultivation activities and social gatherings. The spiral ramp is framing the important water cycle relationship between the sky and the soil. Simultaneously does it give shade to the permeable surfaces, which increasing the infiltration rate even more.



Orientation (Plan -1)

Figure 67. Entrance courtyard. Author's own copyright.



Strategy 7
Visitors follow the water circulation underground

Strategy 5
The permeable surfaces are shaded by the spiral

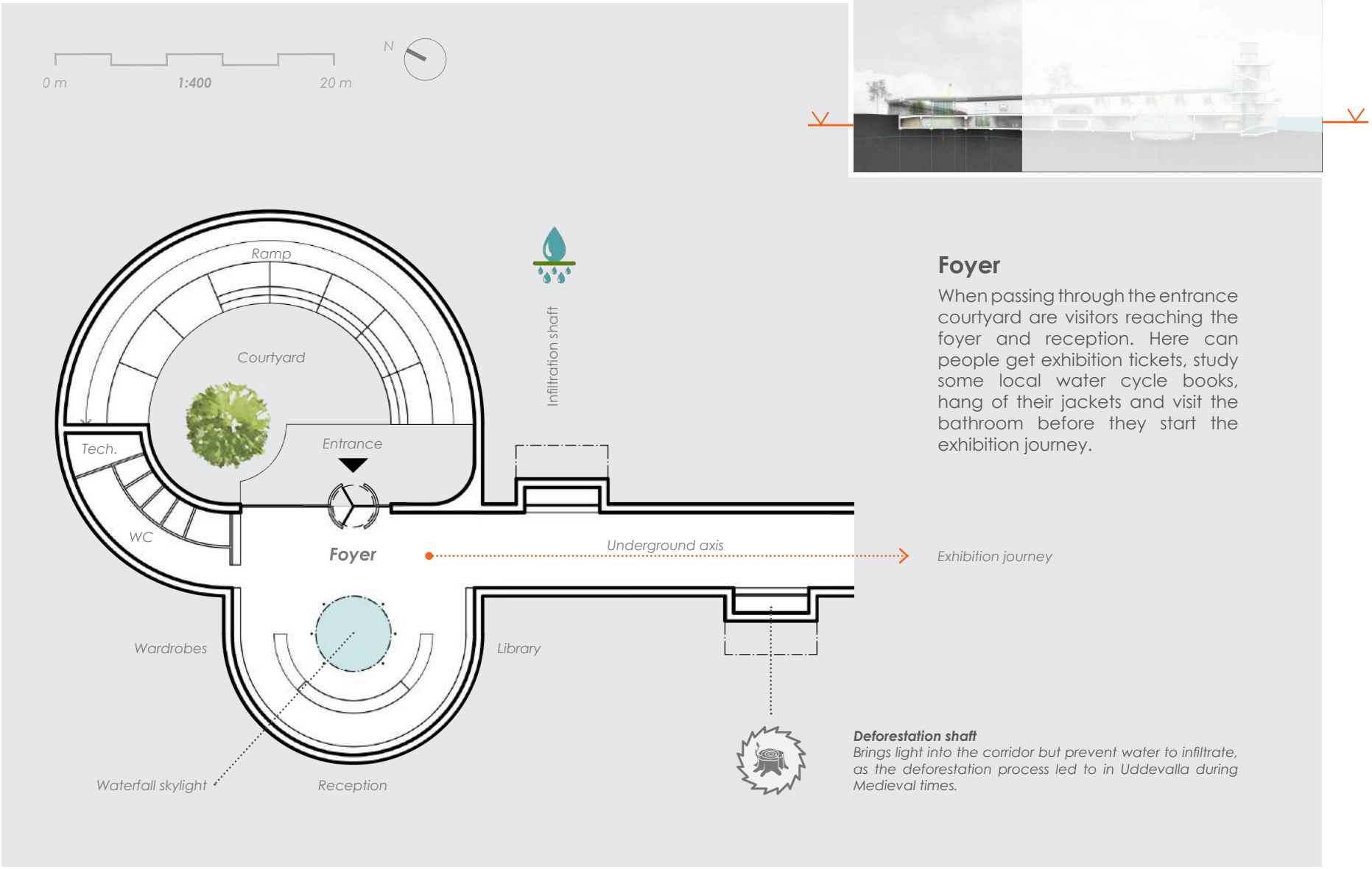
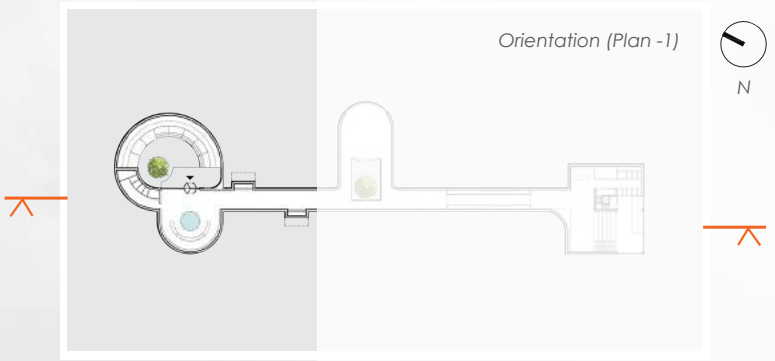


Figure 68. Plan -1: The infiltrator. Author's own copyright.

Waterfall skylight

The first thing visitors notice when they arrive into the foyer is the waterfall skylight. Daylight is penetrating through the moving waterfall down to the foyer. People can even hear the restful sound of water that hits the roof window, which forms the base of the waterfall pond above.



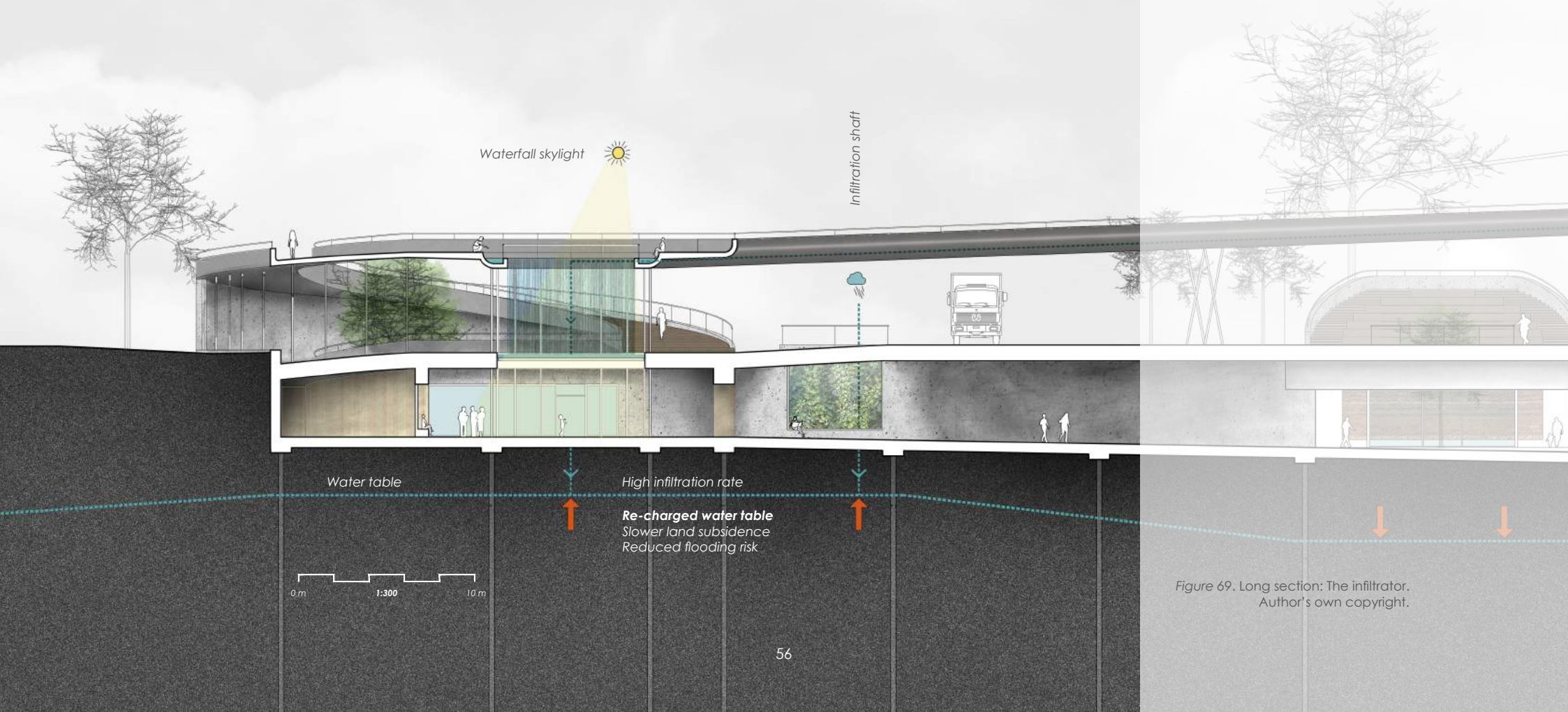
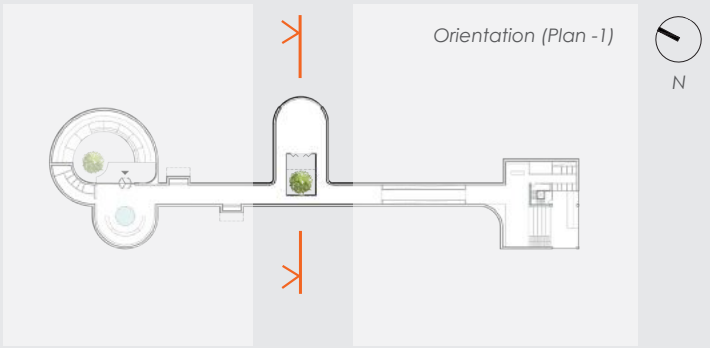


Figure 69. Long section: The infiltrator.
Author's own copyright.

4.2 THE SUBSIDENCER

Exhibition hall

Visitors follow the underground axis until the corridor is opened up towards the exhibition hall, which has a roof formed as an outdoor stage for public lectures and performances.



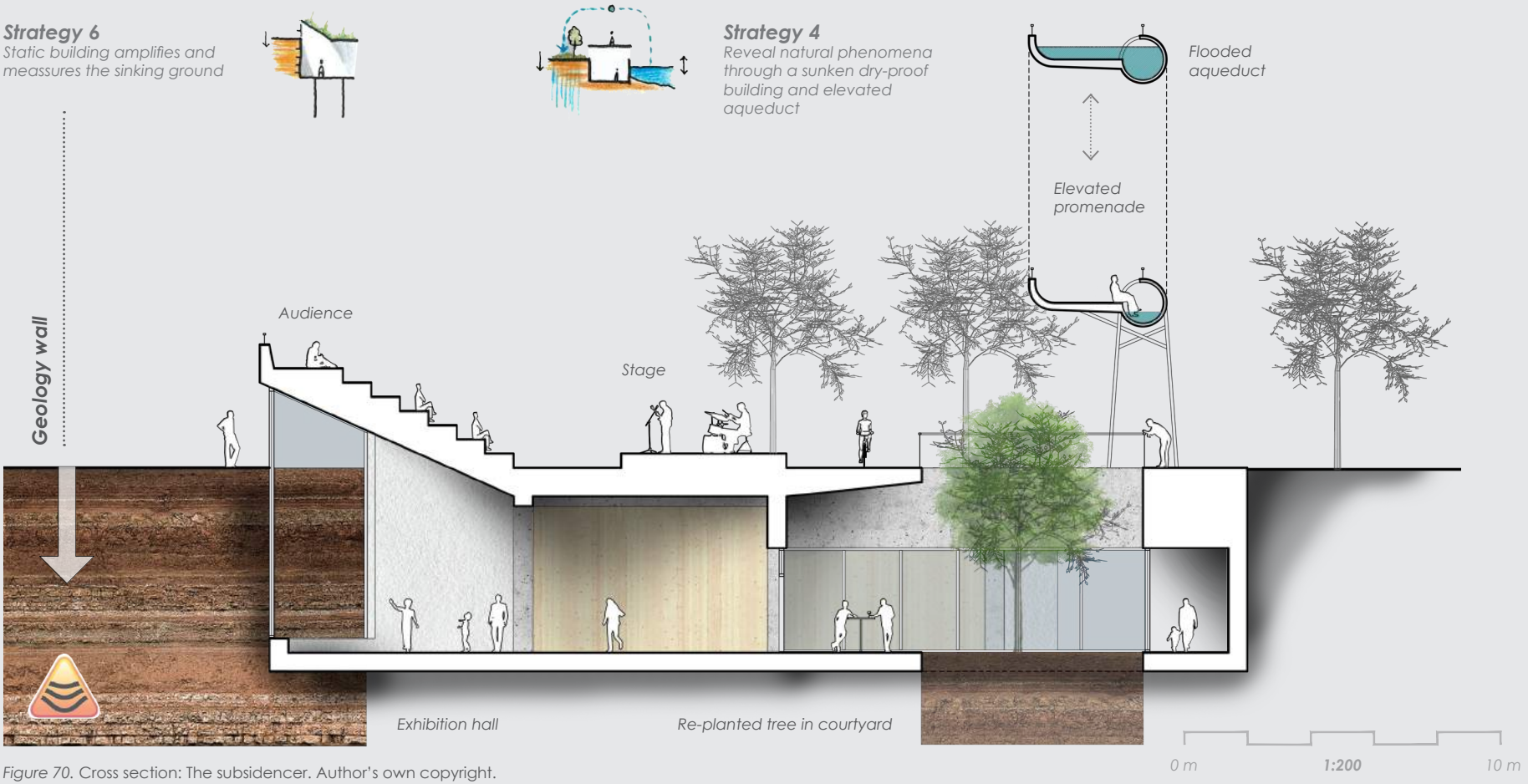
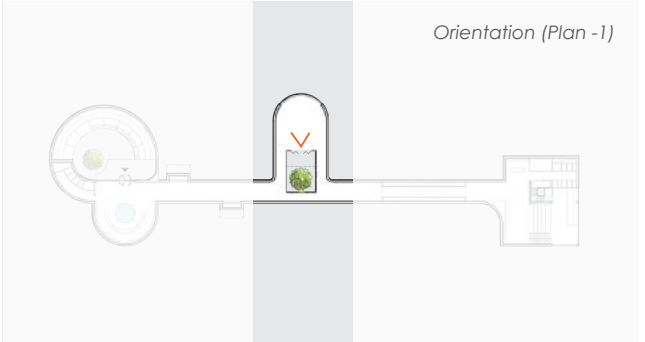
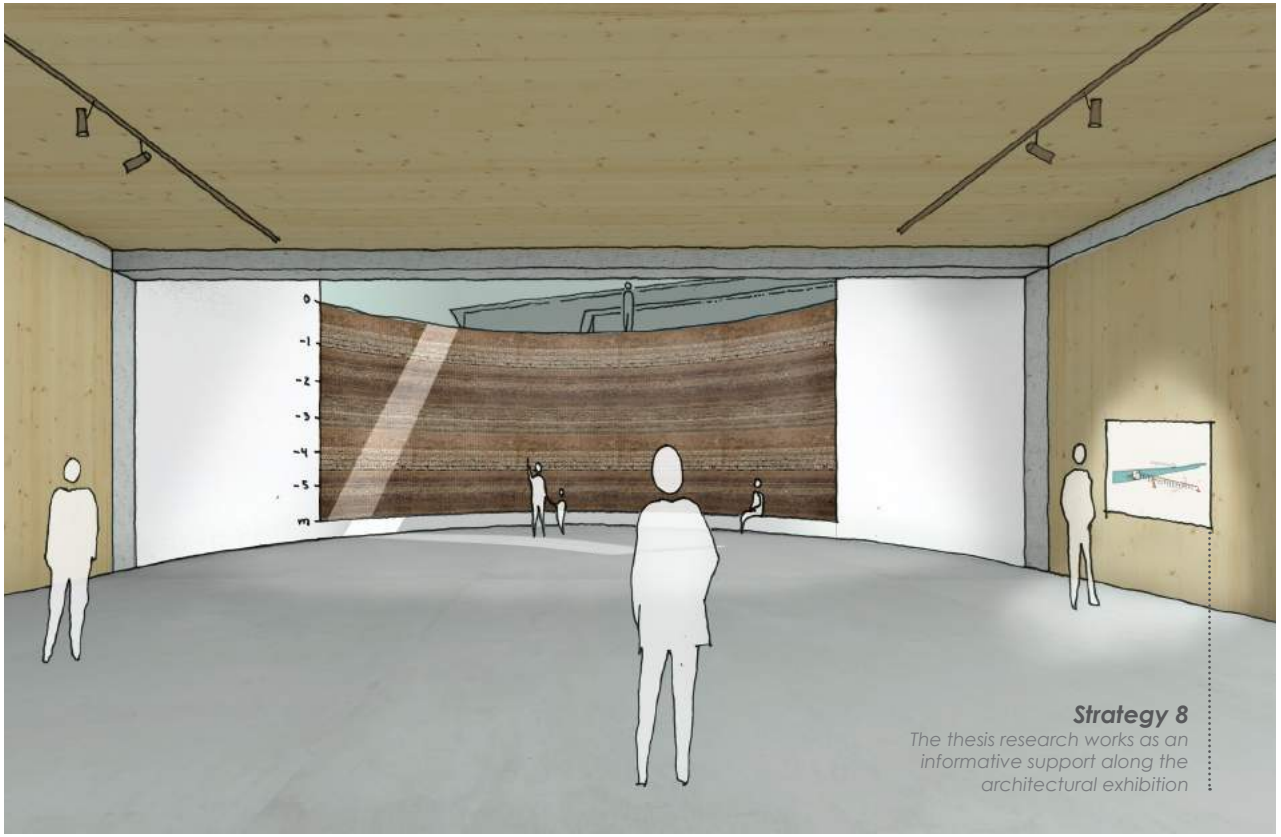


Figure 70. Cross section: The subsidencer. Author's own copyright.

Geology wall

The geology wall is the exhibition hall´s centrepiece, which reveals the story currently hidden below ground. It expresses and measures the sinking archaeological layers of the land reclamation process, which Elevatorn 1.0 was involved in. Here can visitors experience the slow process of land subsidence that in future will give more daylight into the exhibition hall.





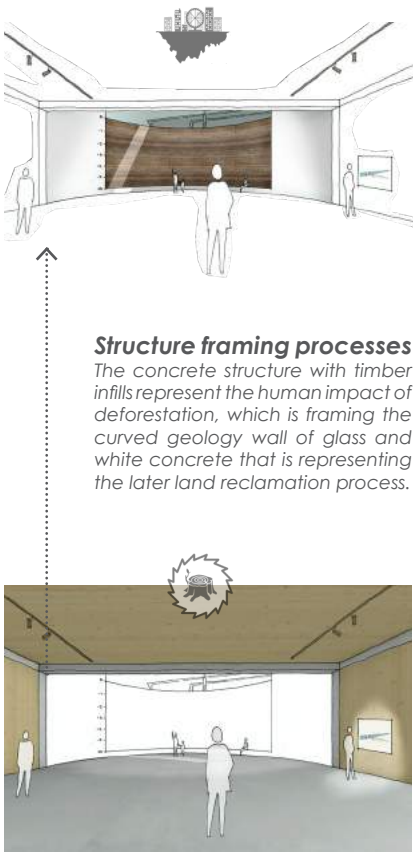


Figure 71. Geology wall. Author's own copyright.

Plan 0

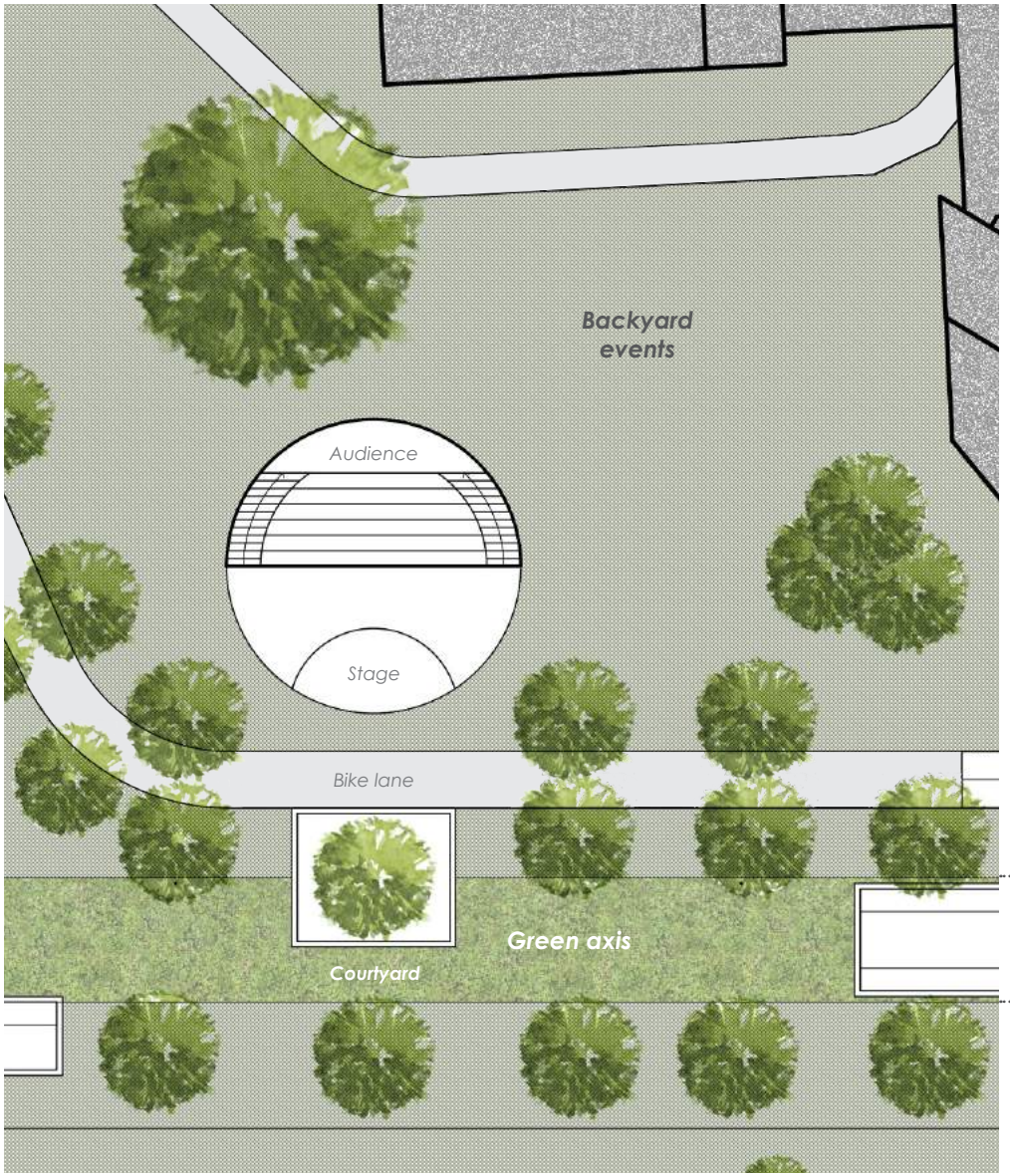


Figure 72. Plan 0: The subsidencer. Author's own copyright.

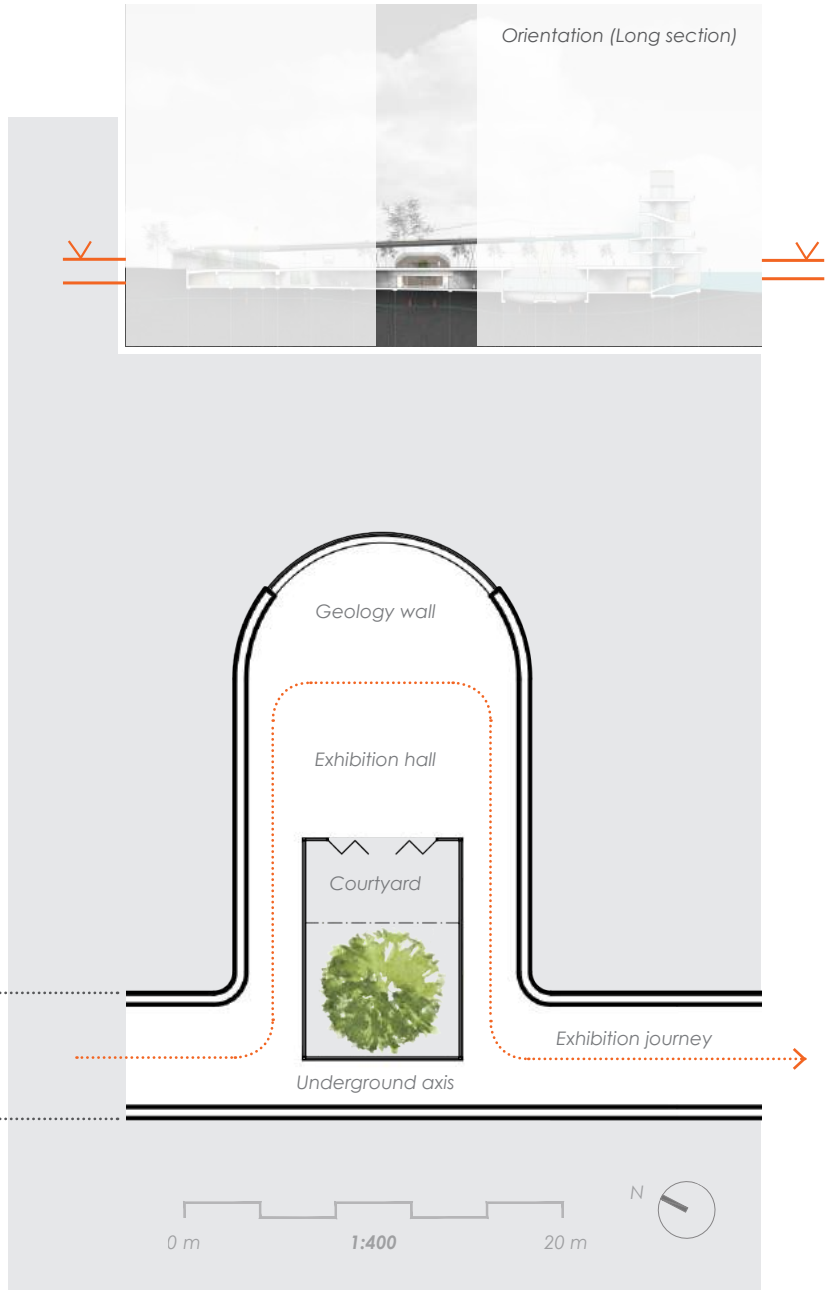
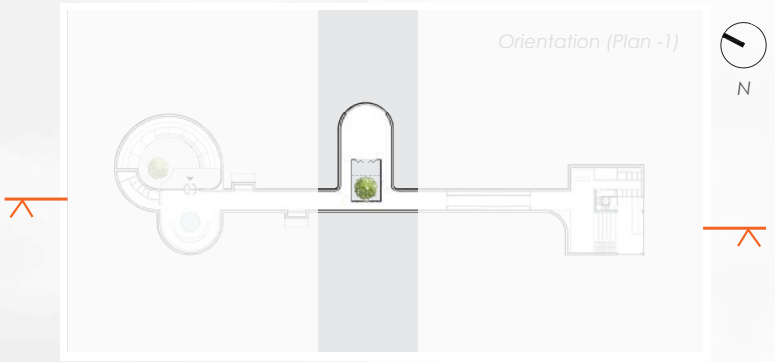


Figure 73. Plan -1: The subsidencer. Author's own copyright.

Plan -1

Courtyard

The courtyard gives a vertical connection between the underground exhibition, the street level and the elevated aqueduct, by representing the ongoing sinking river delta process. It breaks up the long corridor, gives daylight underground and thereby invites people into the exhibition hall. The courtyard also serves as an extended exhibition area of the interior exhibition hall.



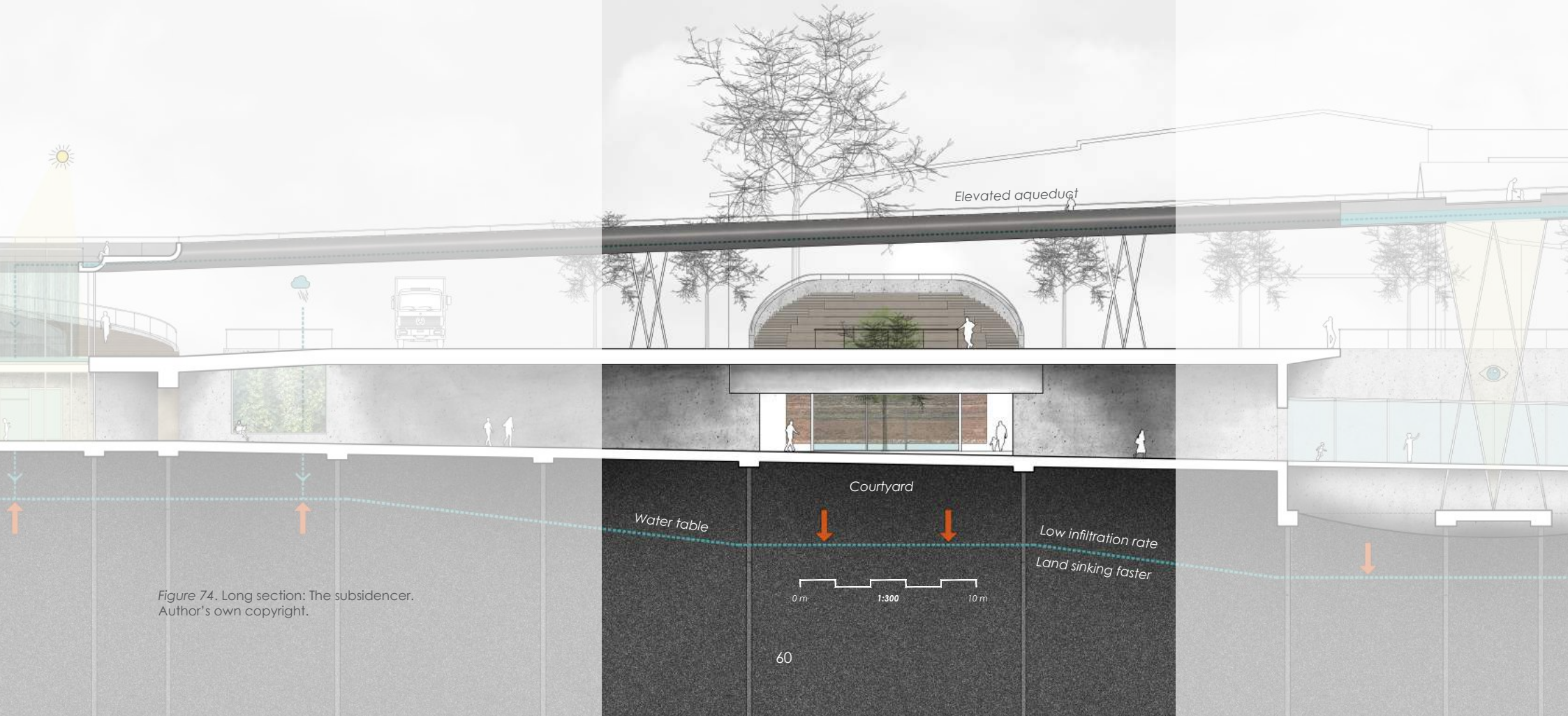
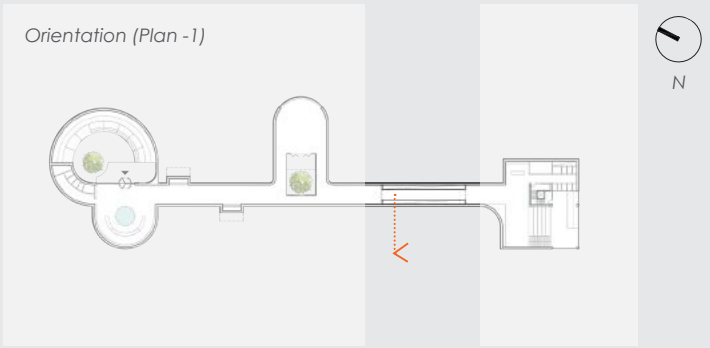


Figure 74. Long section: The subsidencer.
Author's own copyright.

Figure 75. Walkway bridge. Author's own copyright.



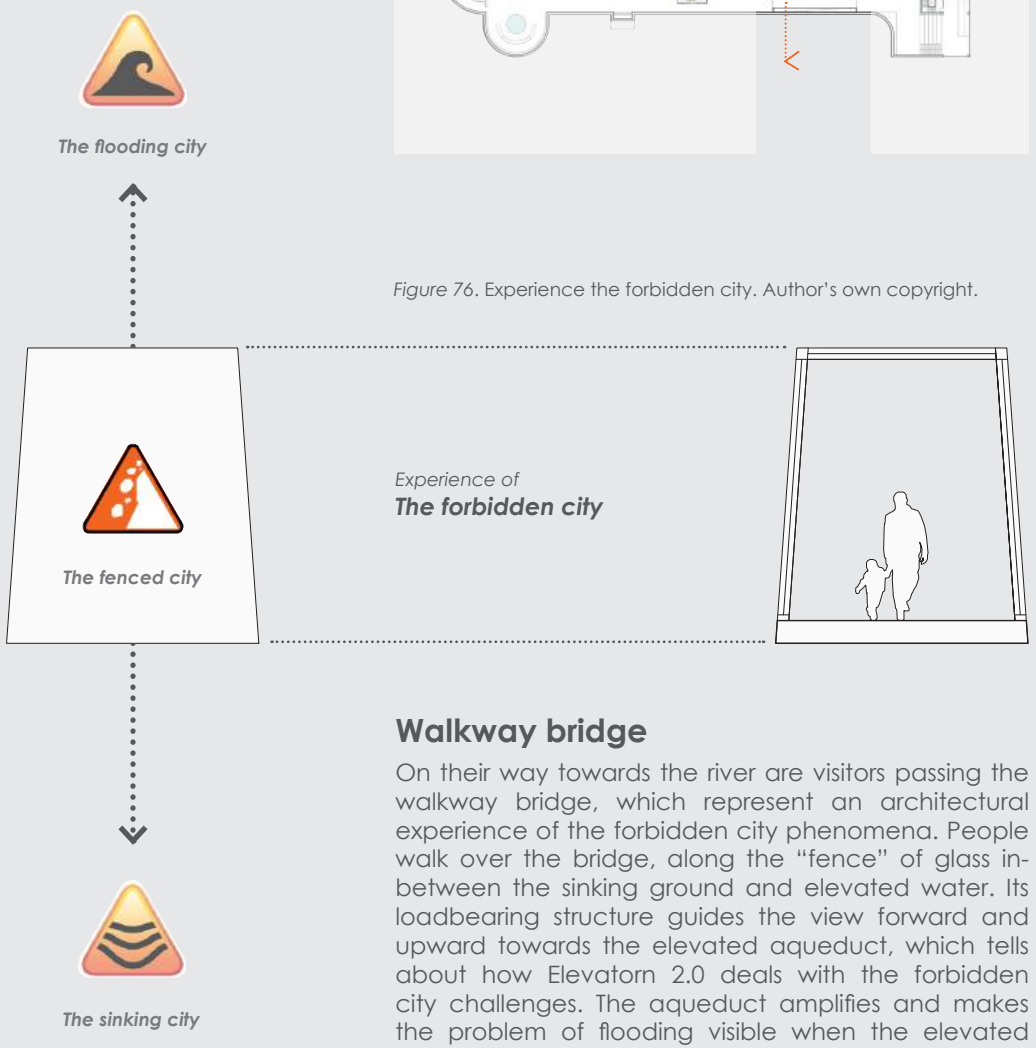


Figure 76. Experience the forbidden city. Author's own copyright.

Walkway bridge

On their way towards the river are visitors passing the walkway bridge, which represent an architectural experience of the forbidden city phenomena. People walk over the bridge, along the "fence" of glass in-between the sinking ground and elevated water. Its loadbearing structure guides the view forward and upward towards the elevated aqueduct, which tells about how Elevatorn 2.0 deals with the forbidden city challenges. The aqueduct amplifies and makes the problem of flooding visible when the elevated promenade is turned into a canal of re-directed storm water (see Figure 70 on page 57).

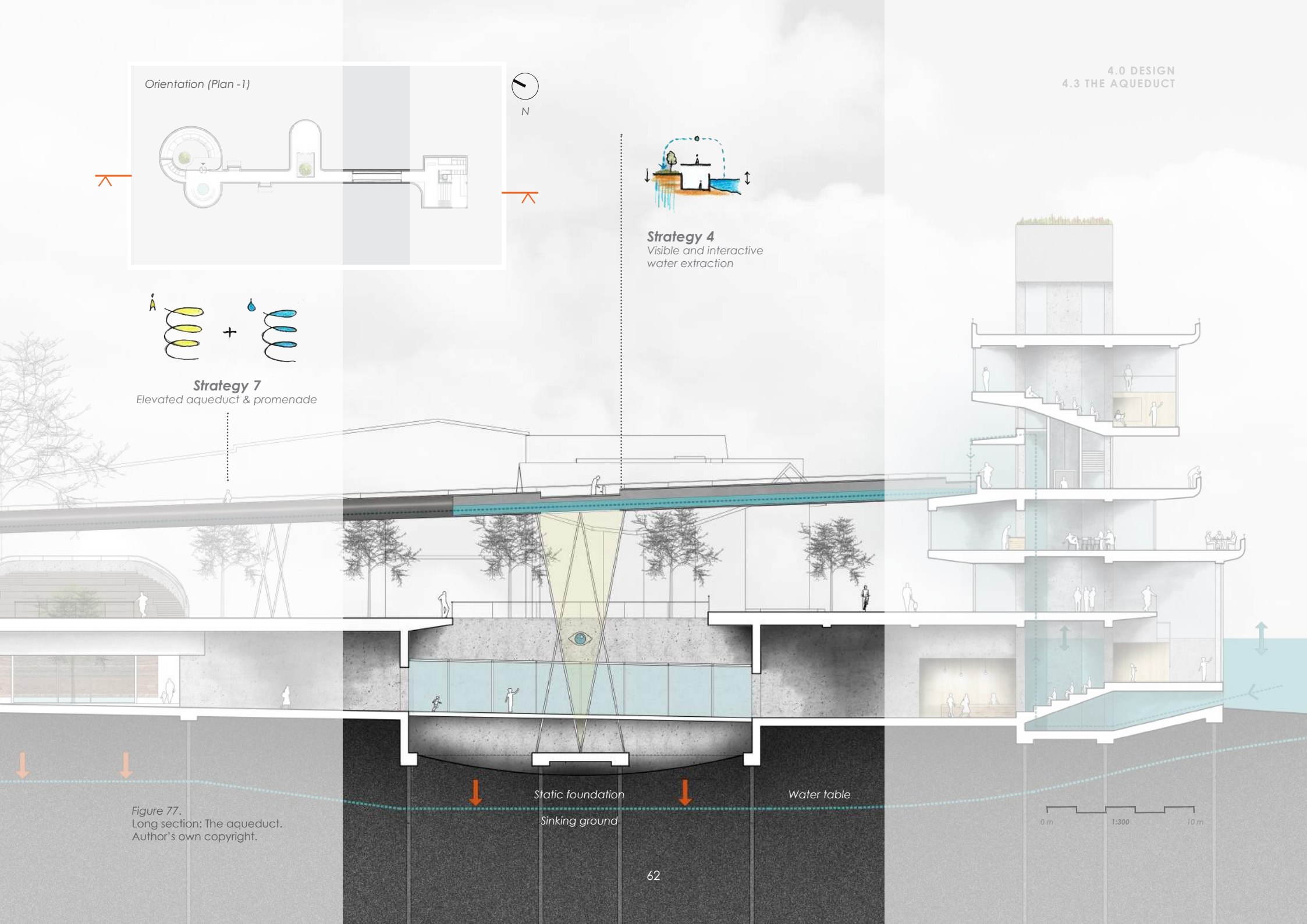


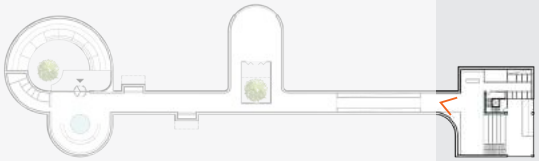
Figure 77.
Long section: The aqueduct.
Author's own copyright.

4.4 THE ELEVATOR

Performance hall

Eventually does the underground corridor opens up into a party and performance hall. This public space can be used by the local community for events like concerts, festivals and weddings. Around the main staircase is water from the river collected and further elevated. Beyond the river aquarium does daylight penetrates into the space through the river wall. These two features expose the water quality of the river and demonstrates spatial qualities of the dynamic water level.

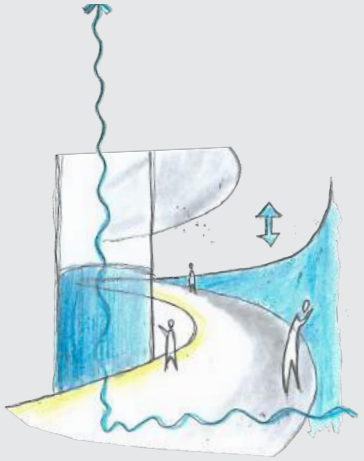
Orientation (Plan -1)



N

Figure 78. Performance hall. Author's own copyright.

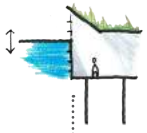
Strategy 7
Pedagogical journey along river level

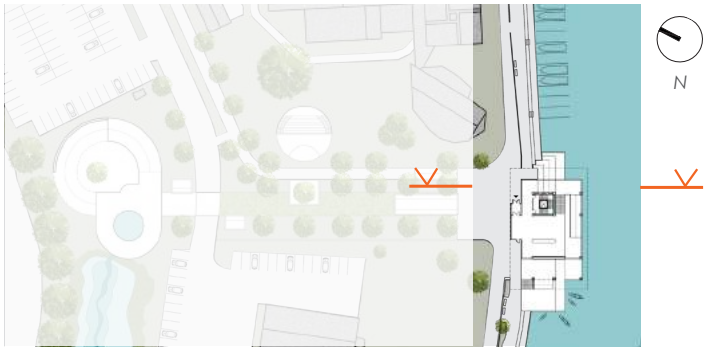


River aquarium & river wall
Visitors walk along and in-between the dynamic river level of the river aquarium and the river wall.

River aquarium & river wall

Strategy 6
Static building amplifies and meassures the dynamic rivel





Orientation (Plan 0)

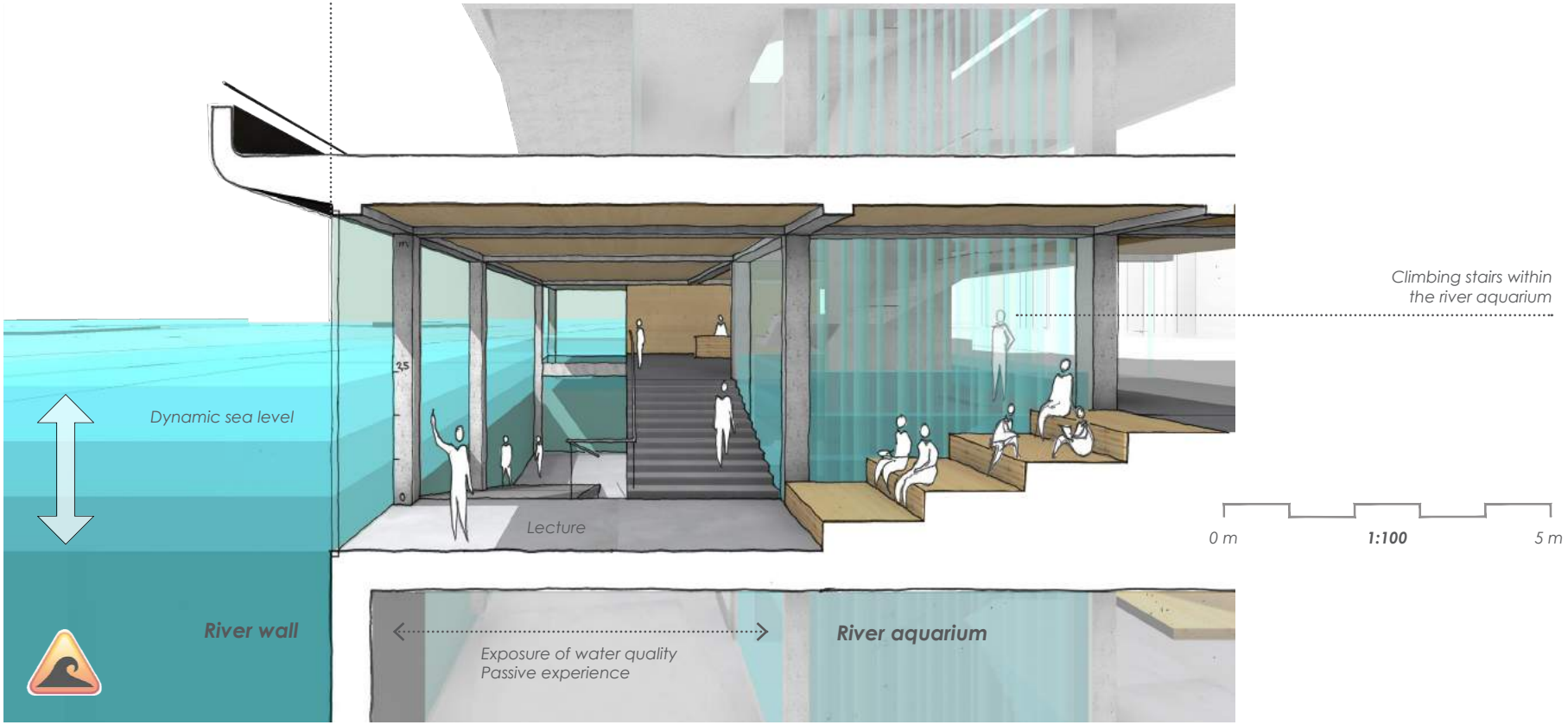


Figure 79. River aquarium & river wall. Author's own copyright.

Plan 0

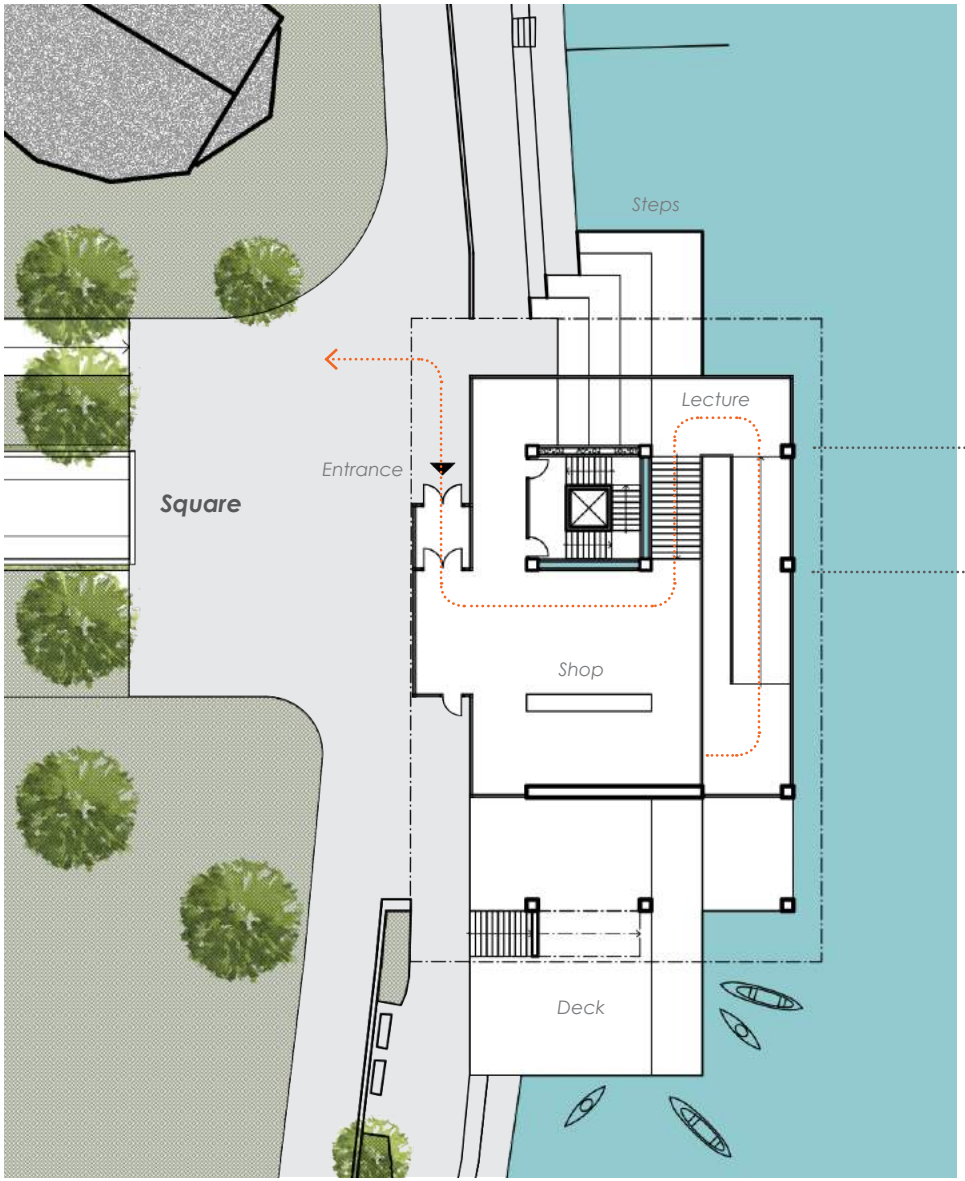


Figure 80. Plan 0: The elevator. Author's own copyright.

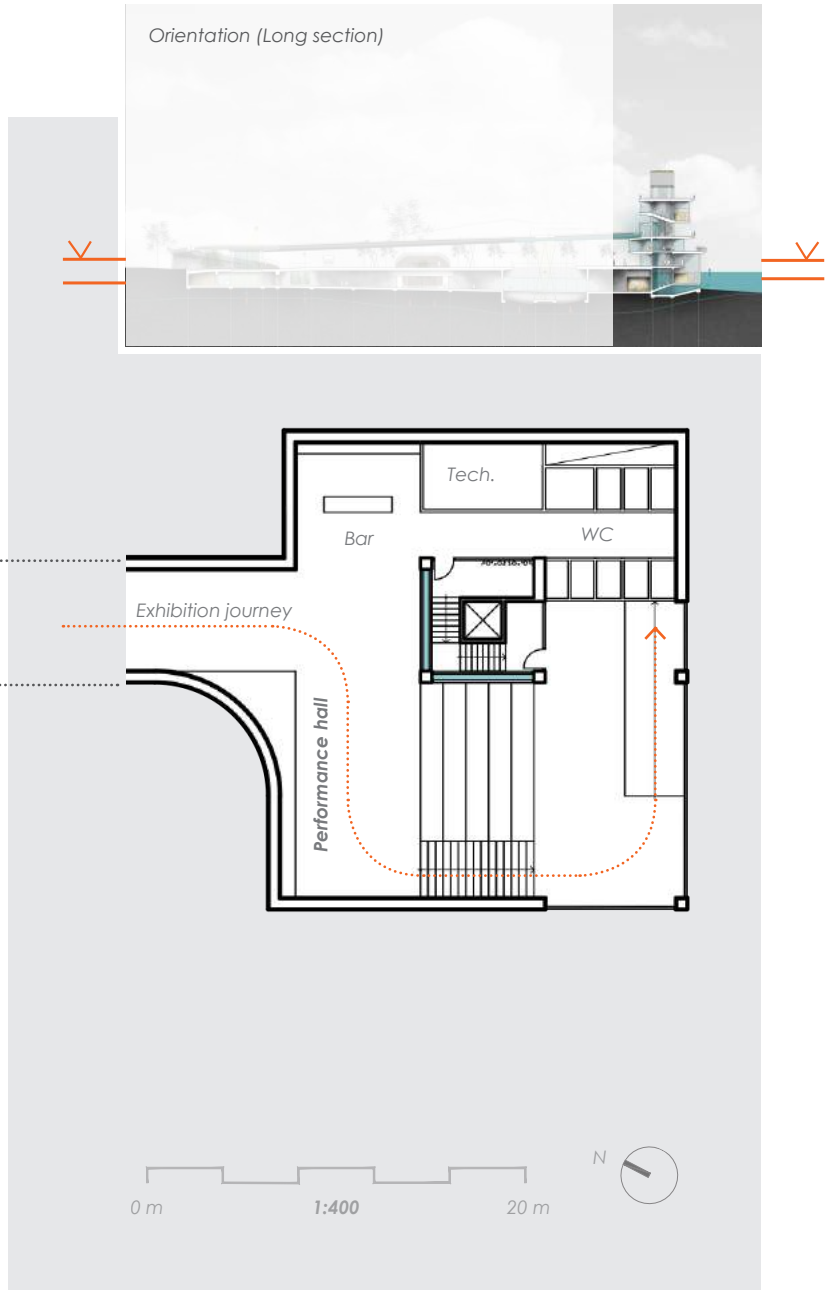


Figure 81. Plan -1: The elevator. Author's own copyright.

Plan -1

Program

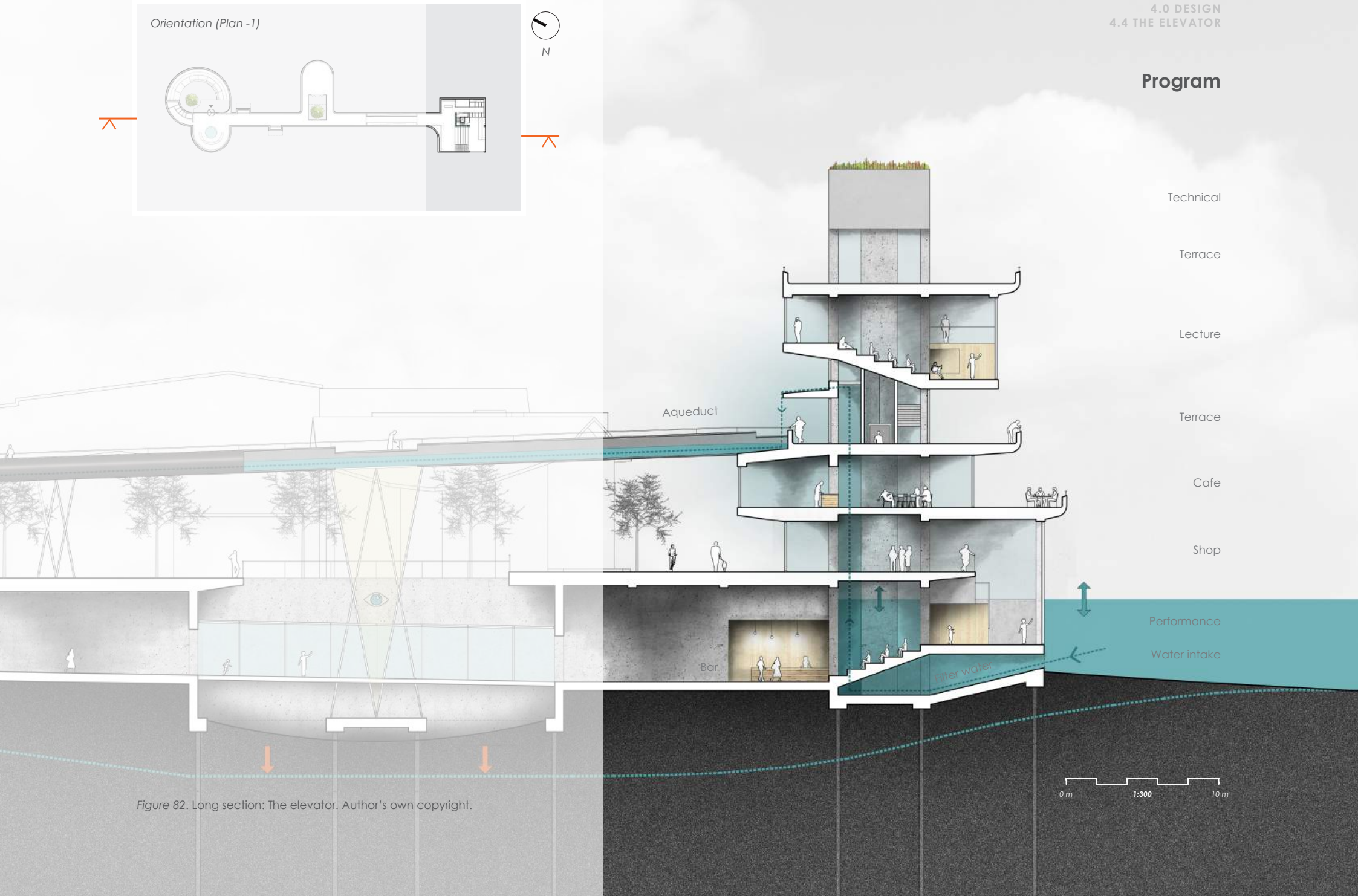
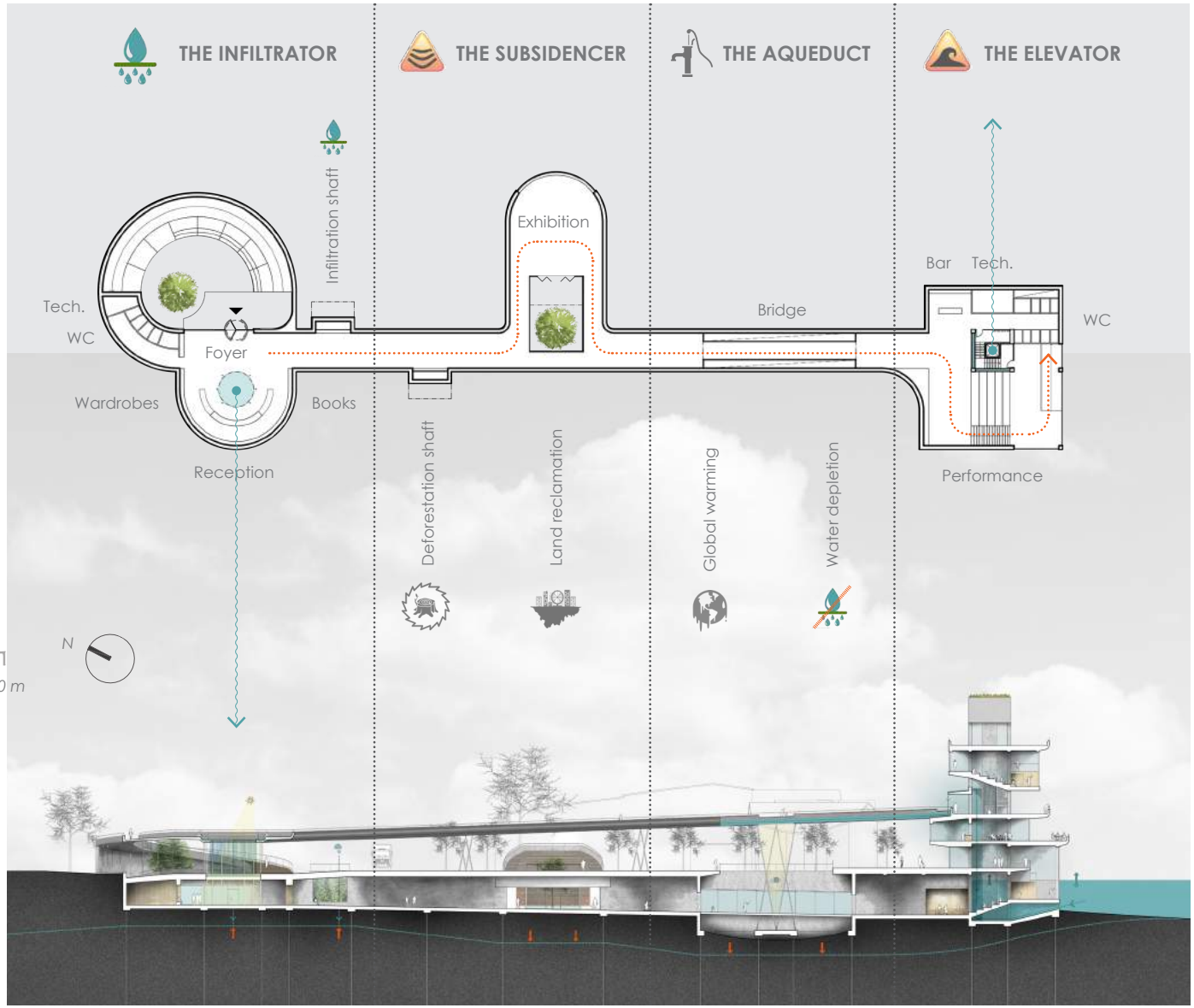


Figure 82. Long section: The elevator. Author's own copyright.

SUMMARY

Plan -1

The underground exhibition starts by infiltrating water and visitors underground. At the elevator does the exhibition continues upward along the elevated water.



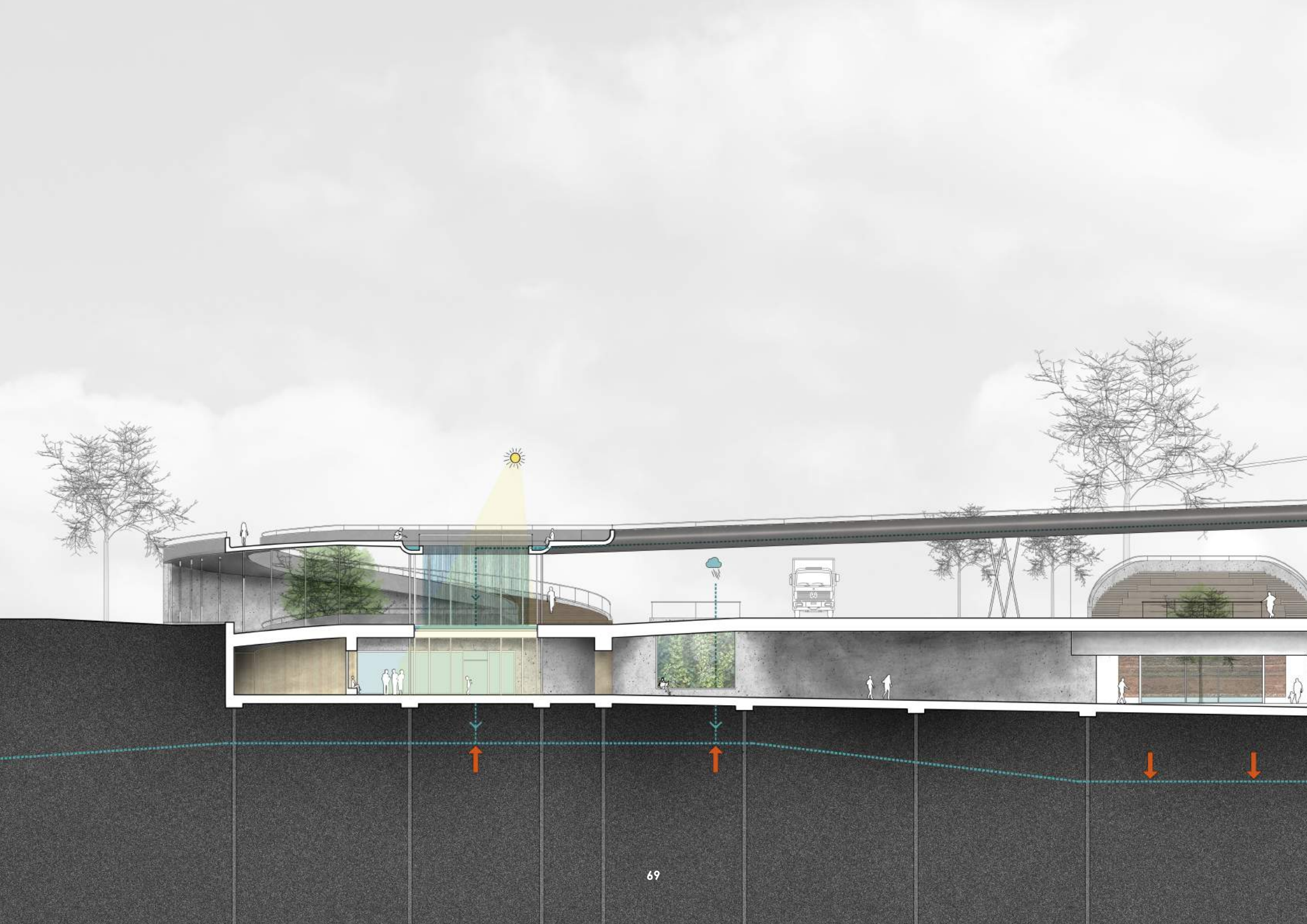
Long section

Figure 83. Plan -1 & Long section. Author's own copyright.

Plan 0 & Plan 3

The exhibition continues outdoor along the green axis on ground level or along the elevated aqueduct. People follows the water back to the infiltrator, where the exhibition ends by closing the water cycle.

Figure 84. Plan 0 & Plan 3. Author's own copyright.



REFLECTION

Reflects upon the thesis topic and concludes with an answer to the research question

5.0

DISCUSSION

Thesis topic

To discover and reveal the hidden potential of Uddevalla was the point of departure of this thesis, which in large perspective aims to explore how people can be more informed about sustainable development in their local environment. Uddevalla is, as many other coastal cities, suffering from the urban challenges of repetitive floods and land subsidence. In today´s Uddevalla is the water level rising with 3 mm/year, while the river delta land is sinking up to 35 mm/year. These values are projected to accelerate even faster in future, which will increase the frequency and severity of flooding. Because of its poor geotechnical conditions are large parts of Uddevalla´s riverfront even closed for public use. Consequently, Uddevalla has become the forbidden city. This thesis aims to create an understanding that the forbidden city phenomena is mainly a consequence of human´s negative impact on natural processes. We as humans have a moral responsibility for future generations to understand how we can act to decrease our negative impact on the environment. More meaningful experience of our local environment is therefore necessary to understand and increase the will and interest to preserve and develop it.

How can architecture contribute to this? We live in a society where globalisation, urbanization and climate change are increasing trends, where our daily lives are less dependent on the local environment. The strong human-nature relationship of the stone age people has throughout history been replaced by destructive lifestyles driven by human greed. By widening the perspective and increasing the understanding of our nature and culture, could inspire people to live in a more efficient, resilient and sustainable way. An urban naturrum is a Swedish institution that can inform us about our common responsibility and show us what we can do locally. Simultaneously, it has to be clear that we all are a part of a larger context which we cannot always affect. An urban naturum cannot solve all problems, but at least be a step in the right direction towards a more sustainable society.

Research vs. Design

The starting point of the thesis was to contextualize the issues of urban densification and climate change into the local environment of Uddevalla. How can architecture amplify and mitigate the risk of land subsidence and sea level rise? Global warming is increasing the amount of water in atmosphere, while the urbanisation processes of land reclamation and water depletion have reduced the waterbody in the city. Water was therefore found to be the common denominator and solution to reduce the vulnerability of land subsidence and sea level rise. The purpose of this thesis became to demonstrate the possibilities to live in more symbiosis with the natural water cycle and thereby question the human history of controlling and disturbing natural processes. Instead of being a destructive force could water become an element embedded in the dynamic landscape, creating new urban qualities and achieving a re-balanced water cycle.

The thesis tries to demonstrate a method of how to re-make space for water in the city and how to re-connect people with the natural water cycle in Uddevalla. Make the past present in our future was implemented as research method to inform and anchor the future design proposal. The historical research discovers the human impact behind the forbidden city phenomena, while the design tries to turn its urban challenges into spatial opportunities. The research findings were turned into an urban naturum or architectural exhibition with focus on spatial and pedagogical experience of the disturbed water cycle in the past and the re-balanced water cycle of the future. The proposal is a combination of architecture, landscaping and engineering that amplifies and mitigates the dynamic changes of land and water by artificially stimulating the natural water cycle.

Elevatorn 1.0 vs. 2.0

The past river delta area in Uddevalla initially served as a natural flood and war protection, but it eventually became a transportation boundary between the river city and fjord harbour. During the industrial revolution was Elevatorn 1.0 used to fill-up the shallow river delta with dredged material from the river. This land reclamation process allowed to move the harbour activity into the city, which in turn expanded towards the fjord. However, the urban densification reduced the city´s flood capacity and discharged its ground water table. Consequently, most parts of the filled-up river delta are sinking while the dynamic river level is increasing by means of global warming. Since Elevatorn 1.0 contributed to a reduced waterbody is Elevatorn 2.0 trying to allow more space for water in Uddevalla, as the river delta did in the past. Unlike Elevatorn 1.0 does Elevatorn 2.0 serves as an urban naturum with many different functions:

Infiltration park
complement to the municipal flood protection plans

Architectural exhibition
visitors experience the history towards a re-balanced water cycle

Public space
for daily recreation and local community events

Think thank
opens the debate of how to mitigate the forbidden city phenomena

Instead of moving dredged material from the river is Elevatorn 2.0 re-directing water from the flooded river to an infiltration park, as a way of restoring some natural flood capacity of the old river delta. By storing flood water and recharging the ground water table can Elevatorn 2.0 mitigate land subsidence and reduce the risk of flooding in other areas. **The infiltration park** works as a complement and critique towards the municipal defensive flood protection plans of static flood walls that are based solely on the consequences of sea-level rise, while land subsidence is currently a far more urgent problem. Elevatorn 2.0 tries to add another mindset to the discussion of flood protection strategies through an integrated approach that is dealing with both land subsidence and sea level rise.

In addition to capture, store, infiltrate and treat storm water can the infiltration park sustain habitats for plants and animals. The **architectural experience** starts and ends at the infiltration park, which serves as a recreational and educational space for visitors. From here can visitors enter an underground exhibition that amplifies the cultural driving forces behind the ongoing land subsidence and sea level rise, while the elevated aqueduct re-directs water and people from the river back to the infiltration park. Along this architectural machine are visitors experiencing an interactive play between artificial and natural moments of water. However, the water interaction is mostly visual and could have been developed into more active experiences. Due to the limited time is the engineering and landscape design rarely developed in this project, in favour for the conceptual public building design. A naturum is supposed to protect and articulate the character of its local environment. Elevatorn 2.0 is sunken into the old river delta to amplify the dynamic changes of land and water in Uddevalla. However, the underground typology is making a rather big impact on the local environment and somehow contradicts both the intentions of flood mitigation and naturum. Although, the sunken building makes a clear statement of how the environment response to our negative impact in history.

Beside from being an architectural exhibition does Elevatorn 2.0 serve as a **public space** for daily recreation and local community events. It also serves as an urban **think thank** where city authorities, property developers and citizens can discuss and showcase ideas of how to mitigate the forbidden city phenomena. People with different interests can come together in this inclusive and multifunctional facility to reflect upon how our ways of living affects the environment and how we can contribute to create a more sustainable future. This type of multifunctionality can re-make space for water that brings wildlife to the old river delta, which in turn brings a sensorial experience to people. A sense of human-nature relationship can be re-established, which motivate visitors to make use of the old river delta in such a way that its values can be conserved. Elevatorn 2.0 informs about the importance of stimulating and protecting natural processes in general and the water cycle in particular. Once visitors are appreciated these values are they more likely to become supporters of protecting and restoring the local water cycle. Elevatorn 2.0 can provide a well-informed and more engaged community that is ready to turn problems into more sustainable opportunities.

CONCLUSION

Elevatorn 2.0 vs. 3.0

Even though Elevatorn 2.0 does not try to save the whole city from flooding, can even a small effort bring about a positive effect. The project demonstrates a method that can motivate people to discover and conserve their local environment and cultural history. It is a multifunctional public building in a strategic location that can strengthen the identity of place, awake curiosity and put Uddevalla on the map in a broader context. The thesis proposal can hopefully serve as an inspiration for the city authorities, property developers and citizens in Uddevalla to re-activate the old river delta as a vibrant public space. Moreover, the strategies and design of this thesis project could perhaps inspire other cities that are struggling with similar urban challenges.

How can this thesis be further developed? If Elevatorn 2.0 restores a small part of the natural flood capacity of the old river delta in Uddevalla could Elevatorn 3.0 improve the local water cycle at a larger scale. Elevatorn 3.0 could have incorporated other systems and infrastructures within the city to make the proposal even more resilient. This integrated approach could have been even further developed by involving interdisciplinary collaborations and community participation.

Designing with water

Water is going to be a burning issue as urban densification and climate change will change the way we live. Instead of getting water out of the city as quickly as possible could we keep it and use it as an element of attraction, where people want to go and visit. Elevatorn 2.0 can enrich the city landscape by providing amenity and habitat as well as purifying and sustaining the urban environment, like the lungs and liver of the human body. Designing with water, rather than against it, can make our built environment more resilient to flooding, more environmentally responsible and a far richer place to live in the 21th century.

"If sustainable development is to mean anything, such development must be based on an appropriate understanding of the environment - an environment here knowledge of water resources is basic to virtually all endeavors."

(WMO/UNESCO, 1991)

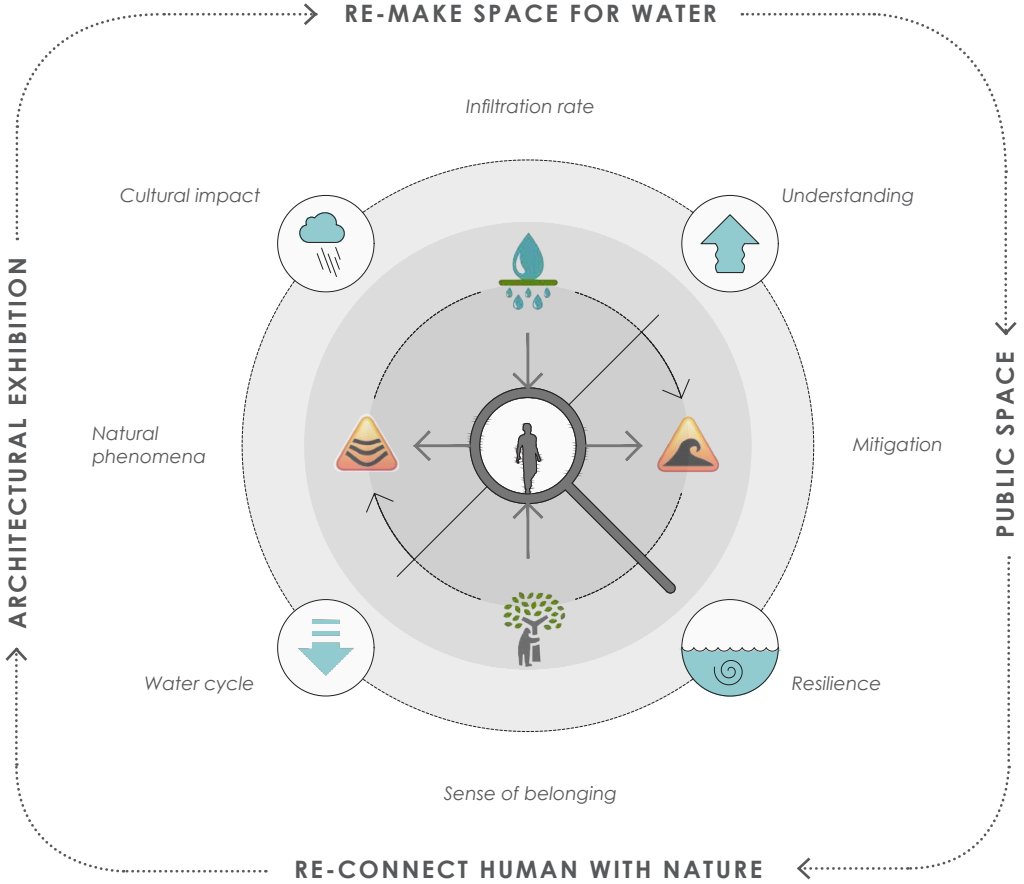


Figure 86. Reflection. Author's own copyright.

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FIGURES

Figure 1. *Architectural approach* [Diagram]. Author's own copyright.

Figure 2. *Sea level rise and land subsidence* [Diagram]. Author's own copyright.

Figure 3. *Re-balance water cycle* [Diagram]. Author's own copyright.

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Figure 12. Bohusläns hembygdsförbund (1981). De första människorna i Bohuslän - Uddevalla/Bäve. *The coastline 60-65 m above current sea level* [Map]. Adapted with permission.

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Figure 28. *Dredging cycle of the river Bäveån in Uddevalla* [Diagram]. Author's own copyright.

Figure 29. *Sinking river delta 2018* [Diagram]. Author's own copyright.

Figure 30. *The forbidden city* [Diagram]. Author's own copyright.

Figure 31. Rydholm, J (1867 - 1874). *Sawmill at Strömberget* [Photo]. CC PDM. Adapted with permission. Retrieved from https://digitaltmuseum.se/011014465502/enligt-tidigare-noteringar-vy-over-strombergsfallet-i-bavean-och-intilliggande

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Figure 50. *Vertical land and water movements* [Section sketch]. Author's own copyright.

Figure 51. *Dynamic landscape river delta* [Section sketch]. Author's own copyright.

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Figure 53. *The waterfront city* [Diagram]. Author's own copyright.

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Figure 59. *Vision* [Diagram]. Author's own copyright.

Figure 60. *Strategies* [Icons]. Author's own copyright.

Figure 61. *Site* [Map]. Author's own copyright.

Figure 62. Fredgren, B. (2016). Översvämningsskydd Uddevalla kommun. Bilagor Översvämningsskydd förstudie: Rapport angående höjdförändringar i hamnområdet. *Sinking ground on site* [Map]. Adapted with permission. Retrieved from https://www.uddevalla.se/bygga-bo-och-miljo/byggprojekt/oversvamningsskydd.html

Figure 63. *Sunken parkland with existing water storage capacity* [Photo]. Author's own copyright.

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Figure 67. *Entrance courtyard* [Perspective]. Author's own copyright.

Figure 68. *Plan -1: The infiltrator* [Drawing]. Author's own copyright.

Figure 69. *Long section: The infiltrator* [Drawing]. Author's own copyright.

Figure 70. *Cross section: The subsidencer* [Drawing]. Author's own copyright.

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Figure 72. *Plan 0: The subsidencer* [Drawing]. Author's own copyright.

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Figure 74. *Long section: The subsidencer* [Drawing]. Author's own copyright.

Figure 75. *Walkway bridge* [Perspective]. Author's own copyright.

Figure 76. *Experience the forbidden city* [Diagram]. Author's own copyright.

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Figure 79. *River aquarium & river wall* [Section perspective]. Author's own copyright.

Figure 80. *Plan 0: The elevator* [Drawing]. Author's own copyright.

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Figure 82. *Long section: The elevator* [Drawing]. Author's own copyright.

Figure 83. *Plan -1 & Long section* [Drawing]. Author's own copyright.

Figure 84. *Plan 0 & Plan 3* [Drawing]. Author's own copyright.

Figure 85. *Long section* [Drawing]. Author's own copyright.

Figure 86. *Reflection* [Diagram]. Author's own copyright.

Appendix

Figure 87. *Poster layout 1*. Author's own copyright.

Figure 88. *Poster layout 2*. Author's own copyright.

Figure 89. *Bird view of the model 1:100*. Author's own copyright.

Figure 90. *Indoor view of the model 1:100*. Author's own copyright.

Figure 91. *Concept model*. Author's own copyright.

APPENDIX

EXPO

POSTER LAYOUT

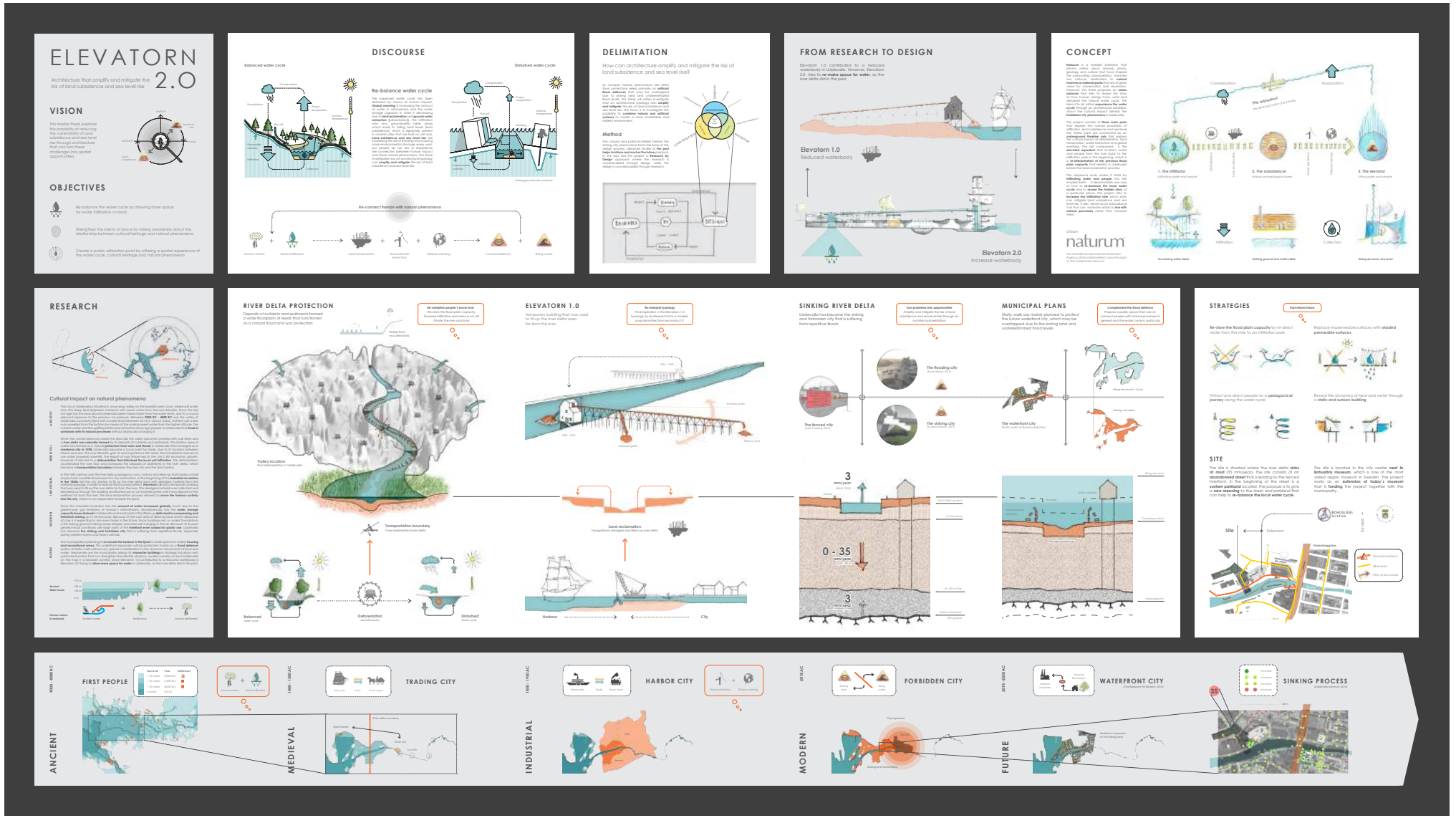

Figure 87. Poster layout 1. Author's own copyright.

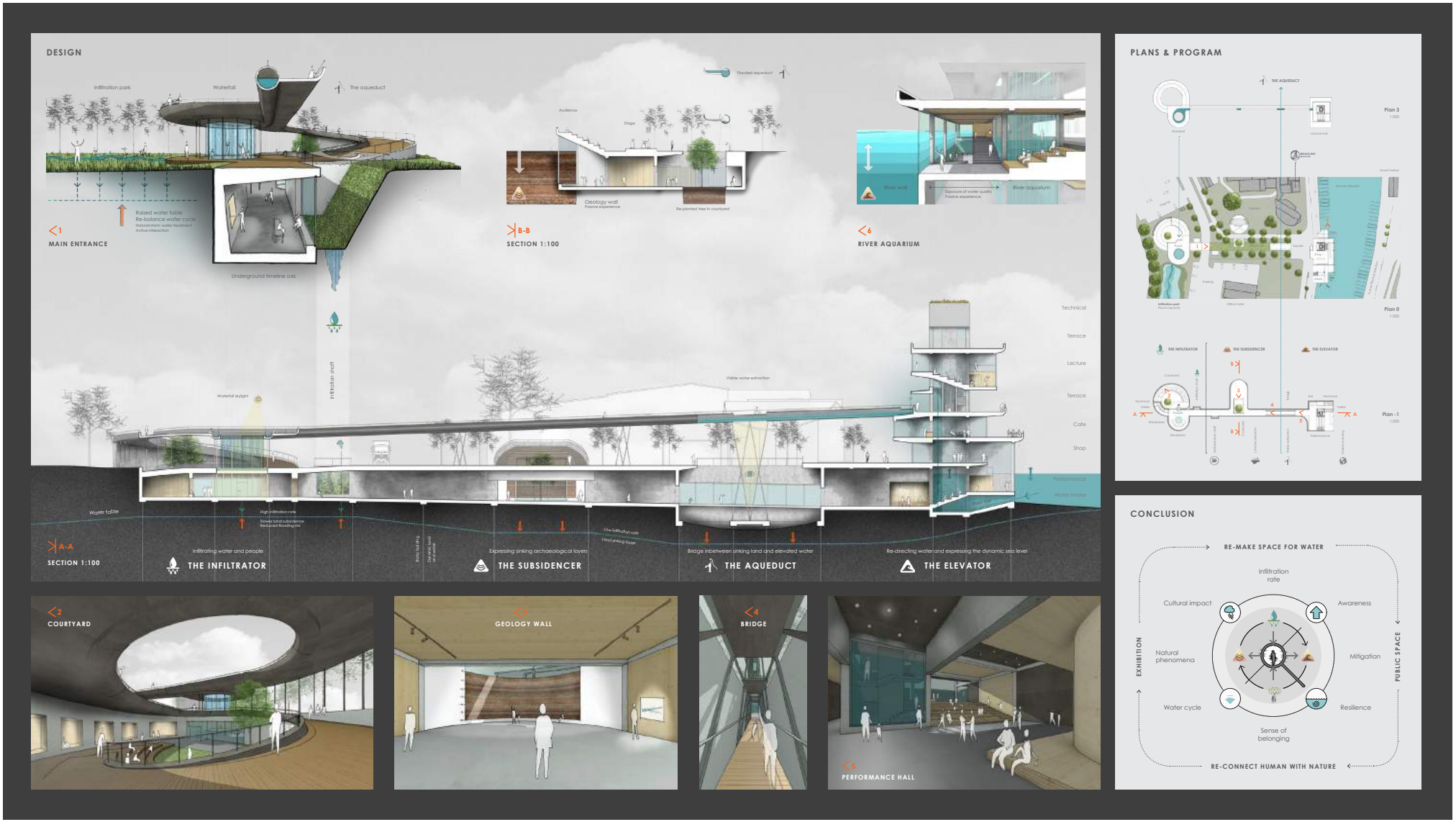

Figure 88. Poster layout 2. Author's own copyright.

Figure 89. Bird view of the model 1:100. Author's own copyright.

Figure 90. Indoor view of the model 1:100. Author's own copyright.

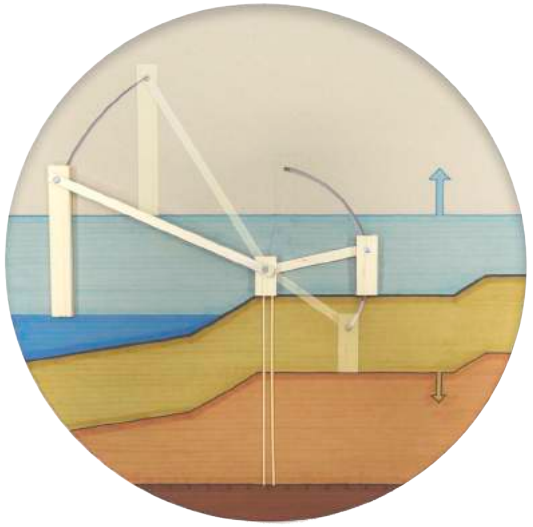

Figure 91. Concept model. Author's own copyright.

Mayor design decision

In the beginning of the process was the idea to create a dynamic building that follows the movements of land and water, see Figure 91. However, the end result is a sunken and static building that instead expresses the dynamic movements of land and water, see Figure 90.