Re(f)used Resources:

Landscape approach for Reykjavík's future resilience

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Figure 1: Aerial image of Reykjavík peninsula

Abstract

Reykjavík, is a coastal city in Iceland facing growing challenges from climate change, urbanization, and overwhelmed infrastructure. Throughout this research, the primary objective is to explore the potential of a landscape-based blue-green network to enhance climate resilience and serve as a foundational element for water management, ecological inclusivity, and sustainable urban development in Reykjavík's historical center.

Research questions were formulated to provide a framework for investigating the evolution of Reykjavík's socio-ecological system, understanding the challenges and potentials associated with current dynamics, and exploring how landscape-based approaches can address these challenges effectively and become applicable spatial design. A comprehensive methodology is employed, encompassing an extensive research and literature review on the applied theories of landscape resilience, and landscape based urbanism with focus on Reykjavík's historical center. Nature based solutions and sponge-city principles are used as a methodological approach to develop design interventions applicable to the urban context of Reykjavík. The findings indicate that by establishing a blue-green network with integrated hydro- and ecologically inclusive design principles, increased climate resiliency can be attained and such network contributes to the goals of the municipal plan of Reykjavík, the ambitious goals of gaining carbon neutrality before the year 2040 as well as it complies with tightened requirements on water management for all countries in the European Economic Area (EEA). In summary, this research underscores the significance of landscape-based design approaches for increased climate resilience.

“The point is not so much to contest or contradict our tools of work but rather to understand how they have been misused, abused and manipulated in both the design and decision making processes. We know that the contemporary city is no longer the product of a single thought or plan, the vision of some prince, but rather the diffuse result of successive layers of decisions rarely having anything to do with each other.”

(Girot, 91)

Preface

When reflecting back to the origin of my work, the foundation of this thesis project started developing in May 2023. This was during Q4, the last course of the first year curriculum in the masters programme of Landscape Architecture under the coordination of Dr. Fransje Hooimeijer. The outcome of the course was to write a research paper while simultaneously working as an intern at an office which I pursued at the Nordic Office of Architecture in Reykjavík, Iceland.

During the time of the internship I analyzed and researched Reykjavík's wastewater management, its history and infrastructure development. After a few months working on various projects along with writing the research paper, I realized that a landscape based approach in water management within the built environment of Reykjavík was a topic I wanted to explore further for my thesis. The internship extended into the summer and when I came back to school in September 2023 I decided to apply for the Resilient Coastal Landscapes graduation laboratory.

Fascinated by improving climate resiliency within the urban fabric of Reykjavík provided me with the foundation of my thesis. Utilizing a landscape-based design approach as a guideline to address climate related challenges, increased urbanization and overwhelmed infrastructure towards increasing climate resilience in Reykjavík's urban context aligned closely with the criteria set by the RCL studio. Shortly after presenting the idea, I began collaborating with Prof. Dr Steffen Nijhuis, the lab coordinator on developing this thesis project.

Going forward, this involved gaining a deeper understanding of Icelandic landscapes and their various systems and processes, as well as the current conditions of Reykjavík's landscape. It was essential for this thesis to comprehend how the evolution of urban development and water infrastructure has shaped Reykjavík's history and impacted the quality of its landscape. As research progressed, a landscape-based strategy to enhance urban ecology, water management and promote urban development manifested by establishing a blue-green network in Reykjavík, which emerged as the central framework for my study.

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1.0 Refused Resources

1.1 Introduction

The impacts of climate change are already affecting the world with extreme weather conditions such as severe storms, heat waves and droughts becoming more frequent (Parliament, 2019). Other consequences of the rapidly changing climate include rising sea levels, ocean acidification, food scarcity, biodiversity loss and increasing health related threats for humanity (United Nations, n.d.). This impacts urban life and fundamental cities' services, infrastructure, housing and overall human health (Cities and Climate Change, n.d.). The effects of climate change are anticipated to raise the frequency and magnitude of rainfall events which results in increased stress on urban hydrology. Globally, rapid urbanization over the last decades has inevitably resulted with greater stormwater runoff volumes at the same time cities are facing growing climate-related challenges (Ahmed et al., 2022).

Increased urbanization entails an increase in city infrastructure. Roads are paved, pipes are laid, areas of impervious surfaces increase in magnitude and size and the risk of environmental degradation within urban areas increases. As stated in a report on the impacts of climate change in Iceland led by the Icelandic Met Office, there is already a considerable rise in extreme weather events and climate projections indicate that a further increase is likely. There has also been recorded a significant increase in annual precipitation (Climate Report | Climate of Iceland | Icelandic Meteorological Office, n.d.).

Reykjavík is the capital- and the largest city in Iceland and is located on the southwest peninsula of the island. The city has been experiencing rapid population growth since the end of the 19th century and population estimations are still on the rise. According to Statistics Iceland, the total population count in Iceland was 383.726 inhabitants on January first, 2024 which accounts for 2.3% increase from January 2023. About 63% of the population lives in the Capital Region of Reykjavík and the total Icelandic population is estimated to be about 600.000 by the year 2070 (Statistics Iceland: The Largest Population Increase Ever, n.d.).

The groundwater table is lowering in Reykjavík Iceland (Hjartarson et al., 2019/2019). Extensive urbanization and outdated infrastructure are disrupting the natural hydrological cycle by hindering deep infiltration, undermining aquifer recharge, disrupting wetland areas and contributing to the decline of local ecosystems. The increased urbanization along with the impacts of changing climate is surpassing the capacity of existing water infrastructure and instances of overflow, where untreated water is flushed into the ocean are increasing (Friðriksson, 2021). This issue recurs in Reykjavík, particularly during heavy rainstorms and periods of snowmelt.

Biodiversity underpins urban ecosystem functions that are essential for human health and well-being (Marselle et al., 2021). Exposure to nature and biodiverse environments has been shown to have direct benefits to physical and mental well-being. Biodiversity can reduce stress, improve mood, and enhance mental health, contributing to a better quality of life. (Jimenez et al., 2021). Furthermore, urban biodiversity enhances ecosystem services, supports healthier and more resilient cities. There are multiple benefits of urban green areas such as improved air-and water quality. Reykjavík faces a challenge of lack of biodiversity and qualitative green areas, which hinders the city's ability to provide robust ecosystem services and maintain a resilient urban environment.

In this thesis attention is drawn to the overlooked environmental consequences of treating stormwater as wastewater and the significant effects it has on the urban environment. Hydrological cycles are disrupted, urban soil quality diminishes, ultimately causing a decline in urban ecology affecting the overall quality of life in Reykjavík. Therefore, this thesis proposes a landscape approach to increase climate resilience in Reykjavík, by restoring the hydrological cycle through the means of qualitative urban green areas, green connections and urban development for a healthy urban environment and to provide balance for people and nature in Reykjavík's historical center.

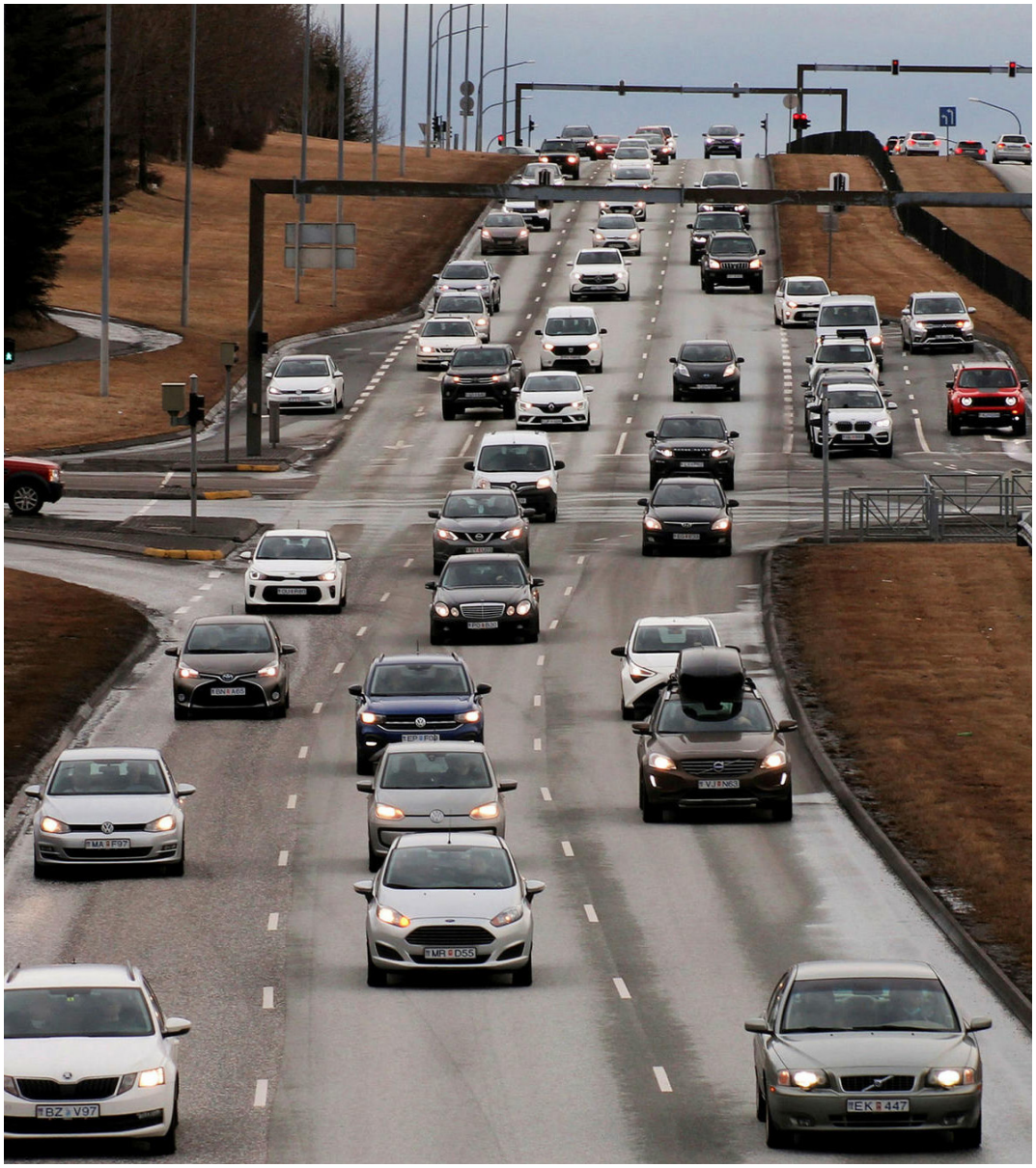


Figure 2: (Sævarsson, 2021)

1.2 Problem statement

As the capstone of the information provided above, this research project delivers the following problem statement:

Reykjavík has been experiencing rapid growth since the beginning of the 20th century and population estimations are still on the rise. The convergence of climate change impacts, increasing urbanization, and overwhelmed infrastructure in the Capital Region of Reykjavík presents pressing water management challenges, fragmented urban green spaces and declining biodiversity. The current situation disrupts not only the local water cycle, but also causes an ecological decline and affects the overall quality of life in Reykjavík.

These challenges that Reykjavík is facing require a shift in focus where stormwater and social-ecological inclusive urban green space is acknowledged as valuable resources for the multiple ecosystem services and benefits they provide. Addressing the importance, a blue-green network is established to improve the urban environment. By connecting the city through green spaces, creating habitats for biodiversity, offering accessible and inclusive public areas and a network of alternative routes of transportation for walking, biking and public transportation. By utilizing the landscape and its ecological processes as the foundational elements for design, the blue-green network enhances climate resilience and offers opportunities for sustainable urban development. It emphasizes the integration of nature and green infrastructure within urban planning and landscape architectural design, guided by hydrological and ecological considerations.

Ultimately, this strategy aims to create a more sustainable and climate-resilient landscape for the residents of Reykjavík by addressing the challenges stated above. The design of the blue-green network alleviates hydrological stress and pressure on existing infrastructure, it provides opportunities for qualitative green connections and public spaces as well as landscape based urban development. This thesis will demonstrate how climate resilience is improved for the city through the establishment of a landscape-based network, a new blue-green heart for Reykjavík.

Figure 3: (Jónasson, 2018)

Figure 4: (Nachtmann, 2024)

Figure 5: (McCulley, n.d.)

Figure 6: (Reykdal, 2016)

1.3 Research objective and questions

The main objective of this thesis is to explore the potential of a landscape based blue-green network through design for Reykjavik to provide a cornerstone for water management, ecologically inclusive urban environment and sustainable urban development within the city.

Research questions were formulated as a framework to guide the research in order to address the issues stated above.

1. How has the socio-ecological system in Reykjavík evolved from its historical functioning to its present state, informing the development of a blue-green network by considering the impacts of urbanization and the main challenges and potentials associated with the current dynamics?

2. How can the development of a landscape-based strategy systematically serve as a crucial tool to address the challenges that Reykjavík is facing, leveraging the potential to contribute to urban development, water management, urban ecology and qualitative green spaces as well as exploit the city's spatial capabilities?

3. By exploring possibilities, how can the translation and application of the principles and strategies developed be incorporated into landscape architectural design?

In summary, this research aims to understand how landscape based design approaches can increase climate resilience in the context of Reykjavík by establishing a blue-green network as a cornerstone for water management, urban ecology and qualitative green areas as well as to foster urban development within the city.

1.4 Relevance

The Flowscape design studio for the master's track of Landscape architecture aims to develop innovative systems and processes for urban and rural development by looking at the landscape at its basis and work comprehensively through its various layers at different scales in order to develop a design framework.

This thesis is built on the previously mentioned approach, starting by looking at the landscape at its basis and analyzing its systems and processes to proceed towards a landscape-based framework for the future of water management, urban ecology and urban development of the city of Reykjavík, Iceland.

The thesis is very well fit for the emphasis of the resilient coastal landscape studio in such way that its main focus is landscape-based design in Reykjavík, which is a coastal area that is experiencing an increased need for resilience due to climate change impacts, increased urbanization and overwhelmed infrastructure in the city. Landscape Resilience theory is applied by developing design concepts and a framework to restore and create a landscape system that tolerates disturbance, can undergo change and still retain its function, structure and identity for a better, sustainable future in Reykjavík, Iceland.

According to the municipal plan for Reykjavík 2040 few of the main priorities are: Increased urban development within the existing boundaries of the city, a greener city where improved air quality, better water management and increased access to green areas play a big role. Another goal from the municipal plan is the emphasis on more sustainable ways of transportation to promote a better urban environment (Reykjavíkurborg, 2022). All of which are supported in this thesis design along with other significant sub-goals for the city in the municipal plan.

Iceland aims to achieve carbon neutrality before 2040 and to cut greenhouse gas emissions by 40% by 2030 under the Paris Agreement (Climate Change, n.d.). There is a Climate Action Plan for Reykjavík that outlines the goals and the wide range of projects needed to achieve this and create a carbon-neutral society (Icelandic government, 2020). An energy transition from fossil fuels is an important step to make to achieve this goal. The blue-green network promotes alternative ways of transportation with improved connections throughout the city, offering more pedestrian friendly options such as walking and biking routes. A sufficient treatment of wastewater reduces greenhouse gas emissions (Aukin Hreinsun Fráveituvatns Dregur Úr Losun Gróðurhúsalofttegunda, 2021). Therefore, separating stormwater from general wastewater infrastructure is an important step that needs to be made, as well as ensuring adequate treatment of wastewater entering the treatment facilities before being disposed into the ocean also contributes to achieving the carbon neutrality goals.

Additionally, the current treatment of wastewater in Reykjavík doesn't fulfill the tightened requirements for wastewater treatment for countries that are a part of the European Economic Area (EEA) ("Stöðuskýrsla Fráveitumála 2022," 2023), marking another relative aspect of this thesis project. The EEA has tightened requirements regarding wastewater treatment and Iceland, being a member, needs to implement these improvements accordingly. This marks an interesting time where important decisions need to be made for the future of wastewater treatment in Reykjavík.

Ultimately, a resilient landscape framework in the shape of a blue-green network in Reykjavík supports various goals of the municipal plan of Reykjavík and results in strategies to achieve carbon neutrality in the city before 2040 as well as it provides an landscape-based approach to counterattack current and upcoming challenges in water management and treatment. The significance of this thesis addresses these challenges by interconnecting an approach through the establishment of a blue-green network by acknowledging the importance of hydro- and ecologically sensitive design as a valuable resource to increase resilience in cities.

1.5 Structure of report

Going forward, this report is organized into four different chapters each focusing on answering the different research questions stated above. Chapter two, “Research Approach”, explains the theoretical backgrounds and research methods that were used to support this research. Chapter three, “Analysis: Against All Odds”, gives a thorough analysis and overview of the site and its spatial characteristics as well as providing a deeper understanding of the socio-ecological systems, considering the impacts of urban development on the cultural landscape. Chapter four “Reused Resources” puts forward principles that support the aim of this research, that is, demonstrating how a landscape-based, blue-green network can be designed to address current challenges in Reykjavík by developing strategies and principles, where everything comes together, for hydrological- and ecological inclusive design as well as providing options for new urban landscape typologies in the new, blue-green heart of Reykjavík. Chapter four also focuses on exploring design potentials as well as applying and translating the derived principles to different design locations, expressing the outcome spatially. Finally chapter five elaborates on the synthesis of this thesis by addressing the problem statement and research objectives, resonating the need for a blue-green network in Reykjavík. Additionally, All chapters include different graphic representation media in form of maps, plans, diagrams, sections and renderings derived from various computer softwares to support the correlated design of this thesis.

Figure 7:

2.0 Research Approach

2.1 Theoretical backgrounds

Two main theories are followed to guide this thesis: Landscape Resilience theory and the Landscape-based Urbanism theory. These theories guide and support the structure of this research and help formulate the design outcome where principles by Nature based solutions (NbS) and Sponge city are used as a methodology to put forward and shape design strategies.

The Landscape Resilience Theory was studied and can be defined as the ability of a landscape to sustain its biodiversity and ecological functions over time in the face of climate change and other anthropogenic and natural stressors (Ahern, 2011). In relation to landscape architecture, the theory emphasizes landscape's multifunctionality and adaptive capacity to build resilience and the creation of landscapes that can withstand and overcome change whilst providing environmental and social benefits (Ahern, 2011). Connectivity is a critical parameter when an urban landscape is understood as a system that performs functions and therefore connectivity is a primary generator of sustainable urban landscape built around blue-green networks that support biodiversity, hydrological processes, climatic modification, neighborhood identity and aesthetic enhancements (Ahern, 2011).

The landscape based urbanism theory emphasizes the importance of looking at the landscape at its basis and requires an understanding of the landscape's multiple natural processes and scalar properties (Nijhuis, 2022). Prof. Dr Steffen Nijhuis mentiones in Landscape Based Urbanism, Cultivating Landscape Through Design, the landscape based approach considers the biosphere the context for social and economic development and which design-strategies require long-term visioning to create the spatial conditions for ecological, social and economic development while also designing and strategizing adaptive systems that allow flexibility and change. The approach also places emphasis on how landscape merges the concepts of nature and culture, therefore stating that the landscape is a cultural construct (Nijhuis, 2022).

Design principles of Nature based solutions (NbS) were mostly derived from the Nature Based Solution Catalog created by the World Bank. Nature Based Solutions (NbS) is an umbrella concept encompassing green infrastructure, ecosystem services, water management etc. (World Bank, 2021). Nature based design solutions offer multiple ways to tackle climate change impacts and increase resilience of cities while at the same time such implementations can have various social and ecological benefits, such as increasing biodiversity, delivering different ecosystem services, restoring soil, forest and wetlands in urban environments etc. (World Bank, 2021).

Inspired by the ability of a sponge to absorb, retain and release water, sponge city principles revolve around sustainable urban water management to manage stormwater, mitigate flooding and enhance water resilience (Sun et al., 2020). Sponge city principles are often expressed with various design elements ranging from concepts of permeable surfaces, green spaces, parks and wetlands as well as green infrastructure for stormwater management such as bioswales and rain gardens and overall adaptive design to accommodate change in the hydrological context for a more natural function. The aim with sponge-city principles is to create a more sustainable, resilient and livable urban environment that can better withstand the impacts of climate change and provide multiple benefits for ecosystems, communities and economies (Sun et al., 2020).

Various elements derived from the supporting theories and methodology during this research are interconnected and applied with landscape architectural design. The design outcome, a blue-green network to increase climate resilience in Reykjavík demonstrates the relevance to this theoretical background that steered me in the right direction towards the design.

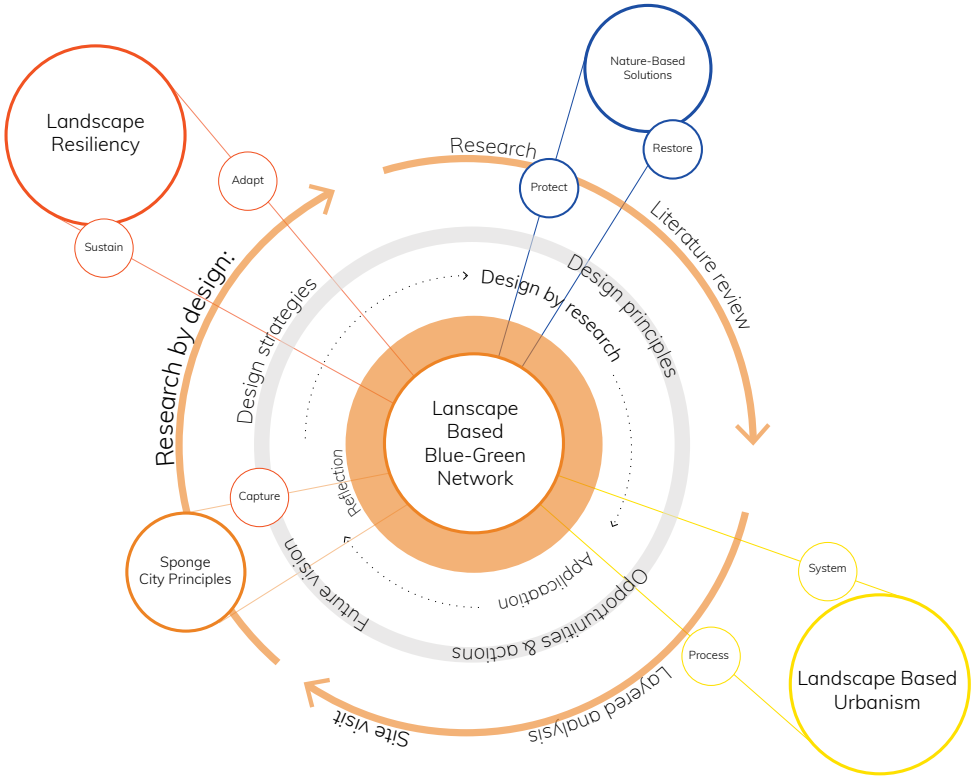


Figure 8: Theoretical Framework graphic

2.2 Research methods

Mixed methods were used for this thesis and the research approach mainly took place in four different stages. Starting with research on design where literature review on successful similar case studies took place as well as various readings to gain a better understanding on the applied theories that support this thesis as well as other significant reading material. The next step during this phase was a thorough site analysis of Reykjavík. That was done with extensive research and a layered landscape analysis approach delivering various maps to gain a deeper understanding of the site's context, its spatial structure and identity. The layered analysis approach entailed a method to explore the site's multiple dimensions and relationships by dividing the site into different layers to better understand its complex and intersectional relationships (Nijhuis & De Vries, 2019b). Starting by analyzing the layer of natural context such as water, relief, geomorphology, and the topography of Reykjavík's peninsula. The next step was to analyze the human impacts, that is, how the landscape has been shaped by humans and the effects of urban- and infrastructure development as well as an analysis of the site's history. Lastly, understanding the cultural layer, the intangible material in the context of the site to gain a deeper understanding of the cultural identity in relation to both humans and nature.

During this phase a lot of insightful reading and collection of information occurred. Local municipal- and water authorities were contacted to gain information and a site visit happened in December 2023. After analyzing the different layers, biotic vs. abiotic, history and the urban- and infrastructure development of the city, a deeper understanding was gained of the landscape authenticity of the site and some design clues represented themselves allowing me to continue into the next step, developing the design strategies.

The analysis was followed by the next step of identifying and developing design principles and strategies that were applicable for the design location. Design potentials and challenges of the site were identified during this phase followed by an in depth review on the applied theories in order to gain deeper knowledge and understanding. This step led to the design of landscape architectural principles and strategies that comply with the research theories to tackle the challenges that the city is facing which then were developed and made applicable at different scales with different functions.

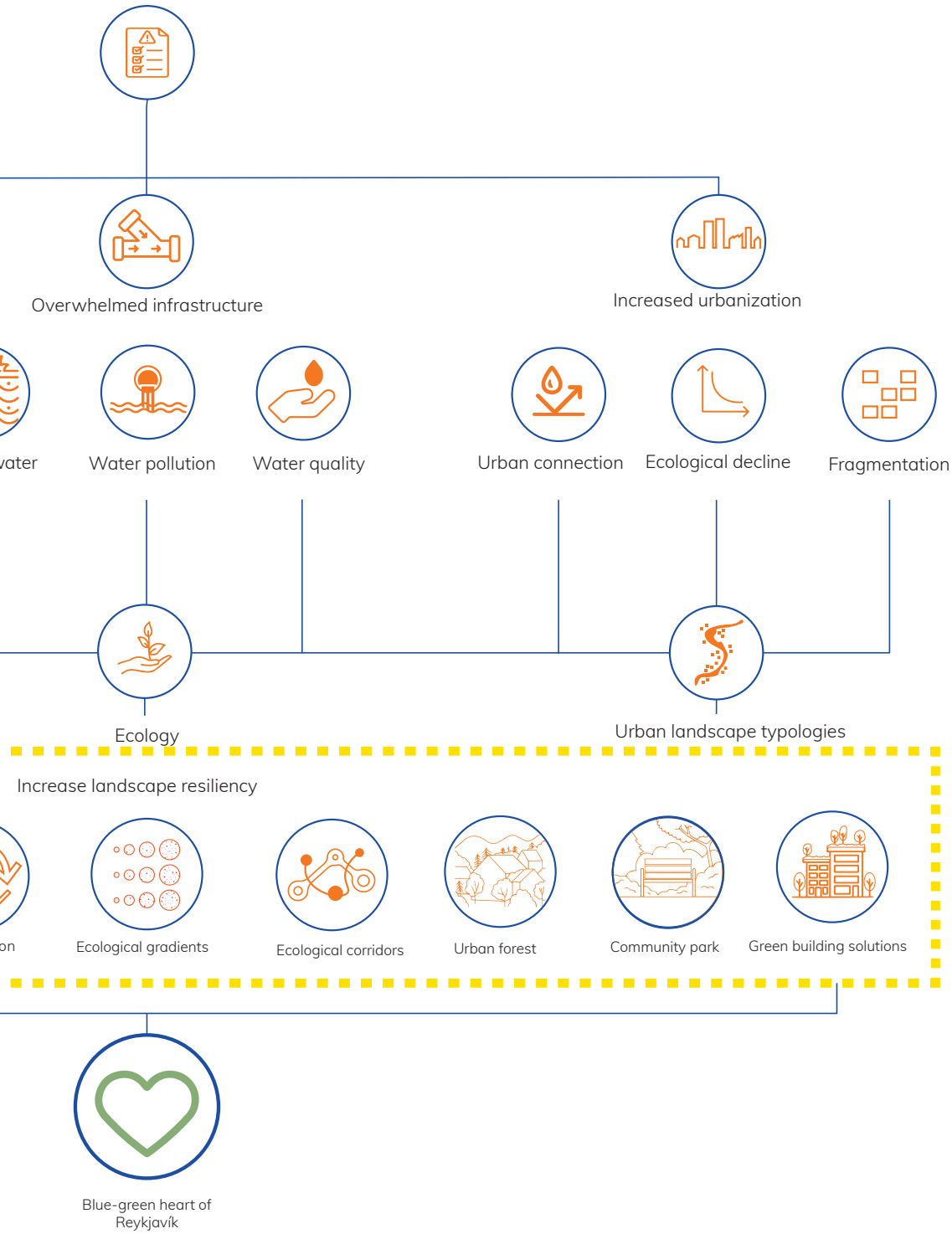
The last phase was research through design (RTD) and application took place where I was able to develop site-specific spatial design and explore different design possibilities for a functioning, blue-green network in Reykjavík. The final design option resulted in a vision map for the blue-green network, in the heart of the historical center of the city with emphasis on three key-design elements integrated into the network. These elements were ecologically and hydrologically inclusive design elements intertwined into new urban landscape typologies for the city of Reykjavík.

Research through design (RTD) is regarded as a powerful research strategy in which complex spatial problems are approached in a creative and integrated manner (Nijhuis & De Vries, 2019) and RTD is used as a wayfinding in the transdisciplinary process of this research. After the steps of analyzing, gathering information, developing design strategies, the research through design was expressed spatially followed by a reflection where the resulting outcome was aligned and reviewed with the initial goal of developing strategies for improved climate resiliency in the city of Reykjavík.

Figure 9: Perlan, landmark located on top of the hill of Öskjuhlíð, a forest in Reykjavík

Research methodology

Figure 10: Problem statement & research approach


Overwhelmed infrastructure
Increased urbanization
vater
Water pollution
Water quality
Urban connection
Ecological decline
Fragmentation
Ecology
Urban landscape typologies
Increase landscape resiliency
on
Ecological gradients
Ecological corridors
Urban forest
Community park
Green building solutions
Blue-green heart of Reykjavík

3.0 Analysis: Against All Odds

3.1 Introduction

The chapter focuses on an analysis of spatial characteristics and landscape within the Capital Region of Reykjavík Although, preceded by a broader overview of general Icelandic environmental conditions and landscapes for broader context. This initial discussion gradually narrows its focus to the historical core of Reykjavík with a thorough hydrological and ecological analysis. Additionally it provides insight into the history and impact of urbanization on the city development, exploring how urbanization has influenced the local landscape ecology over time, particularly in terms of its hydrological cycle. Furthermore, after analyzing the current landscape, considering both its biotic and abiotic elements, and after investigating the historical forces that have shaped Reykjavík's development some conclusions are made that represent the design clues for this thesis design. This analysis occurs across various layers and scales, resulting in the presentation of maps, sections, and diagrams to visually convey these findings

Figure 11: Panorama view from site, smoke from last volcanic eruption in background. Image taken by author, 2024.

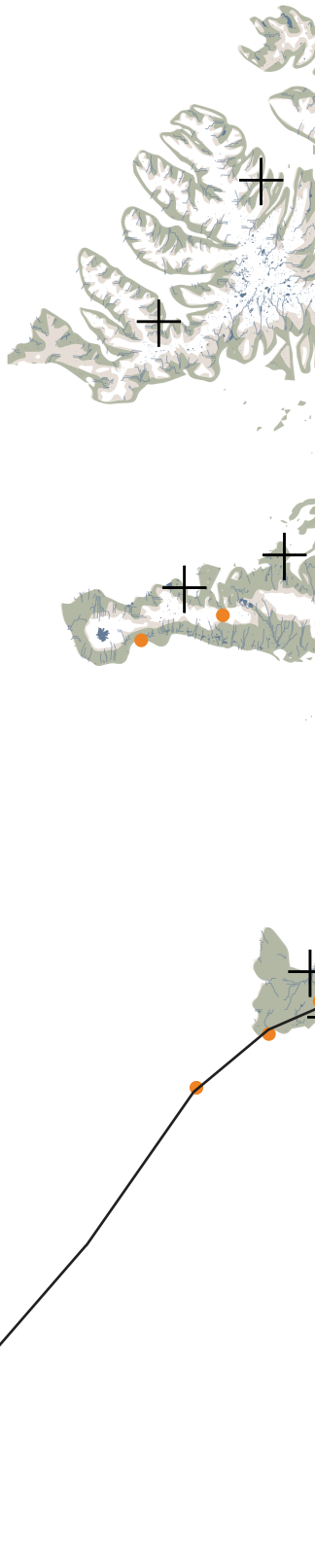
3.2 Cultural landscape of harsh conditions and fragility

Iceland is a volcanic island located in the north Atlantic ocean. Its captivating saga weaves a tale of rugged terrain, formidable challenges, and the determined spirit of resilience. Over time, its inhabitants have displayed remarkable fortitude, steadily adapting to the distinctive demands of their environment, ensuring their survival in this extraordinary landscape. The climate in Iceland is relatively mild in spite of the high geographic latitude due to the warm waters that the Gulf Stream brings to the shores of Iceland. Continental areas at the same latitudes in Siberia and Canada for example experience much colder climates, particularly in winter (Arnalds et al., 2016). Iceland has about thirty active volcanic systems, fed by a volcanic mantle plume under the island, with eruptions occurring approximately every three to five years (Guðmundsson 1996).

Icelandic landscapes are very dynamic and are characterized by a great variety of ecotypes over short distances (Arnalds et al., 2016). Only 24% of the whole island is arable land and everything that thrives on the island grows between the elevation zone from 0-400 meters above sea level. Above 400 meters the barren highlands take over. (Skýrsla Nefndar Um Landnotkun, 2010). The soil cover in Iceland is discontinuous and delicate, the central highlands are more or less barren and the young volcanic areas are in a desert-like condition. The ecotypes of Iceland bear great marks of harsh weather conditions and many volcanic eruptions (Arnalds et al., 2023). This results in very fragile vegetation constantly battling external forces.

The enduring belief in the “Huldufólk” among the people of Iceland offers a fascinating insight into the nation’s rich cultural heritage and strong connection to its natural environment. While the existence of these hidden beings might seem like a charming piece of folklore, their role in contemporary Icelandic society underscores the importance of preserving the country’s unique landscapes and maintaining a harmonious relationship with the natural world.

Iceland, of fire and ice



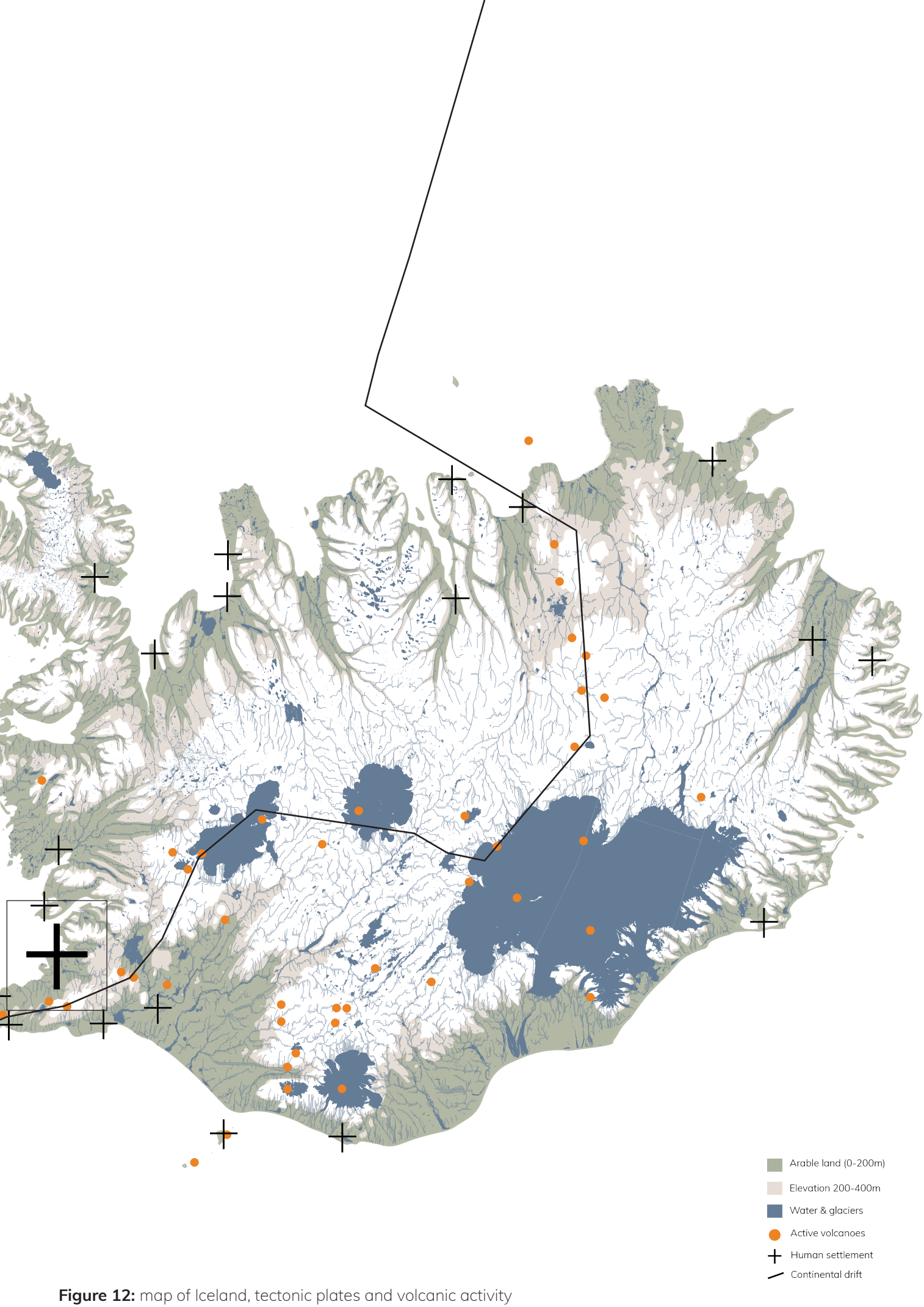


Figure 12: map of Iceland, tectonic plates and volcanic activity

3.3 Urban hydrology: disrupted watercycle

The area of Reykjavík is spatially characterized by relatively flat coastal land with hills and hollows and the shoreline is deeply indented by bays. The landscape is vast and boundless with mountain views and the landform is rough and coarse. The city is located in a low lying area spanning roughly from 0-150 m above sea level. Reykjavík, like much of Iceland, has a wet, cool climate. Winter temperatures average between -3 and 3°C, while summer temperatures range from 8 to 15°C, with extremes reaching lows of -10°C and highs of 25°C. The city receives significant precipitation, predominantly rain, ranging from 400 to 4000 mm annually (Neukirch, 2019).

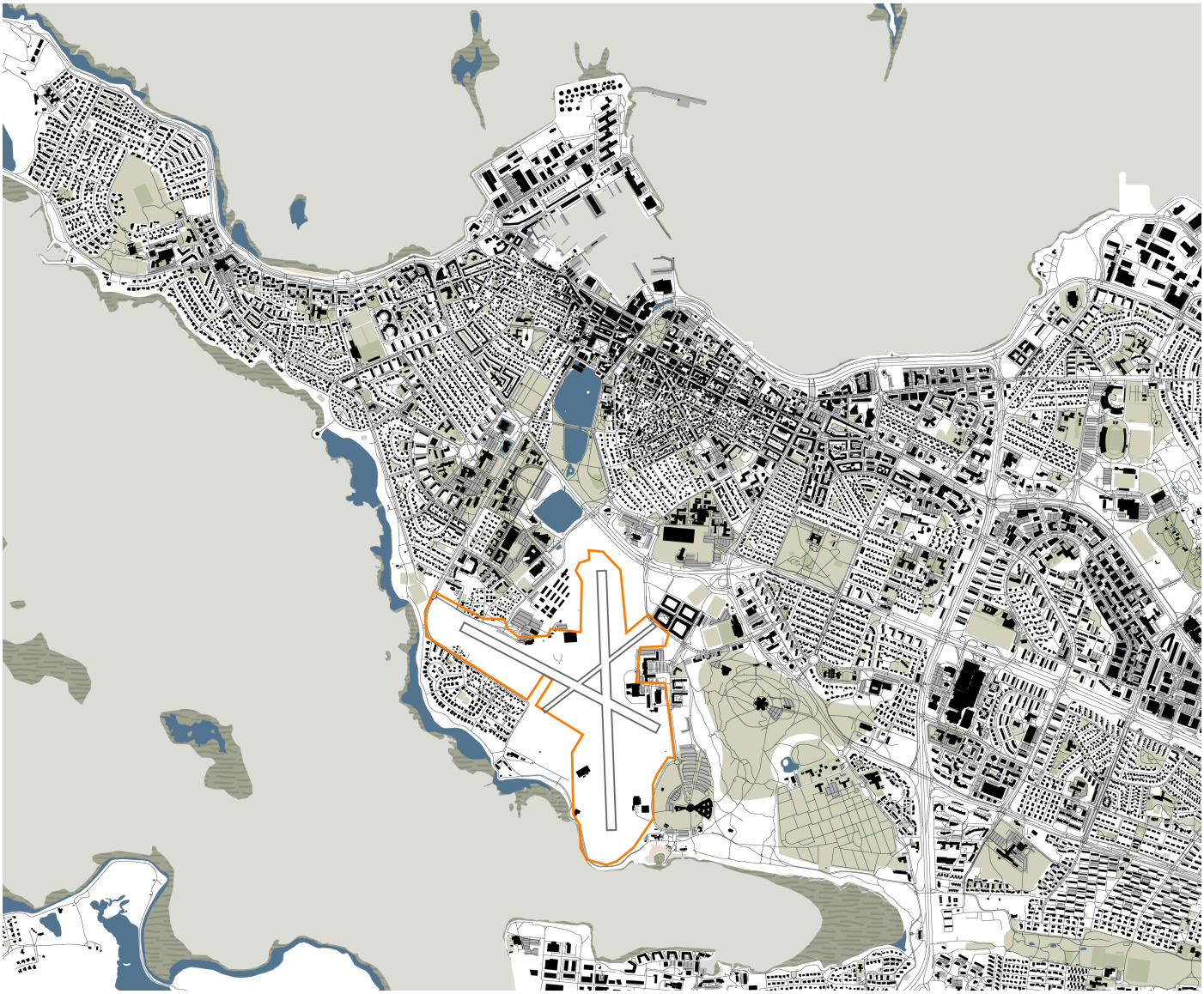


Figure 13: Map of Reykjavík Peninsula, domestic airport marked with orange

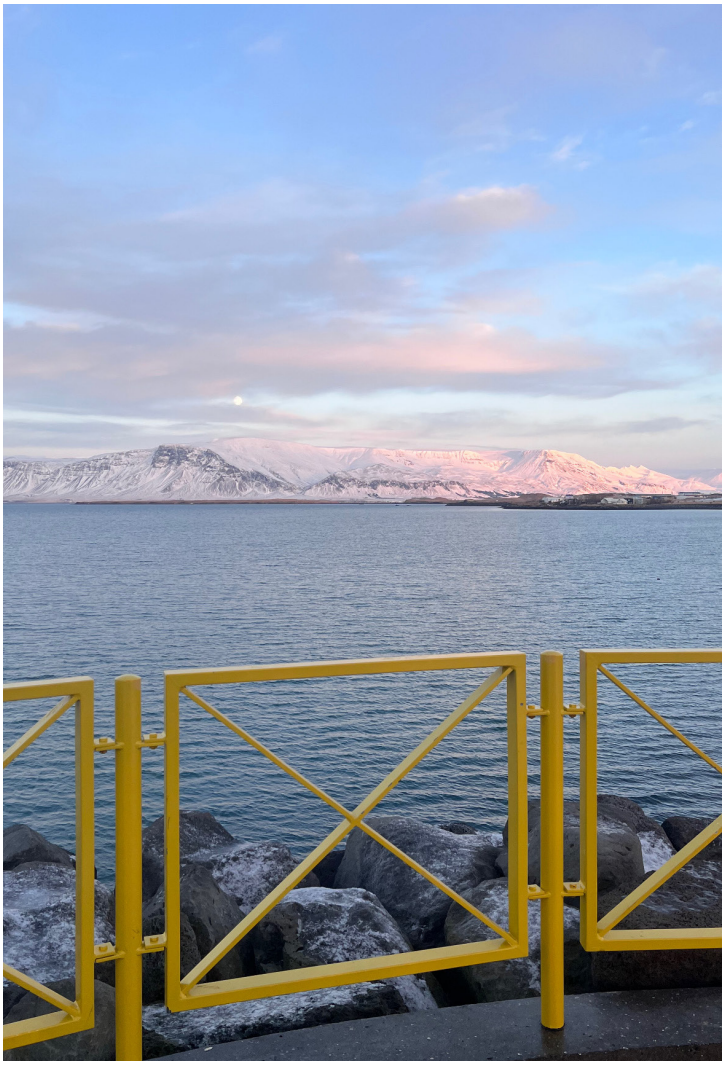


Figure 14-18 : Photographs from a site visit in December 2023, taken by author.

A lot of precipitation and little evapotranspiration results in a wet island in a combination with a porous bedrock that can hold a lot of water. However, the permeability of the bedrock is highly dependent on the conditions under which they were formed. The dominant bedrock underneath the Reykjavík peninsula is mainly layers of porous basalt bedrock that varies in depth and thickness. The depth to the surface spans from -30 to -20 meters below sea level and the thickness varies from 0-100 meters (Hjartarson et al., 2019). The soil in the area consists mainly of loose strata of hydric soil, a discontinuous cover of glacial erosion and thin, weathered sediments along with landfilled areas ("Jarðkönnun Í Skerjafirði – Framhaldsrannsókn Og Magntaka," 2021).

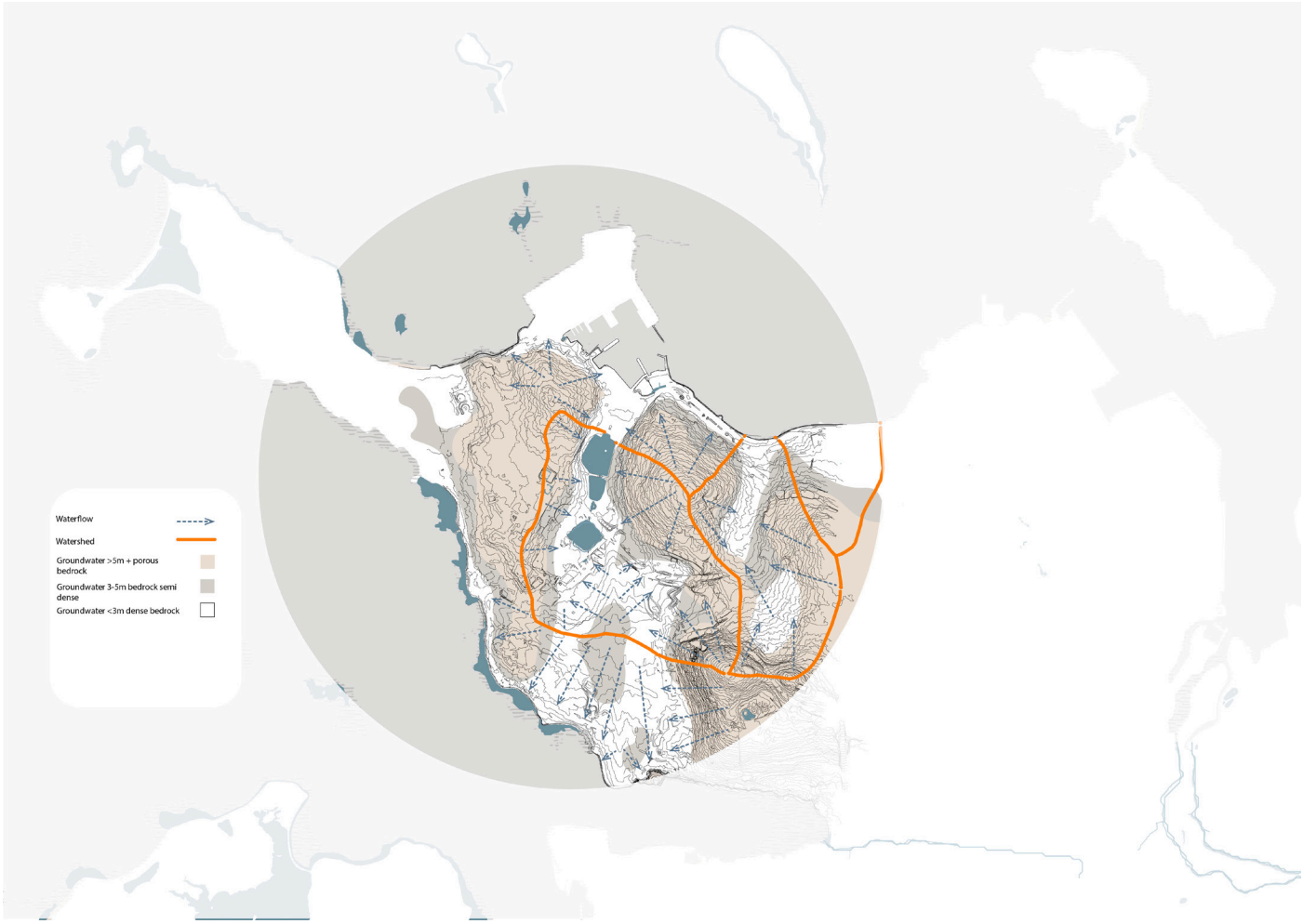


Figure 19: Analysis map of Reykjavík's peninsula watersheds, relief, waterflow and topography

95% of water supply for Reykjavík is groundwater. Drinking water for the city is mainly pumped from nature reserve areas outside the city, although geothermal water extraction takes place in multiple areas within the city boundaries (Uppruni Heita Vatnsins, n.d.). The groundwater table is not in a natural state in Reykjavík. Runoff has become much higher and groundwater levels are falling (Hjartarson et al., 2019). A double water table has formed underneath the city mainly due to human impacts. The higher aquifer is in a closed system and has cold water whereas the bottom one is in a confined aquifer and contains hotter water. Thicker sediments underneath the city separate the two aquifers (Hjartarson et al., 2019).

Figure 20: Analysis map of Reykjavík representing fragmented urban green areas and parking lots

This research and analysis provided the information to state that the natural hydrological cycle is highly affected. Reports indicate that the groundwater table is lowering from lack of recharge and too much water extraction, being more than tens of meters deep in some areas. The difference between high tide and low tide in Reykjavík is about 3.8 meters and salt water inundation can be observed in the groundwater closer to the shore, especially in the oldest parts of the city. Although, no direct measurements have been made and there is a need for better research on salt water inundation (Hjartarson et al., 2019). The information provided above indicates that the hydrological cycle is critically disrupted in Reykjavík and challenged by current water management and increased urbanization. This poses a problem for the future of Reykjavík where actions are needed to restore a more naturally functioning water cycle, making use of stormwater and a change in perspective on water management

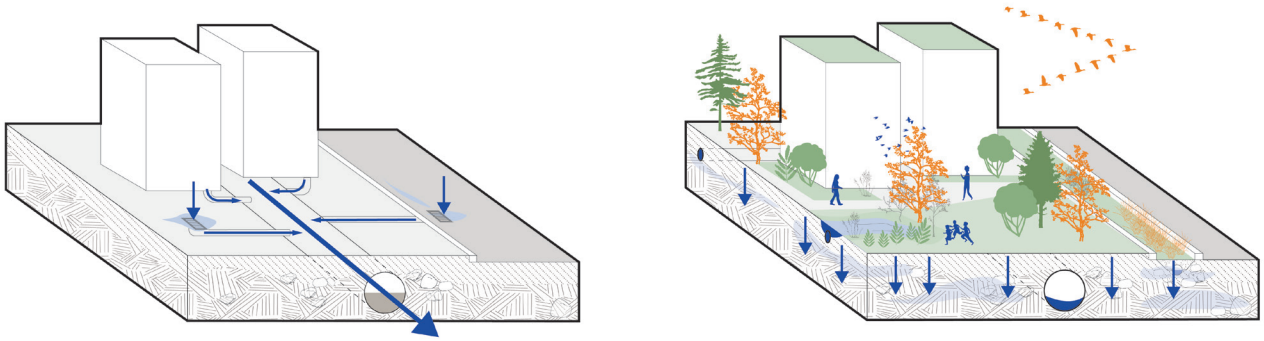


Figure 21: Diagram representing current water management in Reykjavík and proposed improvements

Figure 22: Photograph of site location taken by author, looking towards landfill area of domestic airport

3.4 Vulnerable ecosystems and external forces

Iceland is a rather sparsely populated country and over half of the island is inhabitable. External forces have had a lot of impact on the vulnerable landscape, leading to a slow environmental degradation over the centuries. When the vikings first arrived in Reykjavík around the year 970, birch woodland and shrubland covered about 20-40% of the whole island (Eysteinsson & Aradóttir, 2004). The viking ancestors felled most of Iceland's native and only forest forming tree, the birch (Betula pubescens ssp. tortuosa), a subspecies which all native birch in Iceland is regarded as belonging to (Kristinsson et al., 2018). The birch had multiple benefits for the settlers who used it as building material, fuel and so forth. An overlooked aspect of land degradation in Iceland is the impacts of the free-roaming sheep that the vikings initially brought along and have been roaming freely, grazing year round on the island ever since which, along with other external forces, inhibited regeneration over the centuries, eventually leading to almost complete deforestation. Once extensive, birch woodland and shrublands cover roughly 1.5% of the total area of land today (103,000 km2) and are represented by fragmented patches of birch forests scattered throughout the country (Eysteinsson & Aradóttir, 2004).

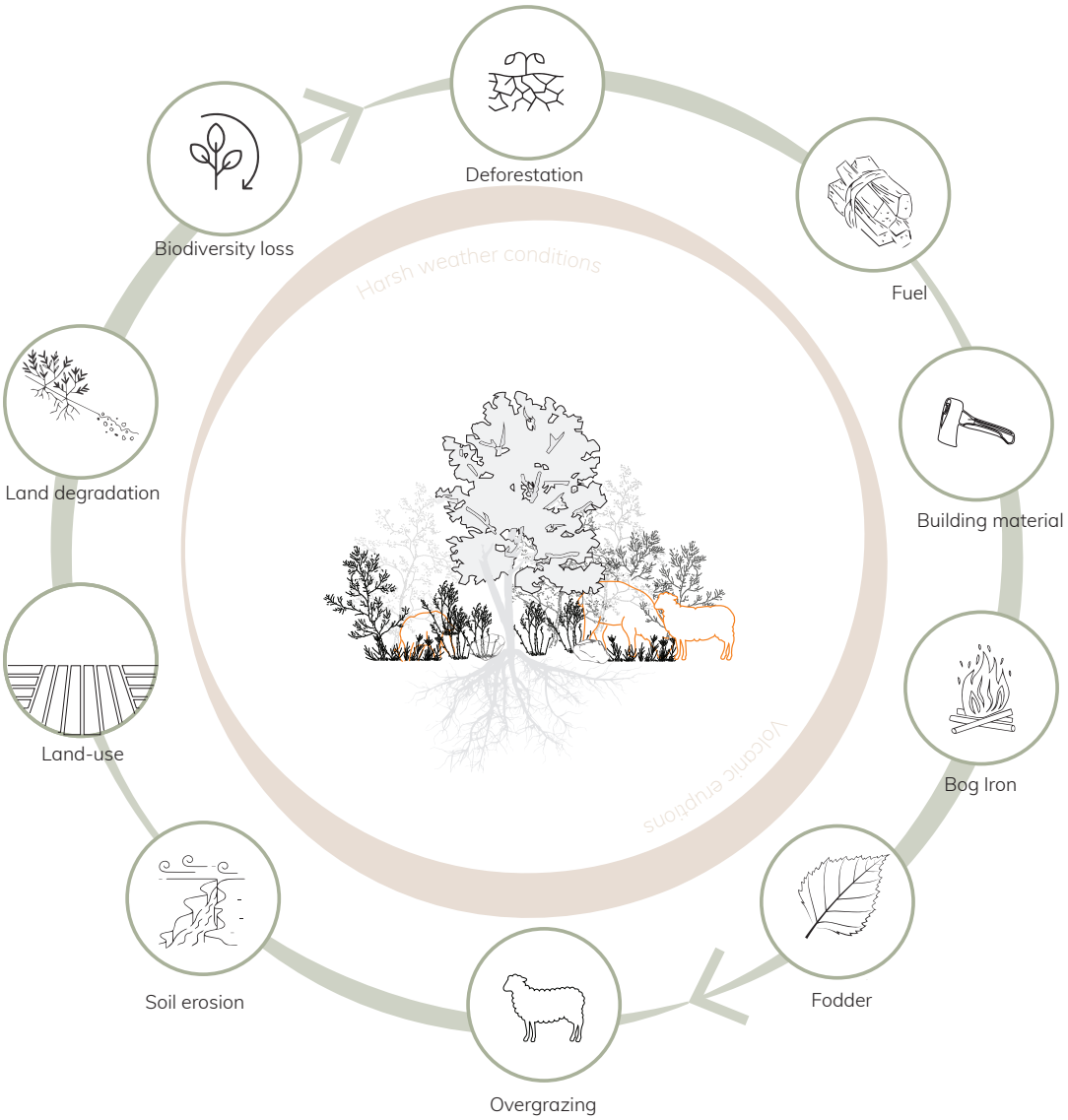


Figure 23: A graphic expression or the cyclic, ecological tension with various external forces

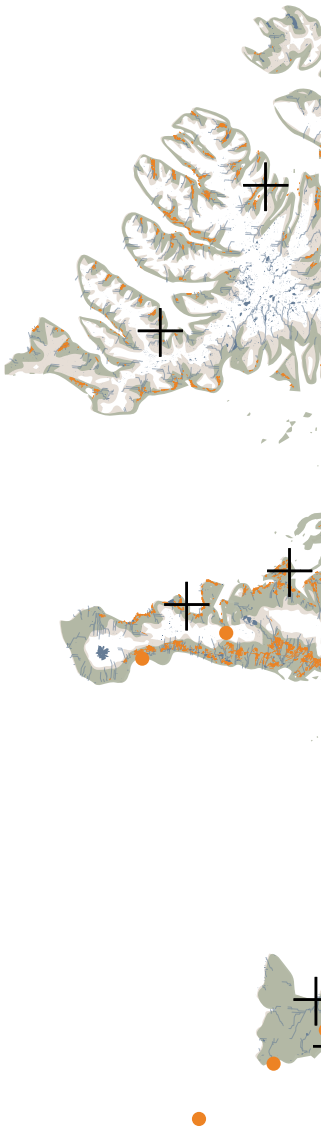
Figure 24: Sections demonstrating a study of Icelandic vegetation

Figure 25: Willows and birches emerging in fenced off areas, photograph taken by author, 2022

Figure 26: Native ecologies emerging in previously disturbed/eroded landscape, photograph taken by author, 2022

Icelandic wetlands are among the most important ecosystems of the country because of their role in biodiversity, water regulation and carbon budgets and they have an international value by supporting large populations of migratory bird species. The Icelandic wetlands support about 20 internationally important bird species (Einarsson et al.2002). For centuries, the wetlands were also used for grazing by livestock and harvested for hay. The wetland sward also provided sod for house construction (Sigurdardottir 2007) and the more organic soils provided peat for fuel (Eldjárn, 1975). Icelandic wetlands are very rich in Andosols and Histosols which is uncommon in the rest of the world which leaves a generally fertile soil with high bird-nesting densities. The wetland soil is usually 1-3m thick and has great carbon storage capacity (Arnalds et al., 2016).

The draining of the wetlands primarily took place during the latter part of the twentieth century and the act was subsidized by the government. This results in drainage ditches spanning about 30.000 km in the lowland areas in Iceland, meaning that about 70% of lowland wetlands in Iceland are impacted by drainage (Arnalds et al., 2016).



The draining of Icelandic wetlands

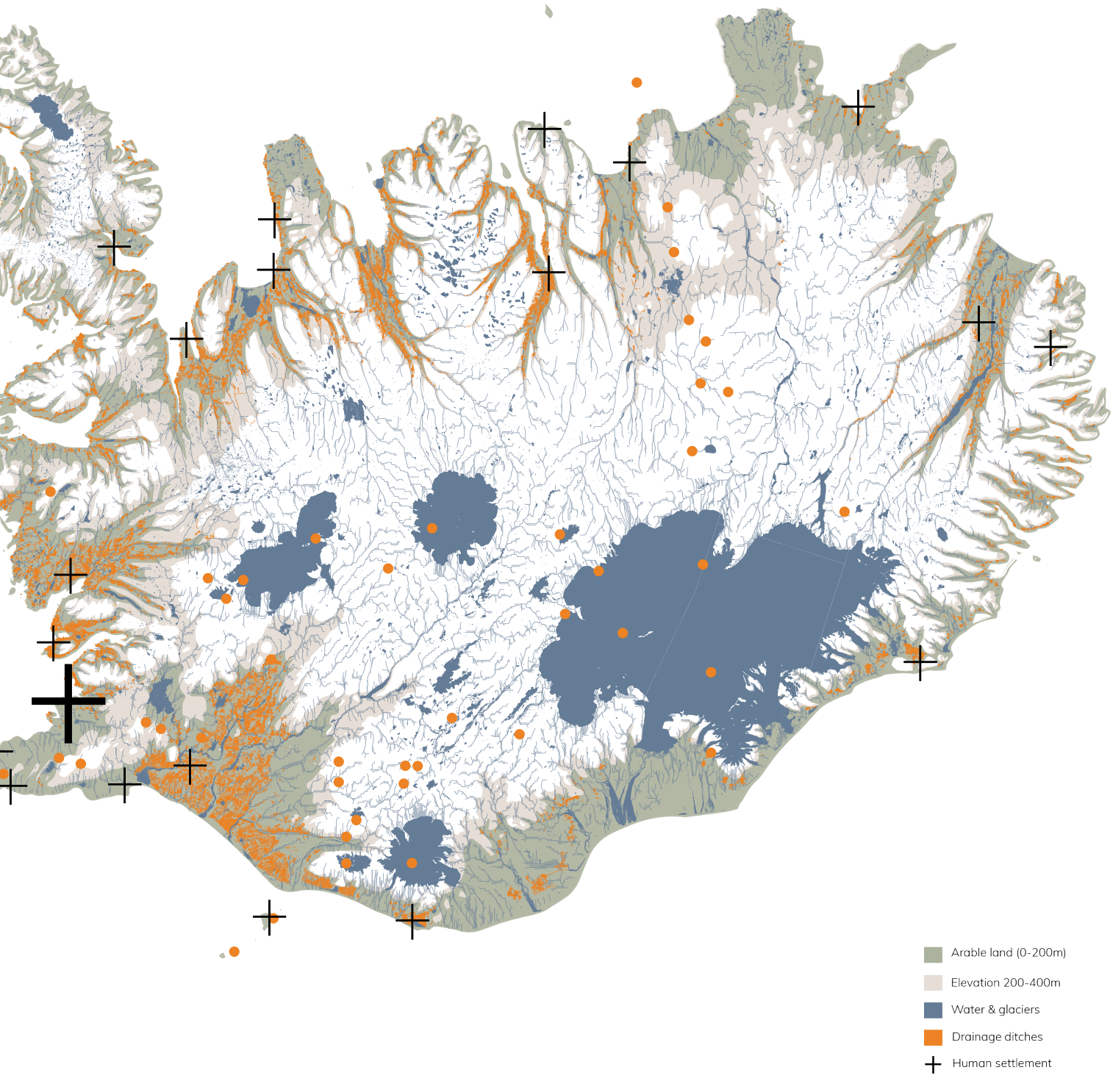


Figure 27: Map of Iceland and drained wetlands

Figure 28: Wetland patch “Vatnsmýri” in Reykjavík, photograph taken by author, 2024

Figure 29: Wetland patch and domestic airport, photograph taken by author, 2024

By gaining a deeper understanding of the deterioration of Icelandic wetlands and the native vegetation, a prevailing tension between the destruction of wetlands and ecological succession against external forces was discovered. This provided the information to conclude that the design location, Reykjavík's peninsula, provides an excellent opportunity to restore and re-introduce the native birch habitat and reclaim former wetlands as an integrated design element of the blue-green heart of Reykjavík.

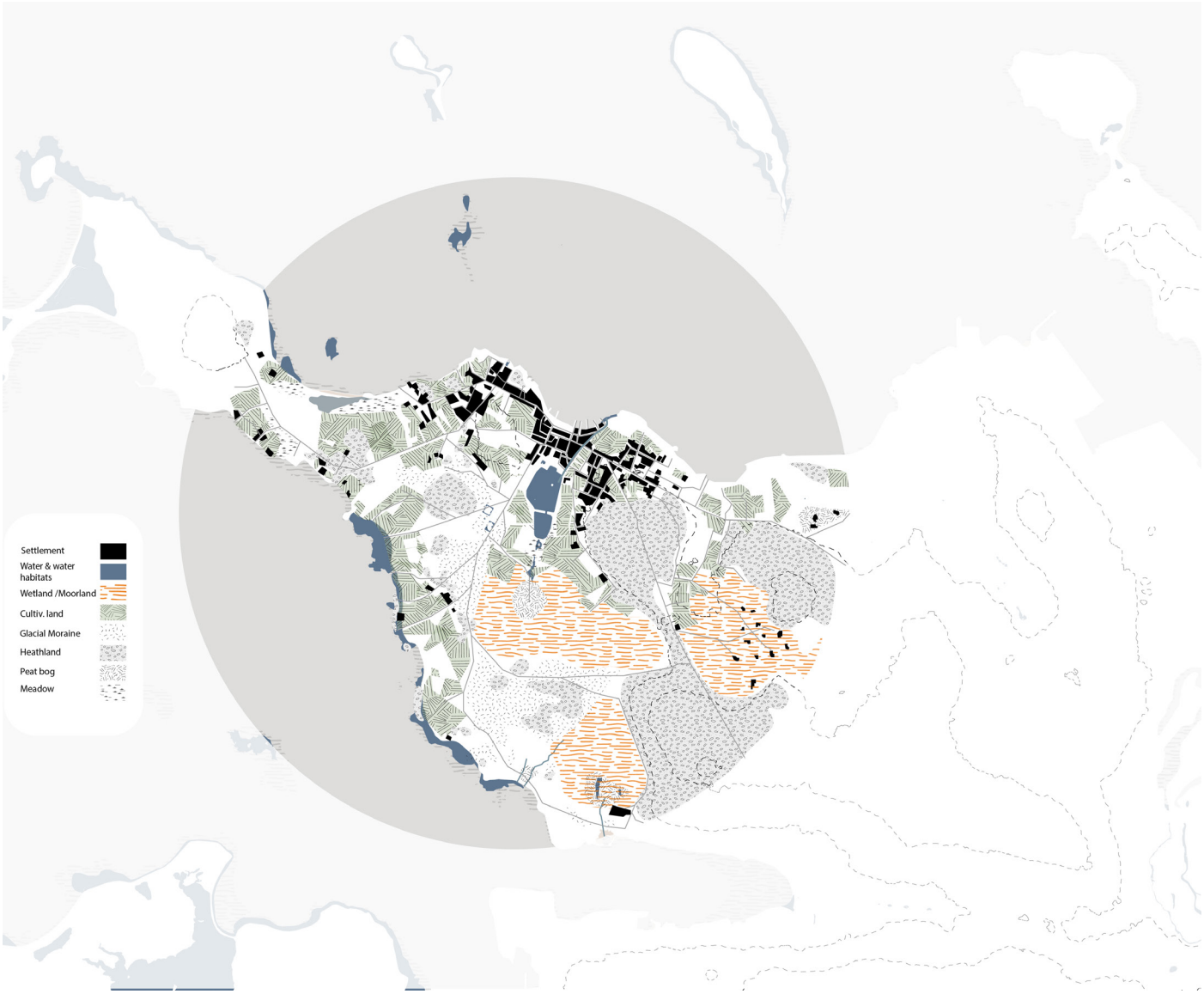


Figure 30: Landscape analysis map of Reykjavík from 1903, urban settlement expanding from old harbour, former wetland areas south of the existing pond, "Tjörnin".

3.5 Infrastructure: Framing the future of Reykjavík

Urban development and settlement in Iceland remained minimal to none until the late 18th century when a gradual growth began, primarily centered around Reykjavík. Throughout much of the 19th century, this development remained at a very slow pace. In 1850, Reykjavík housed a mere 1000 residents, a number that rose to 3000 within two decades. It wasn't until the onset of the industrial revolution at the turn of the century that population growth accelerated significantly, marking the beginning of a sustained period of rapid expansion to this day (Friðriksson, 2021).

In Reykjavík, Iceland, the definition of sewage water is all wastewater from homes and industries, including the stormwater runoff from streets and other impervious surfaces (Reykjavik, n.d.-b). The foundation of the original water infrastructure system in Reykjavík is based on the idea of directing water as quickly as possible away from its source for treatment and disposal. That is done by directing sewage water into accommodating infrastructure which then enters pumping stations where, according to a report made biannually by the Environmental Agency in Iceland, the water undergoes bare minimum treatment, eventually disposing the water into the ocean (Reykjavik, n.d.-b). The current water infrastructure system in the city is mainly composed of two systems, a combined system and a separated system. The former prevails in the oldest parts of Reykjavík where stormwater and wastewater undergo the same treatment. The separated system however, has separate infrastructure for stormwater which is delivered into the nearest receptor. The latter approach is a relatively new practice in Reykjavík and this method only adheres in the latest development areas in the city (Reykjavik, n.d.-b).

Consequently, the impacts of climate change and increased urbanization in Reykjavík have placed greater stress on the existing water infrastructure. This has led to more frequent faults and malfunctions in the system, often resulting in untreated sewage overflow into the ocean. These incidents are followed by increased maintenance- and environmental cost, which society must bear.

Increased urbanization encourages the construction of city infrastructure. From the first decades of urban development in Reykjavík, water infrastructure were open culverts that led usually downhill to the nearest natural receptor. As urbanization expanded, a great need for reforms increased. It wasn't until 1906 that the sewerage system in Reykjavík got off to a good start and underground sewerage pipes were laid in the city center, and with that the history and development of the current sewerage system in Reykjavík began (Friðriksson, 2021). The present water infrastructure in Reykjavík adheres to the initial concept of quickly directing all wastewater, including sewer and surface water, away from its origin to the nearest receptor and this model persists still to this day in the oldest parts of the city.

The expansion from the historical center of Reykjavík to the modern-day city resembles clusters of neighborhoods built in different periods, mostly after 1945 to this time. It was not until after the second world war that the city became civilized and people started moving in larger quantities from the countryside into the city for better opportunities and Reykjavík really started growing. During a period of rapid expansion some not so desirable remarks were left on the urban-planning in Reykjvavík which eventually resulted in a very spread out city, highly dependent on the private car with inadequate public transportation system and large highways which left the city fragmented.

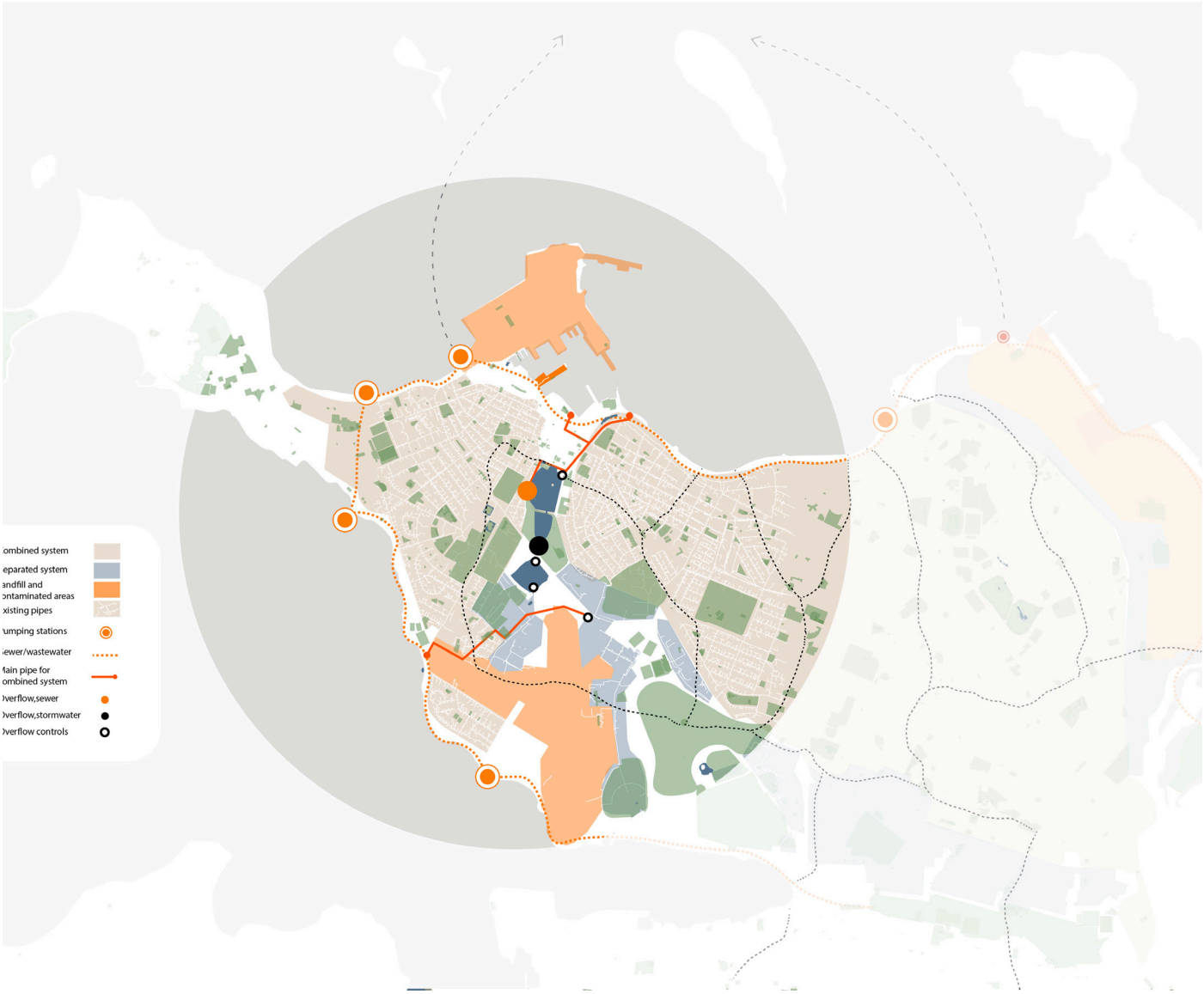


Figure 31: Analysis map of current water infrastructure in Reykjavík

Figure 32: Historic housing in Reykjavík (Árbæjarsafn). Photograph taken by author, 2021

Figure 33: Historic housing in Reykjavík (Árbæjarsafn). Photograph taken by author, 2021

Figure 34: Housing typologies in the historical center of Reykjavík, Photograph taken by author, 2024

Figure 35: Housing typologies in the historical center of Reykjavík. Photograph taken by author, 2024

3.6 Going forward

After analyzing various layers of ecology and urban development I have realized that the Icelandic landscape bears the imprint from both relentless natural forces and human intervention. Since the era of Viking settlement in Reykjavík, the landscape has been subject to transformation through cultivation, the depletion of the native birch habitat and destruction of vulnerable wetlands along with unrestricted grazing over centuries.

With time, the city of Reykjavík's experienced rapid expansion, accompanied by infrastructural decisions that, though expedient at the time, have had enduring repercussions on the environmental quality in Reykjavík. This development results in a disrupted local water cycle, important ecosystems and wetlands in the city (and nationwide) have been depleted and outdated infrastructure can't keep up with the demands of the rapidly growing society. All of which has led to an overall degeneration of the urban quality in Reykjavík.

After gaining a better understanding on how the socio-ecological system in Reykjavík has evolved from its historical function to the present state, design opportunities represented themselves. Going forward, this results with the design of a blue-green infrastructure for Reykjavík that will facilitate and guide a landscape approach for improved urban ecology, water management and urban development with the focus on reclaiming and the former ecologies, by reintroducing wetlands and the native birch habitat in Reykjavík, worked in a network of ecological gradients throughout the city.

Figure 36: Map of design opportunities, the location of the blue-green heart of Reykjavík, ecological connections/ gradients and urban development areas

Reykjavík's peninsula: Landscape timeline

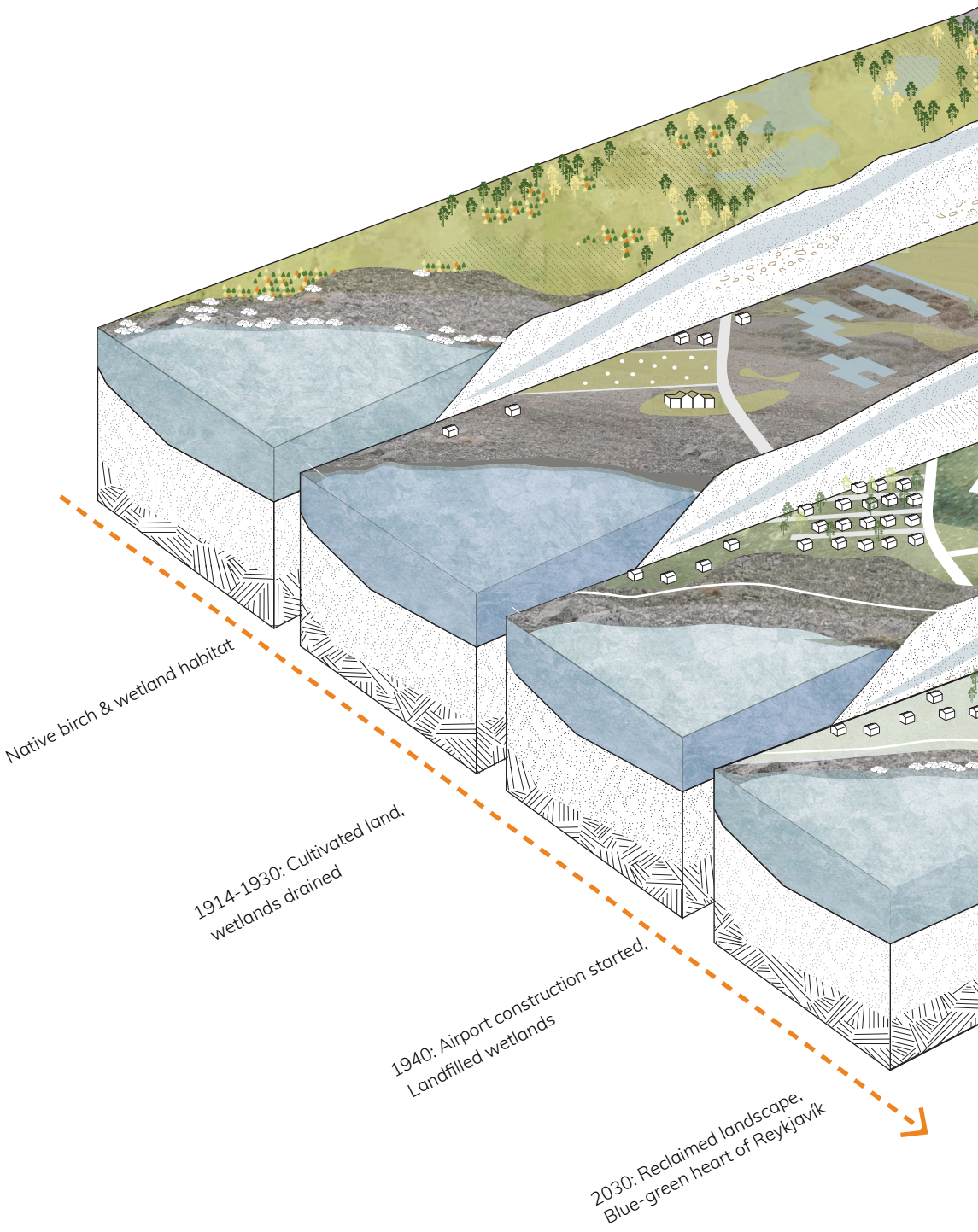
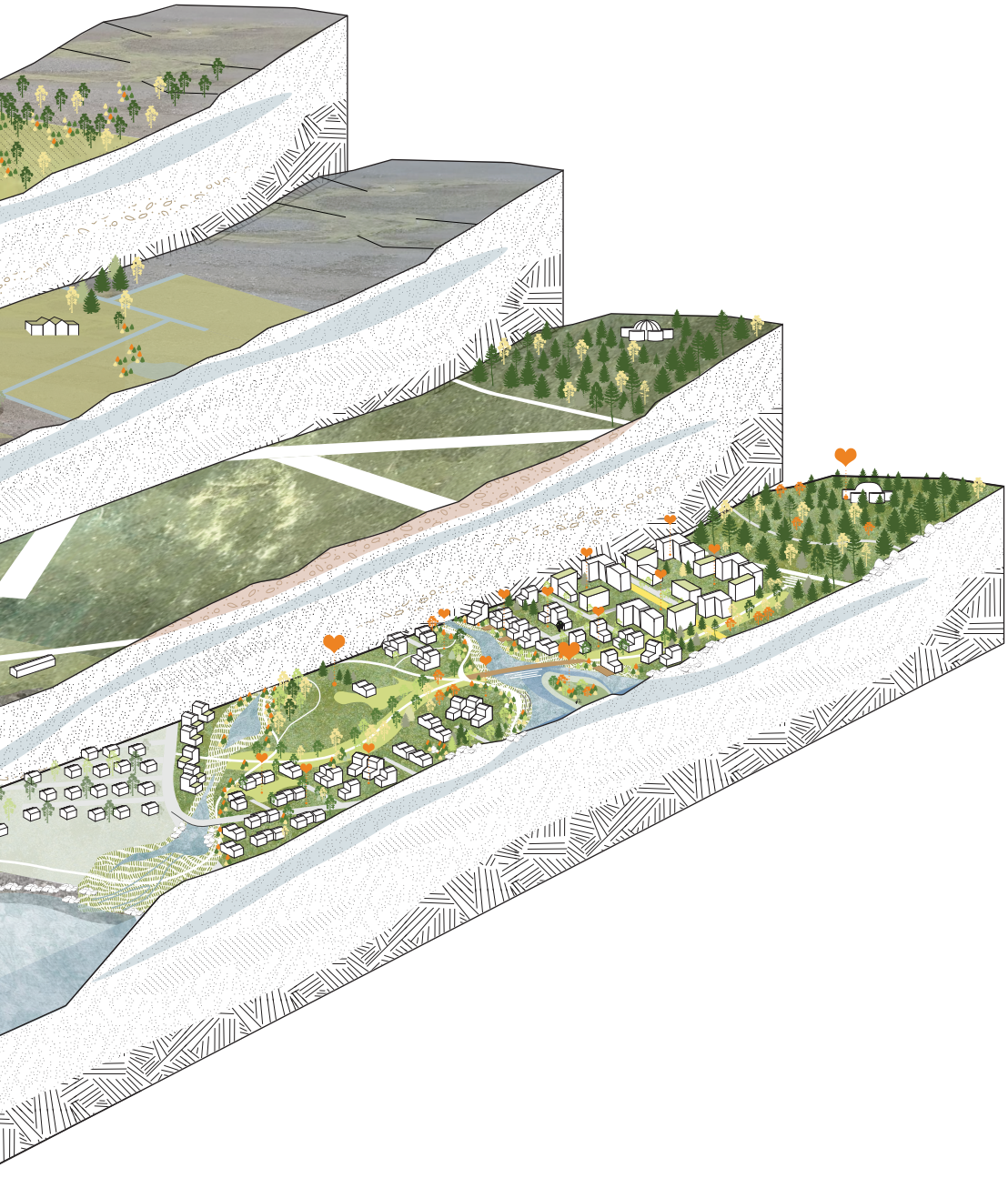


Figure 37: Timeline diagram/section of analysis conclusion and opportunities going forward



4.0 Reused resources

4.1 Future vision

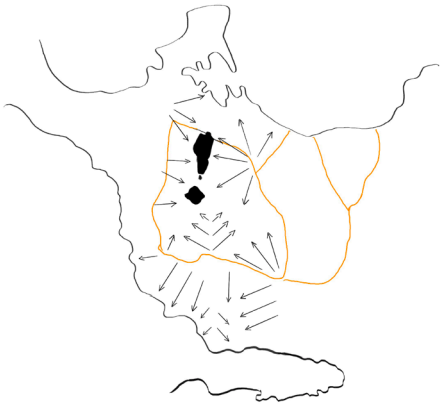
As previously stated, Reykjavík is currently facing challenges from climate change, rapid urbanization, and overwhelmed infrastructure. To address these issues and after the preceding analysis this thesis proposes the development of a green-blue network to enhance the city's climate resilience. This strategy entails the reclamation of previous wetland areas as an important link in water management and that the blue-green network is carefully achieved through ecological gradients throughout the city to ensure qualitative urban green areas and green connections as well as to foster urban ecology. The last component of the network are urban landscape typologies which demonstrate areas for different types of urban development in various landscapes. With this strategy and after examining the landscape from its abiotic and biotic factors and gaining insights into its history and development, as well as understanding the city's needs, I have come to an understanding on the crucial role of leveraging natural landscape functions with the design of the blue-green network to bolster climate resilience.

This chapter will focus on answering the third research question by revealing design expressions of the blue-green heart of Reykjavík where previously mentioned theories have been carefully studied and are implemented into design elements. The design locations focus on establishing the blue-green network across the historical center of Reykjavík, from the existing pond, Tjörnin in Reykjavík, south towards the existing wetland patch called Vatnsmýri; a former larger wetland area, eventually expanding into the landfilled area where the domestic airport is located today.

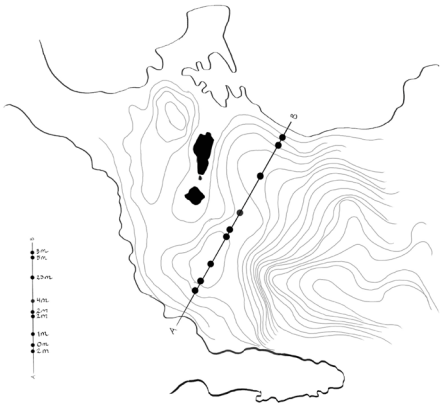
A vision map of the blue-green network was developed following the design concept. Resulting in more detailed plan, the blue-green heart for Reykjavík with focus on ecologically inclusive public spaces by establishing ecological gradients from shore to shore across the Reykjavík's peninsula as well as from the hillsides of the urban forest of Öskjuhlíð towards the western coast. The ecological gradients bring nature and recreation into the city, interlinking city parts through landscape and provide improvements on water management to regenerate the local hydrological cycle and enhance biodiversity. The blue-green heart of Reykjavík completes the natural functions needed in the city where all comes together, urban ecology, water management and new urban landscape typologies.

Design development - concept design

Spatial structure



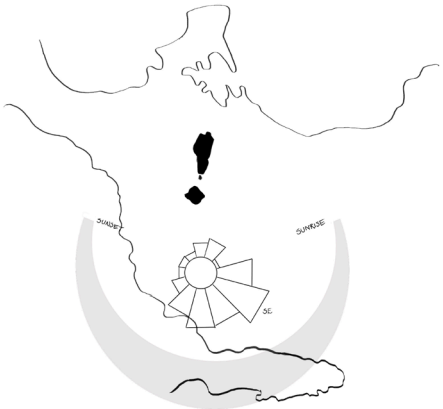
Watershed and flow



Groundwater analysis

Soil, bedrock and permeability analysis

Historic wetland patches



Sun and wind analysis

Figure 38-43: Development of design concept and its various layers

Sketches of the concept development of the blue-green network

Concept of the blue-green network

Blue-green structure

Urban development areas

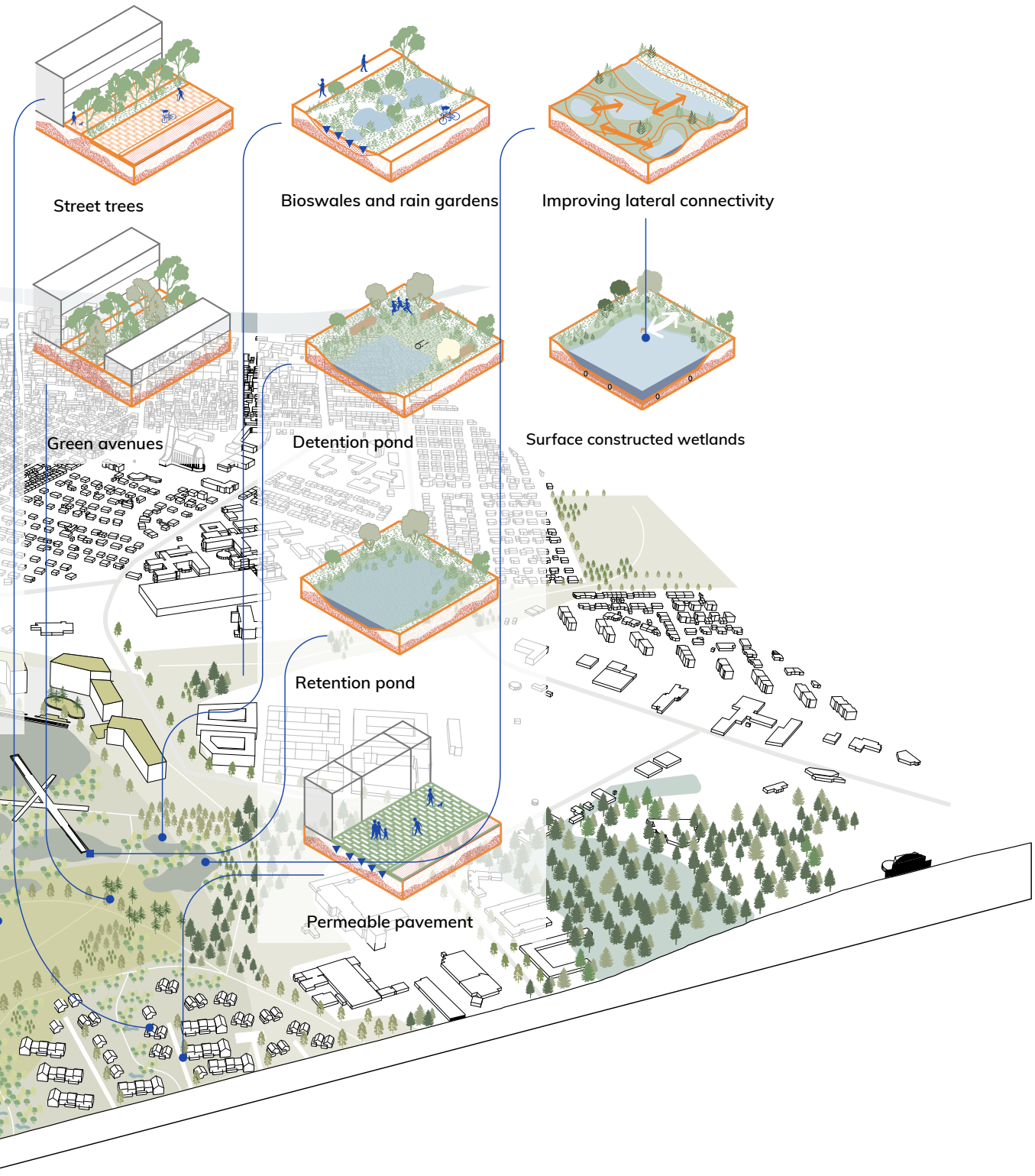
Focal point, viewpoints, orientation

Figure 44-47: Design concept and main design elements constituting the design

Figure 48: Future vision map of Reykjavík

Figure 49: Axonometric of the blue-green network. Toolbox was developed to demonstrate the application of principles derived from nature based solutions and sponge-city principles

Green Corridors Bioretention Inland Wetlands



4.2 Improved hydrology

As the main objective is to increase climate resiliency through the means of establishing a blue-green network, improved water management approaches are represented with a water system map and other design elements to demonstrate an improved hydrological cycle for the area and watershed alterations. Waterflow and stormwater is directed towards the central wetland patches, the heart of the new water system. That is done with landscape based stormwater infrastructure along roads and other green infrastructure within the urban development areas such as pocket parks, rain gardens and bioswales. The emphasis of the water system is capturing and filtrating water locally whilst providing further filtration and aquifer recharge in case of heavy precipitation by directing the flows towards the central, constructed inland wetland patches. The wetland patches provide improved hydrological characteristics for the area and are an important design feature of the blue-green network, re-introducing and enhancing the former natural landscape, from wetlands towards a native birch habitat.

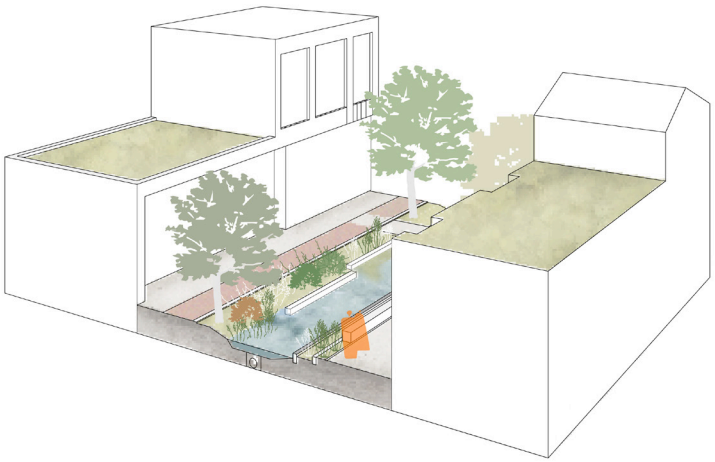


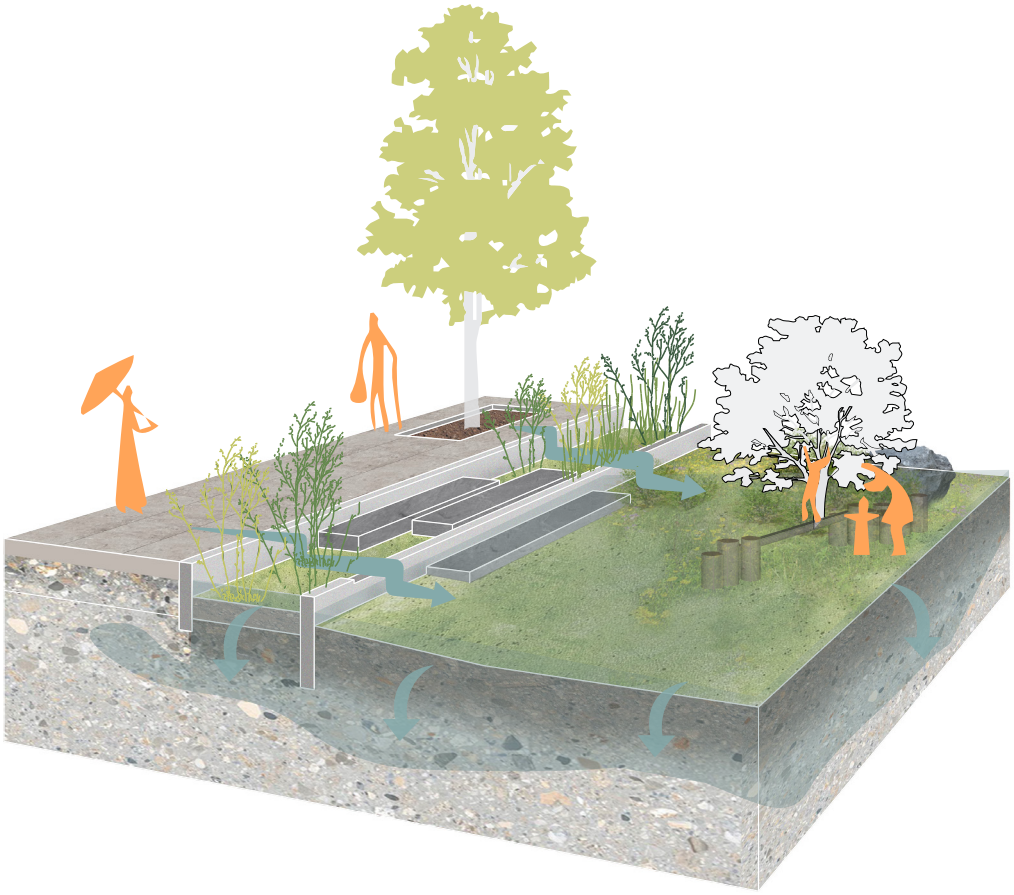
Figure 50: Diagram of a green corridor of hydro- and ecologically inclusive public spacesw

Figure 51: Map of improved watersystem in Reykjavík

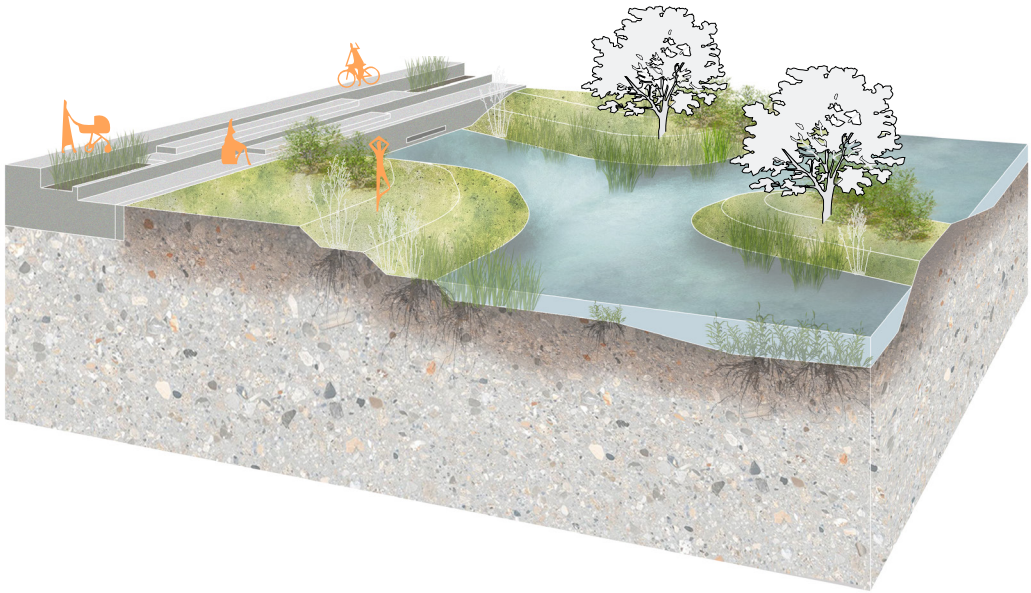
Design interventions for the new water system were mainly supported by the derived theories of the sponge city principles and nature based solutions (NbS). As mentioned, sponge city principles emphasize sustainable water management on the urban scale by strengthening green infrastructure instead of purely relying on gray infrastructure, which is the current situation in the historical center of Reykjavík. The main principles are expressed with design solutions focusing on capturing, filtrating stormwater and recharging groundwater whilst providing accessible green space for people to enjoy nature. Nature based design solutions (NbS) such as bioswales, rain gardens and constructed wetlands are important design elements for stormwater management in Reykjavík's context. The recreational forest Öskjuhlíð, located East of the design area is often referred to as the lungs of the city due to its air-cleansing and sediment trapping capabilities and the improved water treatment within the blue-green system will similarly provide the function of kidneys, filtering(purifying) and removing waste from the city's waters, ultimately strengthening and adding to the natural functions of the city.

Capture & direct

Figure 52-54: Diagrams demonstrating sponge-city principles of capturing, infiltrating and recharging water



Infiltrate & clean



Store & recharge

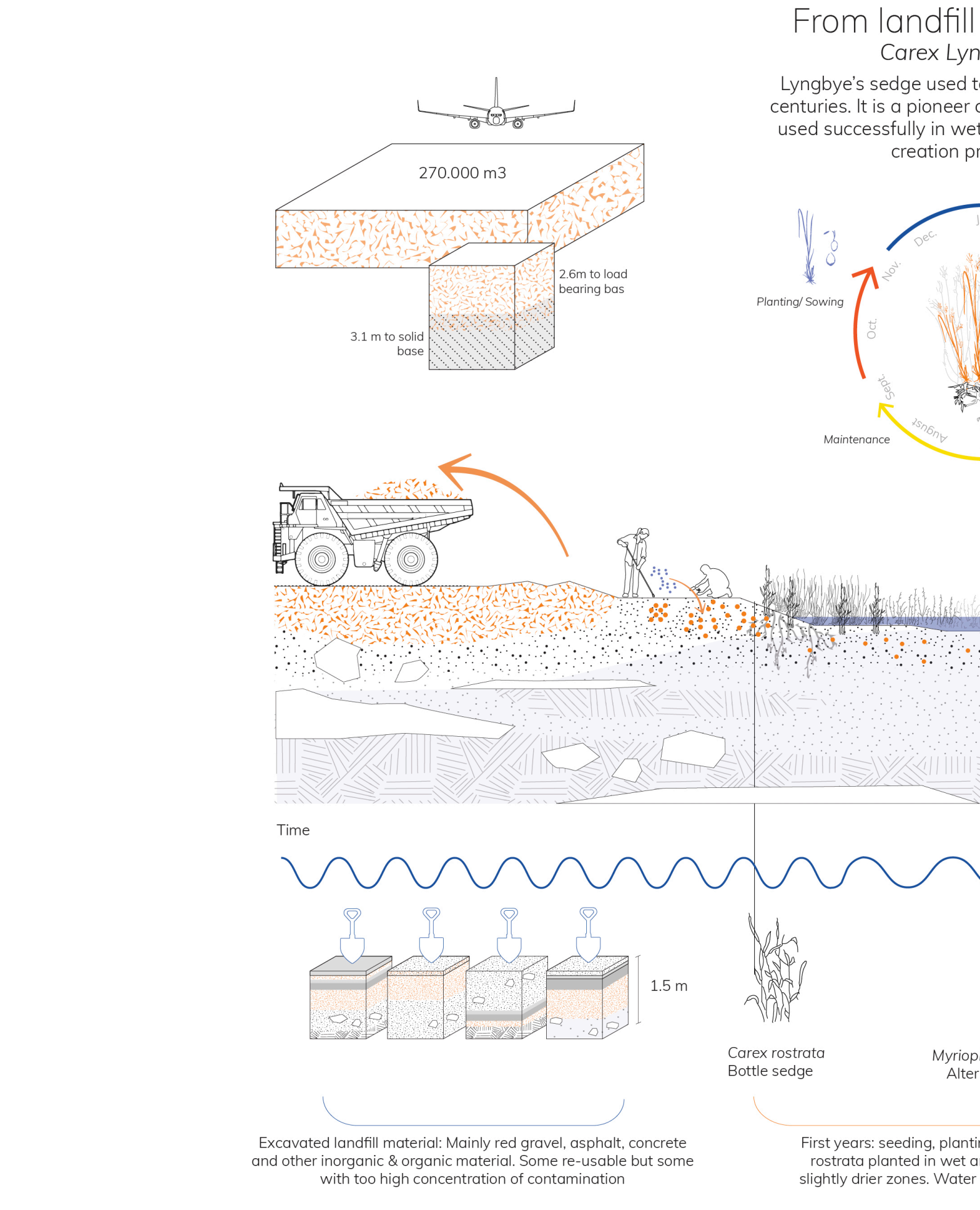
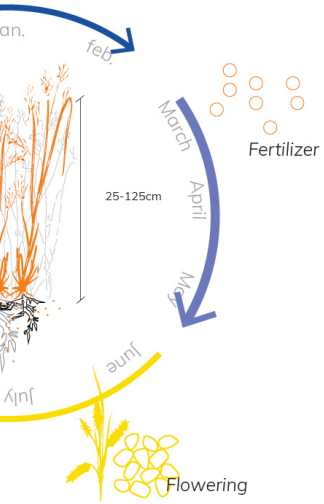


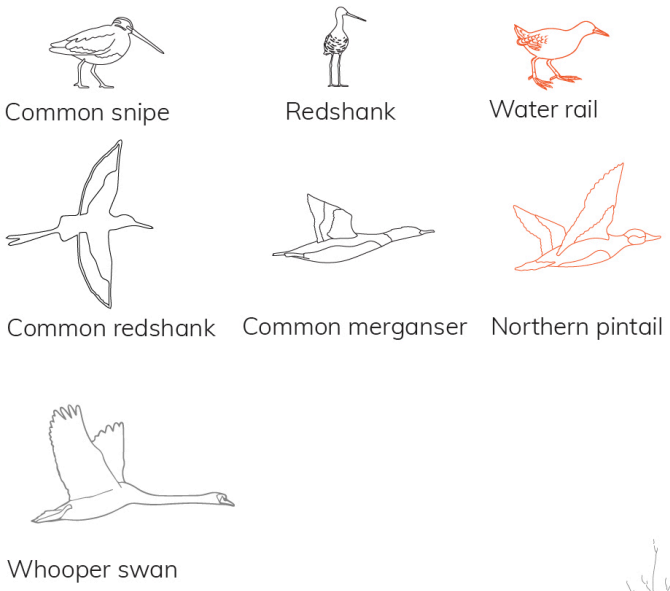
Figure 55: Ecological section of process and time, from landfill to wetland

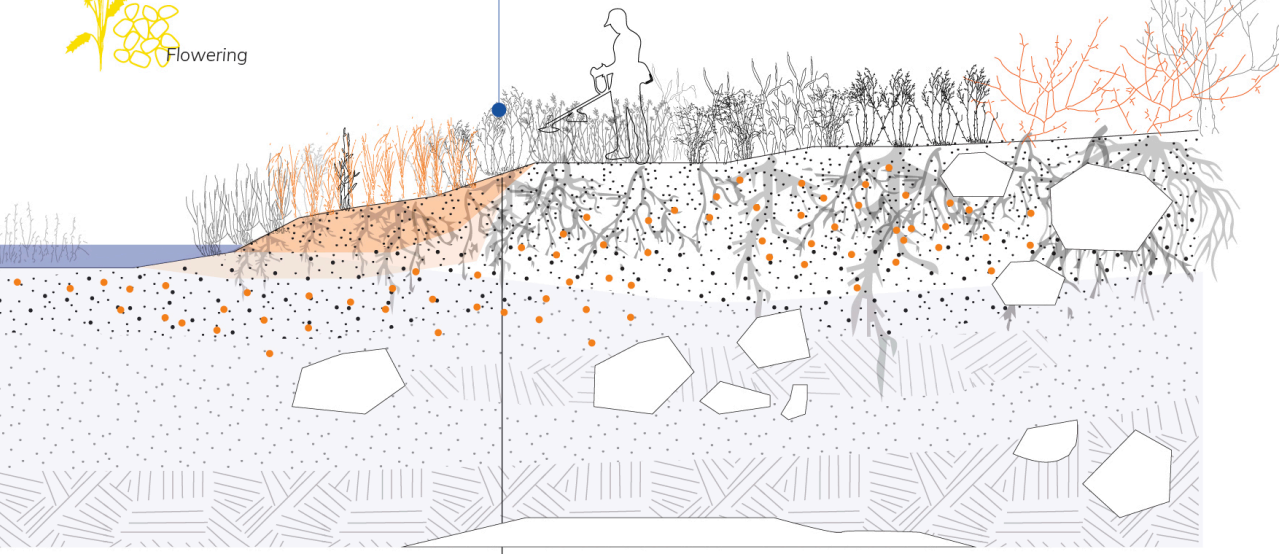
to wetland

gbyei

o grow in the area for colonizer and has been tlands restoration and rograms.







hyllum alterniflorum
nate water-milfoil

Carex Lyngbyei
Lyngbye's sedge.

Deschampsia cespitosa
Tufted hairgrass

Poa pratensis
Smooth Meadow-grass

ng of plugs and the use of fertilizer. Carex reas along banks and Carex Lyngbyei in milfoil eventually emerges in the wetland

5+ years: More sediments & organic matter forms and other species will germinate/spread

4.3 Ecological gradients

The goal of the design is also that the blue-green heart will serve as a green axis throughout the historical center of Reykjavík, connecting the present day disconnected city-parts together with and through landscape by expanding the historical center of Reykjavík across the peninsula into the blue-green network. This new urban ecology alleviates current ecological and water pressure on the existing pond(Tjörnin) and wetland patch(Vatnsmýri) by expanding and improving the hydro-and ecological functions into the blue-green network.

Working in ecological gradients with respect to Icelandic landscape typologies is used as an approach to incorporate nature and native vegetation within the city. Gradients are important landscape features because they provide variation and transition on environmental conditions. These gradients support diverse habitats and species, enhancing biodiversity and ecological resilience and are used as a strategic way to re-establish the connection from the North to Southern coast and from the recreational forest in the west towards the eastern coastline as an integrated part of the blue-green network.

The ecological gradients are used as a tool to increase landscape resiliency from the applied theories which refers to the increased capacity of a landscape to absorb, adapt and recover from disturbances or future changes while still maintaining essential function and identity. Therefore the ecological gradients play a vital role in building landscape resilience by providing essential ecosystem services, supporting biodiversity, mitigating environmental hazards, and enhancing the overall health and functioning of the local ecosystems.

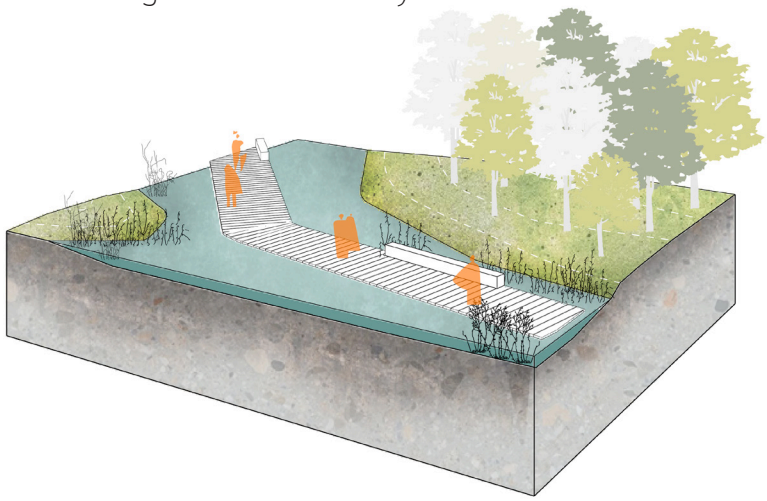


Figure 56: Diagram demonstrating boardwalk through a wetland park

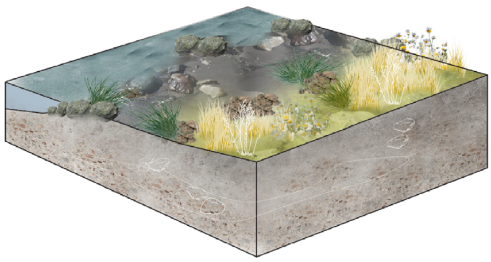
Figure 57: Ecology map of the blue-green network and ecological gradients

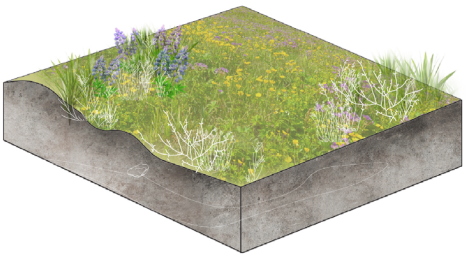
Figure 58: Forest edge in Reykjavík, birch habitat emerging. Photograph takenby author, 2022

Figure 60-65: Egolocigal gradients established to gain a better understanding of local flora and fauna for each landscape typology

Black Tailed Godwit *Limosa limosa*
Common Ringed Plover *Charadrius hiaticula*
Oyster Catcher *Haematopus ostralegus*
Arctic Tern *Sterna paradisaea*

Meadow Pipit *Anthus pratensis*
Common Snipe *Gallinago gallinago.*
Redshank *Tringa totanus*
Grey Goose *Anser anser*
Whooper Swan *Cygnus cygnus*

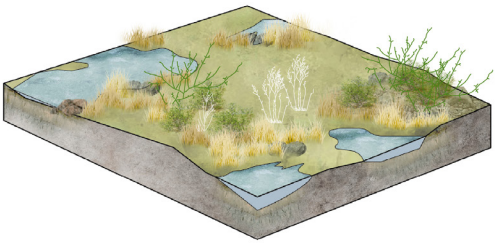




Sea Rocket *Cakile arctica*
Sea Sandwort *Honckenya peploides*
Sea Plantain *Plantago maritima*
Sea Mueweed *Tripleurospermum maritimum*
Sea Bluebles *Mertensia maritima*
Lyme Grass *Leymus arenarius*

Water Avens *Geum rivale*
Woodland Geranium *Geranium sylvaticum*
Meadow Buttercup *Ranunculus acris*
Moorland Spotted Orchid *Dactylorhiza maculata*
Lady's Bedstraw *Galium verum*
Northern Dock *Rumex Longifolius*
Common Dandelion *Taraxacum officinale*
Garden Sorrel *Rumex acetosa*

Figure 59: Native sedges and grasses used as a green roof in Iceland. Photograph takenby author, 2022



Creeping Sedge *Carex chordorrhiza*

Lynbyei's Sedge *Carex lyngbyei*

Beaked Sedge *Carex rostrata*

Black Sedge *Carex nigra*

Cottongrass *Eriophorum angustifolium*

Meadowsweet *Filipendula ulmaria,*

Wild Angelica *Angelica sylvestris*

Northern bilberry *Vaccinium uliginosum*

Moss Campion *Silene acaulis*

Sea Thrift *Armeria maritima*

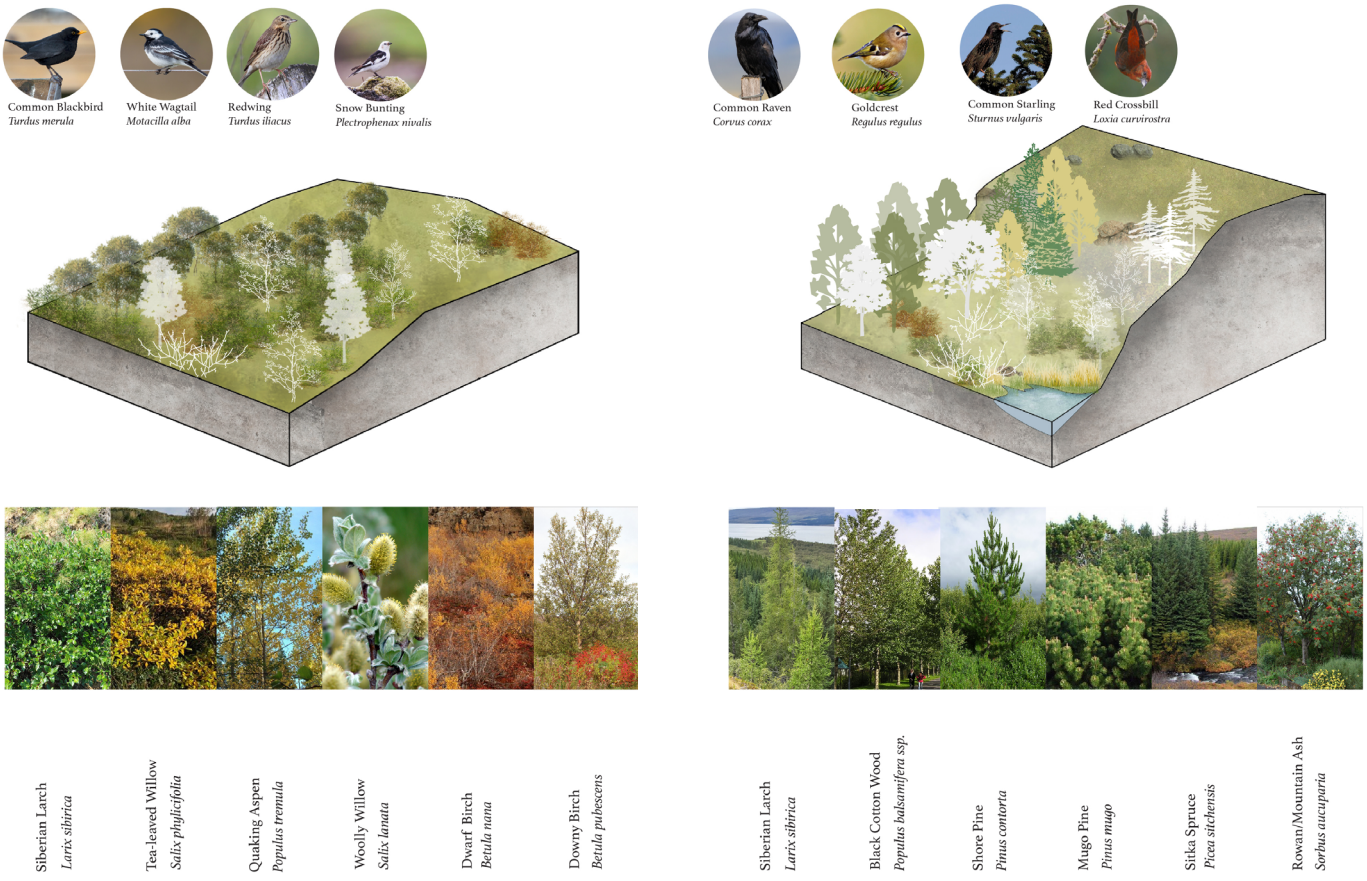
Mother of Thyme *Thymus praecox*

Common Yarrow *Achillea millefolium*

Common Bearberry *Arctostaphylos uva-ursi*

Alpine Blue Grass *Poa alpina*

Figure 66: Evergreen forest edge in Reykjavík, lupin and birch in the foreground. Photograph takenby author, 2022



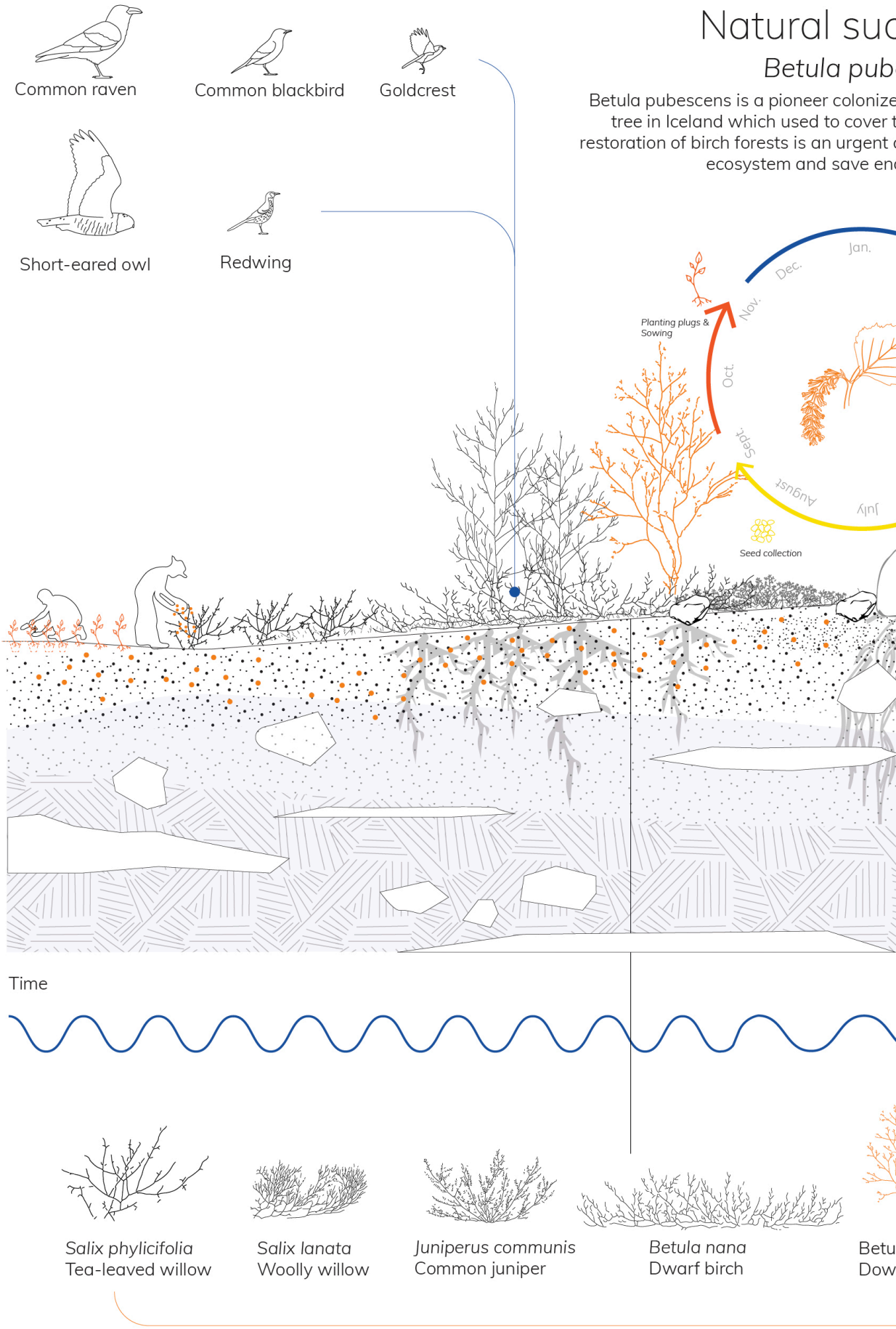


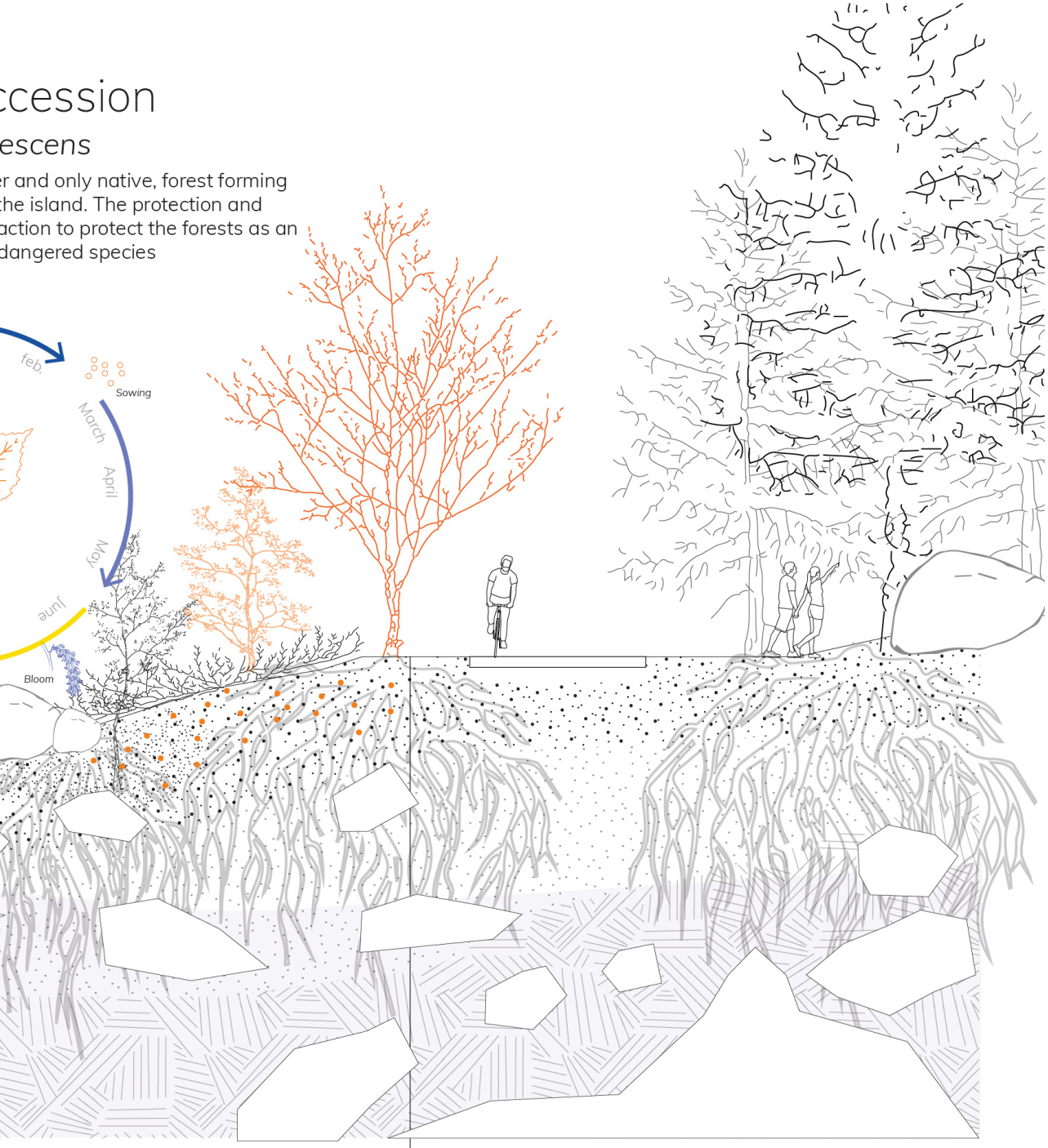
Figure 67: Ecological section of time and process of natural succession

The birch forest ecosystem,
it only takes few years for a birch
forest to start forming

ccession

escens

er and only native, forest forming
the island. The protection and
action to protect the forests as an
dangered species



la pubescens
ny birch

Rowan tree
Sorbus aucuparia

Populus tremula
European aspen

Pinus mugo
Mugo Pine

Larix sibirica
Siberian Larch

Picea sitchensis
Sitka spruce

Other introduced species will emerge and intergrate with the forest

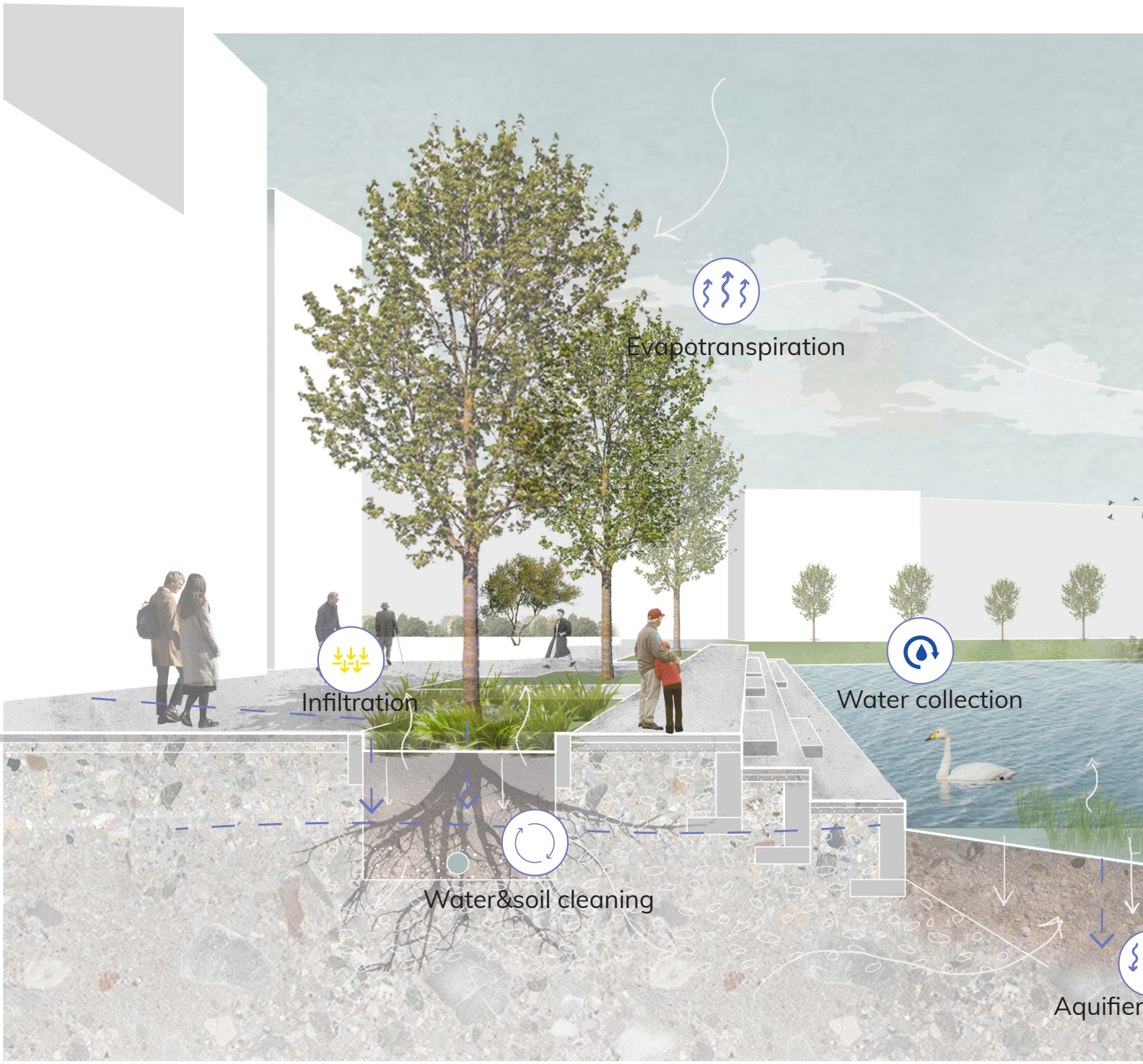
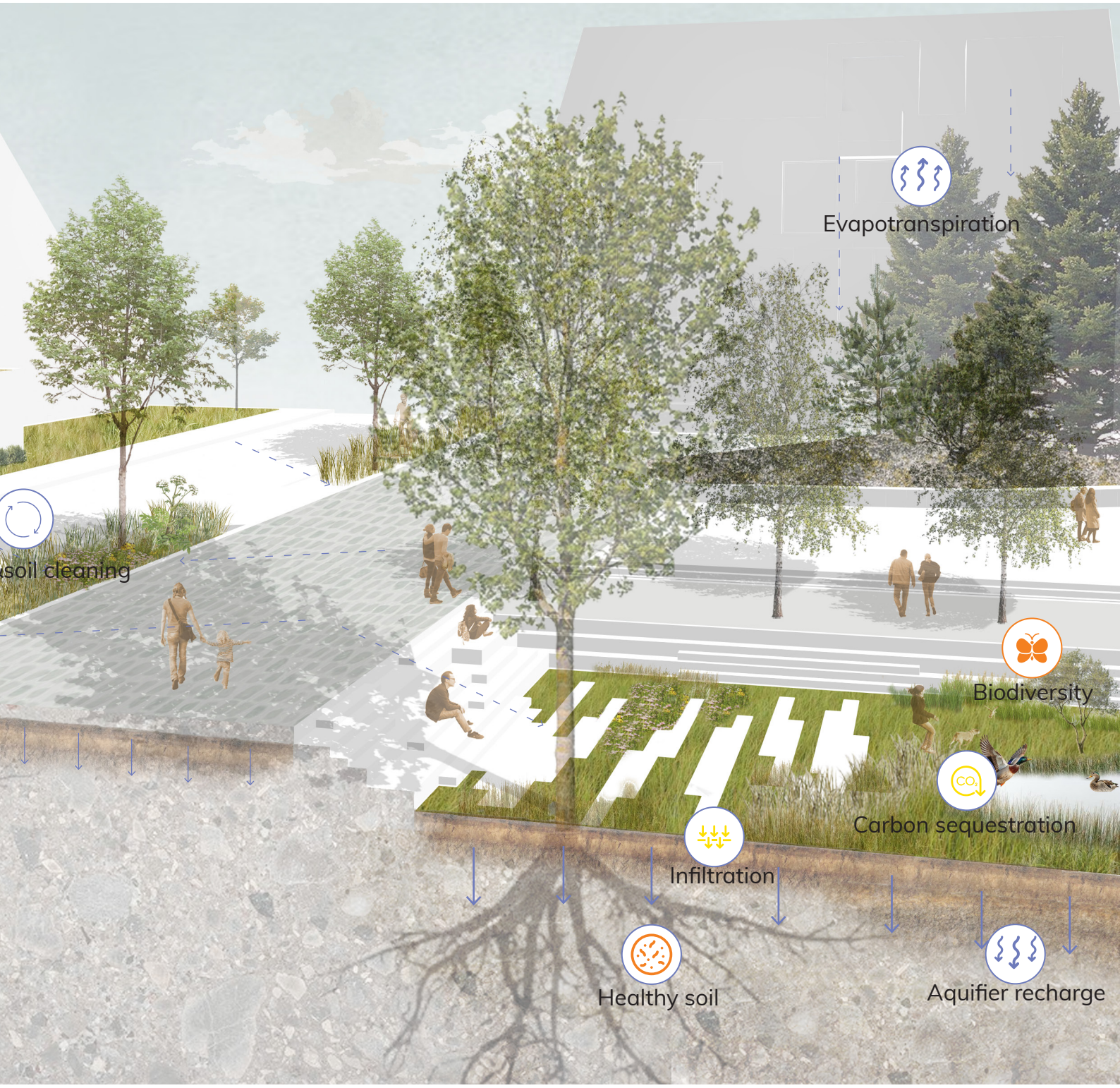


Figure 68: Section of the urban wetland area and the ecological functions


Biodiversity
Carbon sequestration
recharge

Figure 69: Section of different landscape typologies throughout the urban fabric and ecological function


Evapotranspiration
soil cleaning
Biodiversity
Carbon sequestration
Infiltration
Healthy soil
Aquifier recharge

4.4 Urban landscape typologies

Landscape based urbanism is an approach to urban design and planning that emphasizes the logic of the landscape and the integration of its layers of natural systems, ecological processes into the built environment to create more sustainable, resilient and enjoyable cities. This approach recognizes the importance of other landscape elements in the shape of parks, open green spaces, water bodies and other vegetated areas as a fundamental component of urban development where the boundaries between the natural and built environment are blurred.

This Exemplifies a new approach in urban development for Reykjavík where the logic of the landscape provides the foundation for urban development. The goal is to respond to the existing housing needs in the city by increasing single- and multi family housing typologies that are integrated as a final element into the blue-green network. The goal of this urban development is that these typologies resemble the historic style of residential housing in Reykjavík, allowing the character of the historical center to expand further south across the peninsula. A main axis throughout the urban development is established along which the diversity of building typologies increases and the building typologies progress towards a multi-family, mixed-use development along the axis as they get closer to the central wetland park. This approach creates interconnectedness of formerly disconnected city parts with and through landscape and diversity in building typologies. The concept of the urban development plan represented in this thesis was originally inspired by an urban plan made of “Nýi Skerjafjörður” by Ask Architects, an architectural office located in Iceland.

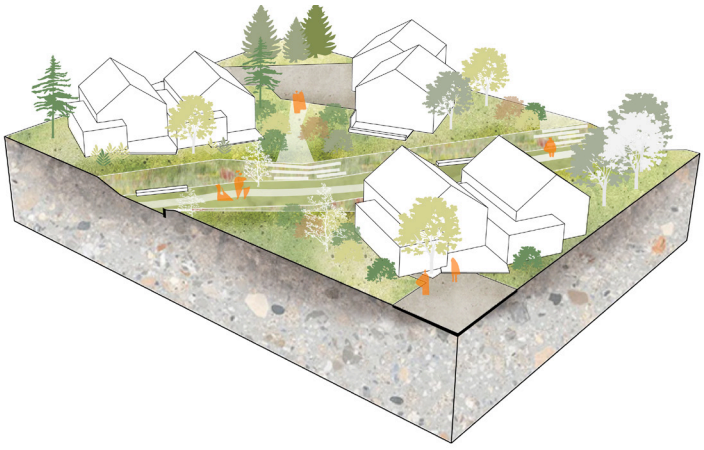


Figure 70: Diagram demonstrating a natural corridor through a residentail area

Figure 71: Urban development map

The new urban landscape typologies are intertwined with the design implementations from the hydrological and ecological aspects where a strong blue-green network is established throughout different types and levels of landscape and urban development. These different typologies are represented in three zoom-in plans derived from the future vision plan. The first plan, zoom-in A, is demonstrating an ecological forest of native birch habitat intercepting a single-family residential area. The location of the area is close to the shoreline, although has slightly higher elevation than the rest of the plan and stable ground underneath.

The second plan developed, Zoom-in B, is the evergreen forest of the hills of Öskjuhlíð stretching itself into the urban fabric and the third plan, Zoom-in C represents the new heart of Reykjavík, where the focal element, the terraced platforms reminiscing the former airport are located, taking advantage of various viewpoints to known landmarks in the city and sloping down into a wetland ecology of native grassess,sedges and bird species that used to predominate in the area for centuries. The location of this new center, the new heart of Reykjavík, improves the connectivity through different city parts experienced through different landscapes.

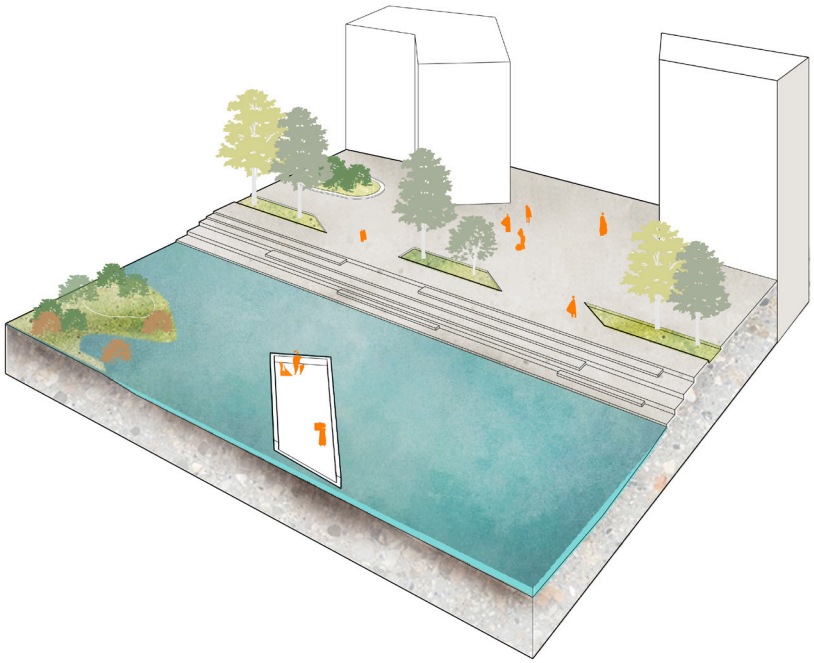


Figure 72: Diagram demonstrating the central wetland area cutting through the focal element of terraced platforms

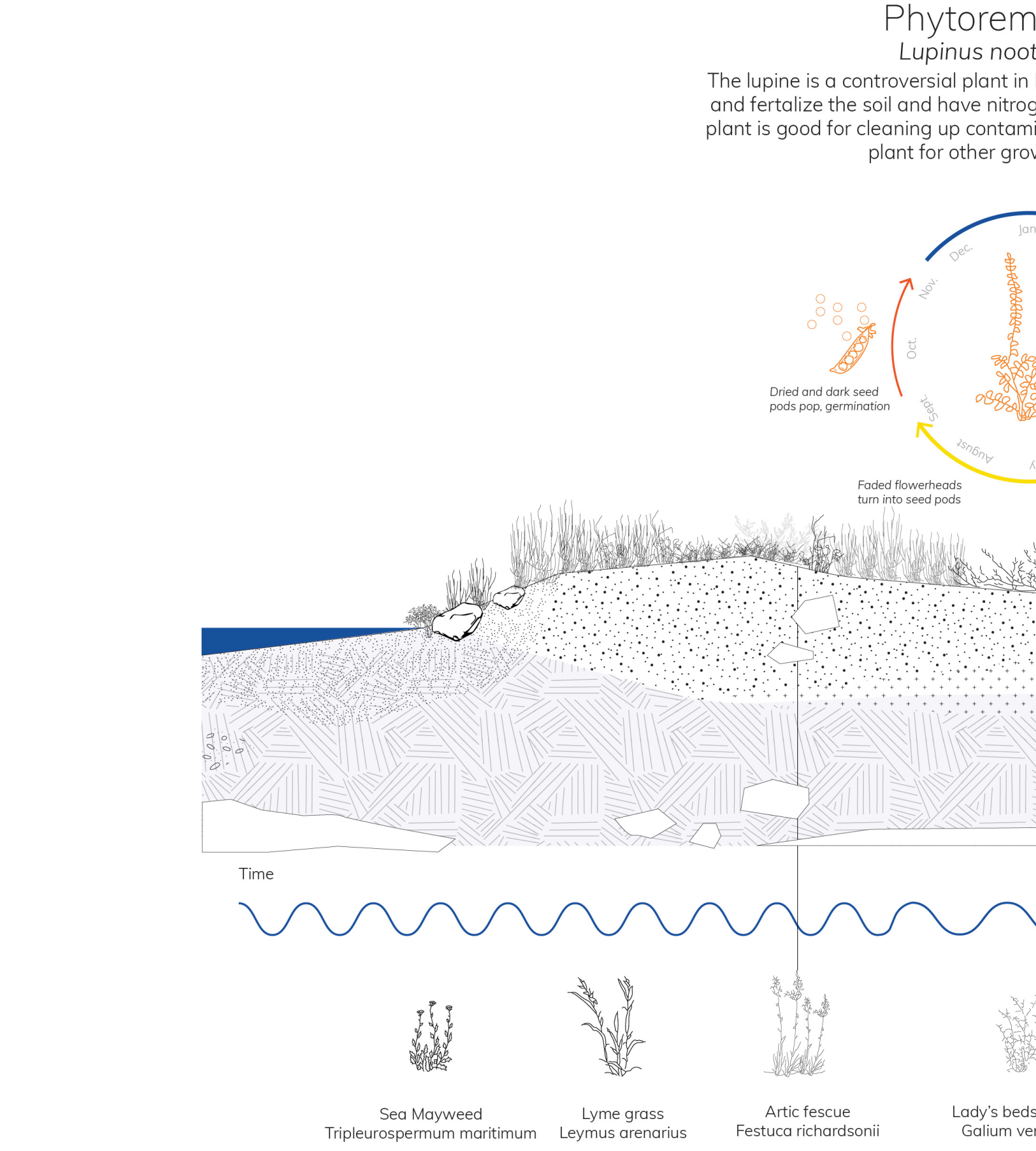


Figure 73: Ecological section of and processes of native vegetation and phytoremediation

ediation

tkatensis

lceland. Its deep roots help to bind
gen binding/fixing cababilities. The
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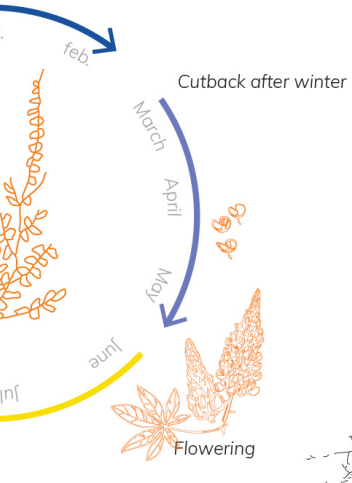
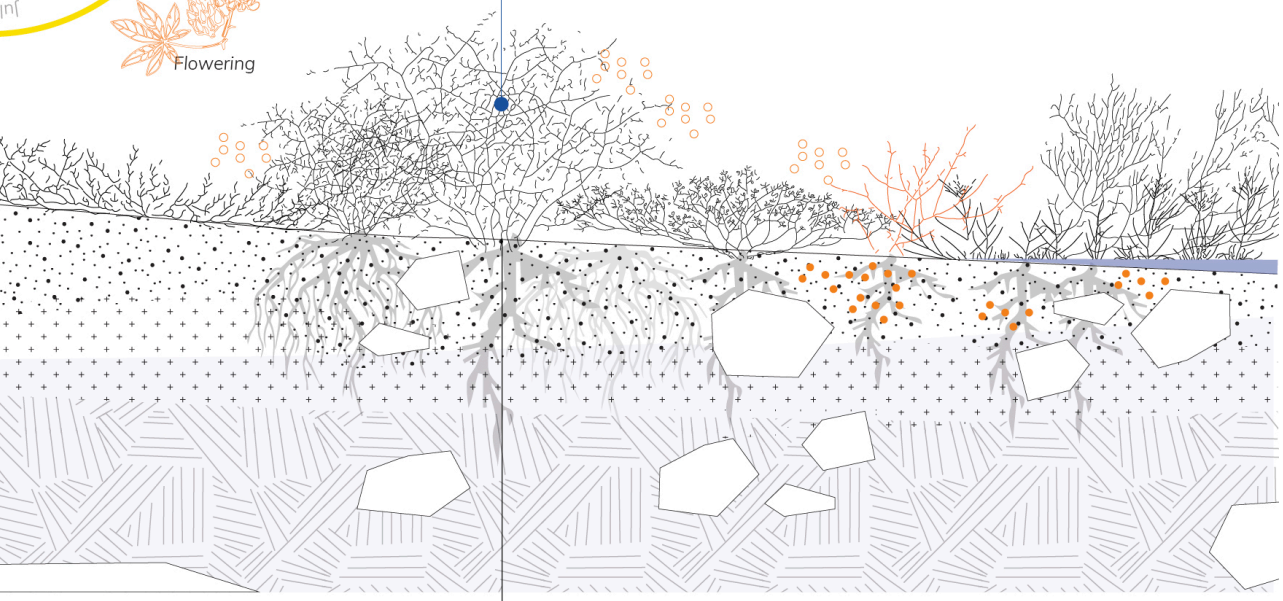
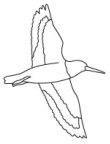
wth to take over.







Oyster catcher

Black-tailed godwit

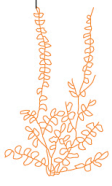
Ringed Plover

Eu. Golden Plover

Whimbrel

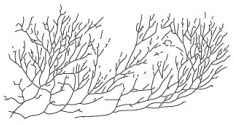
straw
rum

Meadowsweet
Filipendula ulmaria



Alaskan Lupine
Lupinus nootkatensis

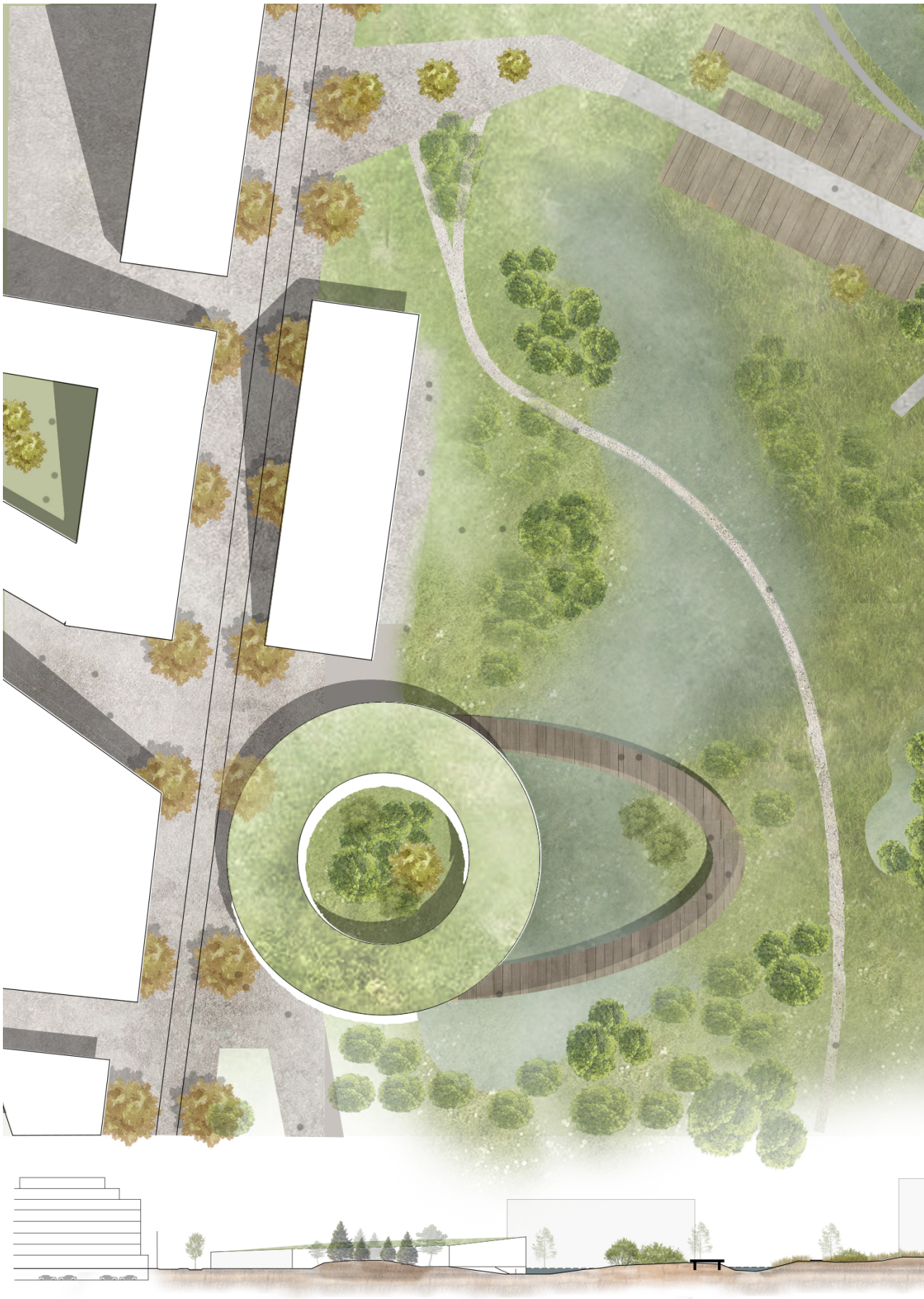
Wild angelica
Angelica sylvestris



Salix lanata
Woolly willow

Figure 74: Zoom in plan A, 1:500. Egological corridor through a residential area providing accessible green space and connections experienced with and through landscape

Figure 75: Zoom in plan B, 1:1000. Urban forest stretching into mixed-use development and multi family housing units



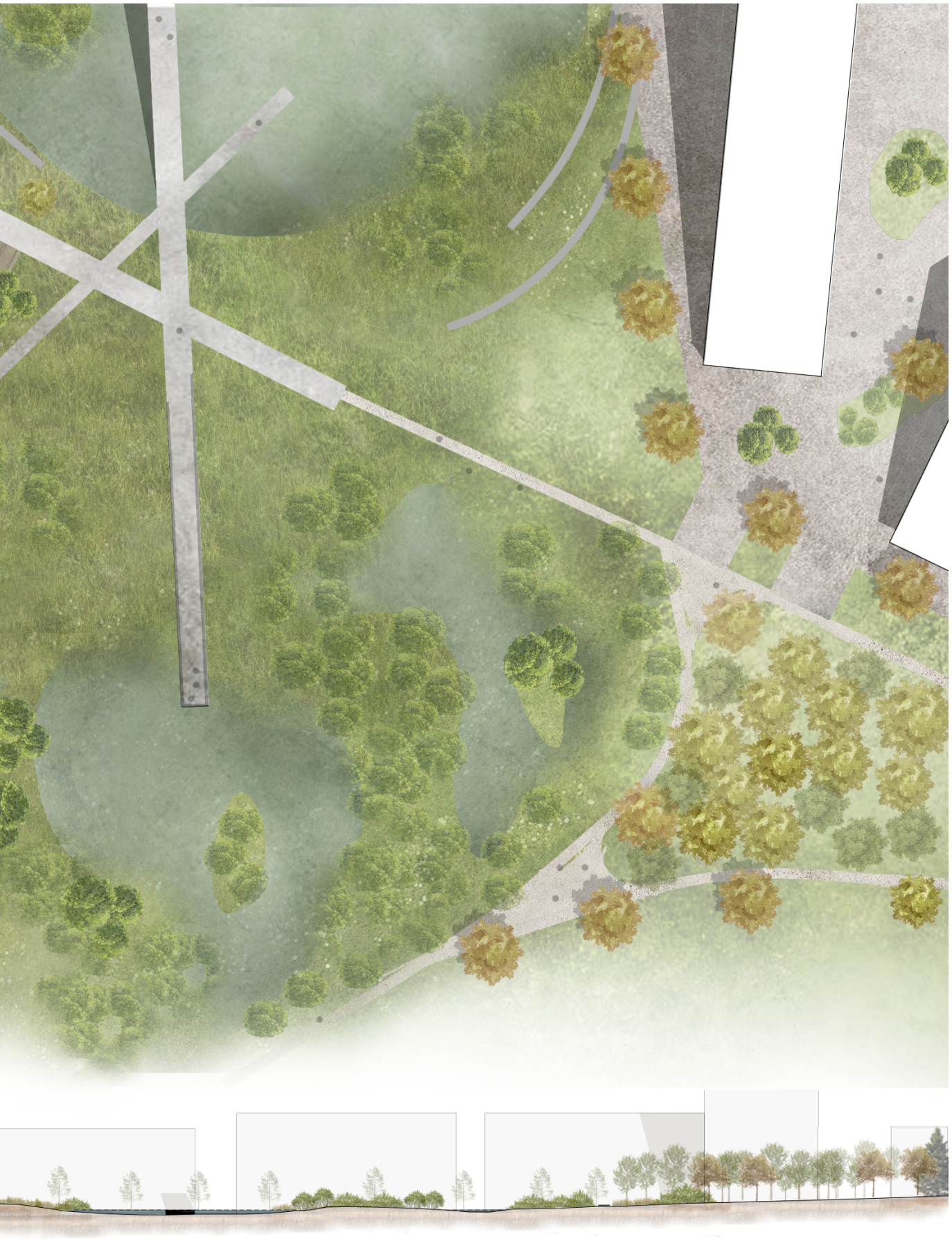


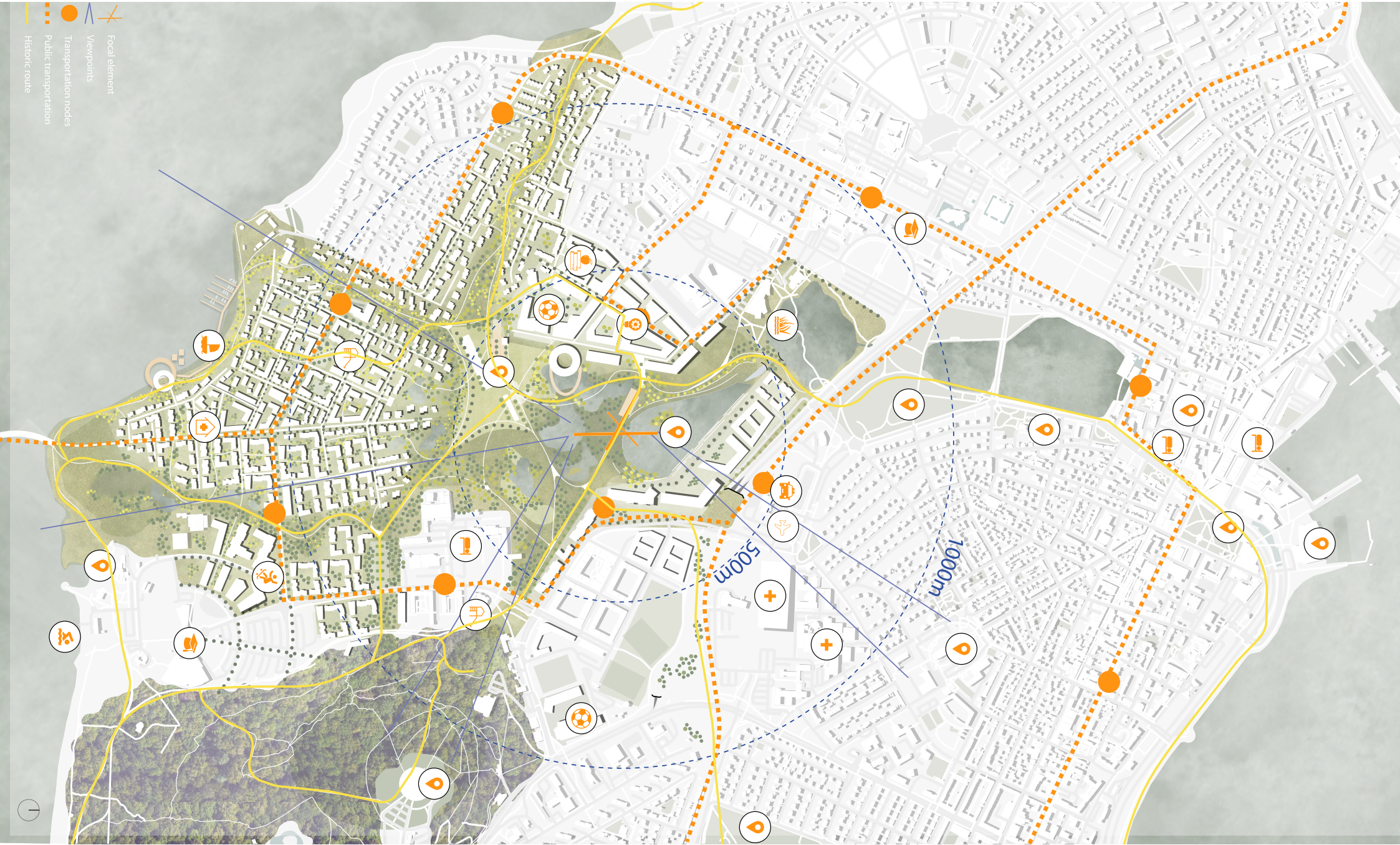
Figure 76: Zoom in plan B, 1:2000. Wetland park, heart of the blue-green network and a central area with focal landscape element, terraced platforms reminiscing the landing strips of the domestic airport

4.5 Blue-green heart of Reykjavík

The design creates a host of new possibilities for Reykjavík's residents and visitors. The network provides gathering space and recreation while improving the overall connection in the city through a historic route embracing the local landscape and its history. A new central wetland area as an extension to the existing wetland patch and urban development area where a focal design element is located, the heart of the blue-green network which is represented with sloping platforms resembling the former airport landing strips, carefully placed to take advantage of the views that the site has to offer over the low lying area in the south and two landmarks in Reykjavík, the church, Hallgrímskirkja and the significant building, Perlan, on top of the hill in the recreational forest of Öskjuhlíð. The heart of the blue-green network is located in proximity to the two universities in the city, a newly constructed hospital and a financial district or innovation hub in Reykjavík, interlinking these elements where culture and nature can continue to thrive and be a part of the historical center of Reykjavík.

The implementation of a blue-green network involves a strategic, multi-step process that highlights water management and green infrastructure to enhance urban resilience and sustainability as the foundational elements. The initial phase focuses on comprehensive planning and assessment, identifying key water bodies, green spaces, and ecological corridors that can be connected and enhanced. This is followed by the design phase, where detailed plans are created to integrate blue-green elements such as wetlands, bioswales, green roofs, and permeable surfaces into the urban fabric. The construction phase is implemented incrementally, starting with pilot projects and critical areas to demonstrate benefits and gather data for optimization. Concurrently, community engagement and education would be prioritized to ensure public support and involvement. The final phase involves continuous monitoring, maintenance, and adaptive management to ensure the blue-green network functions effectively over time, responding to environmental changes and urban growth. This phased approach ensures that the blue-green network is systematically integrated, enhancing urban ecosystems and providing long-term benefits for the city's resilience and livability.

Figure 77: New heart of Reykjavík: focal element, walking distances, connections, historic route and viewpoints



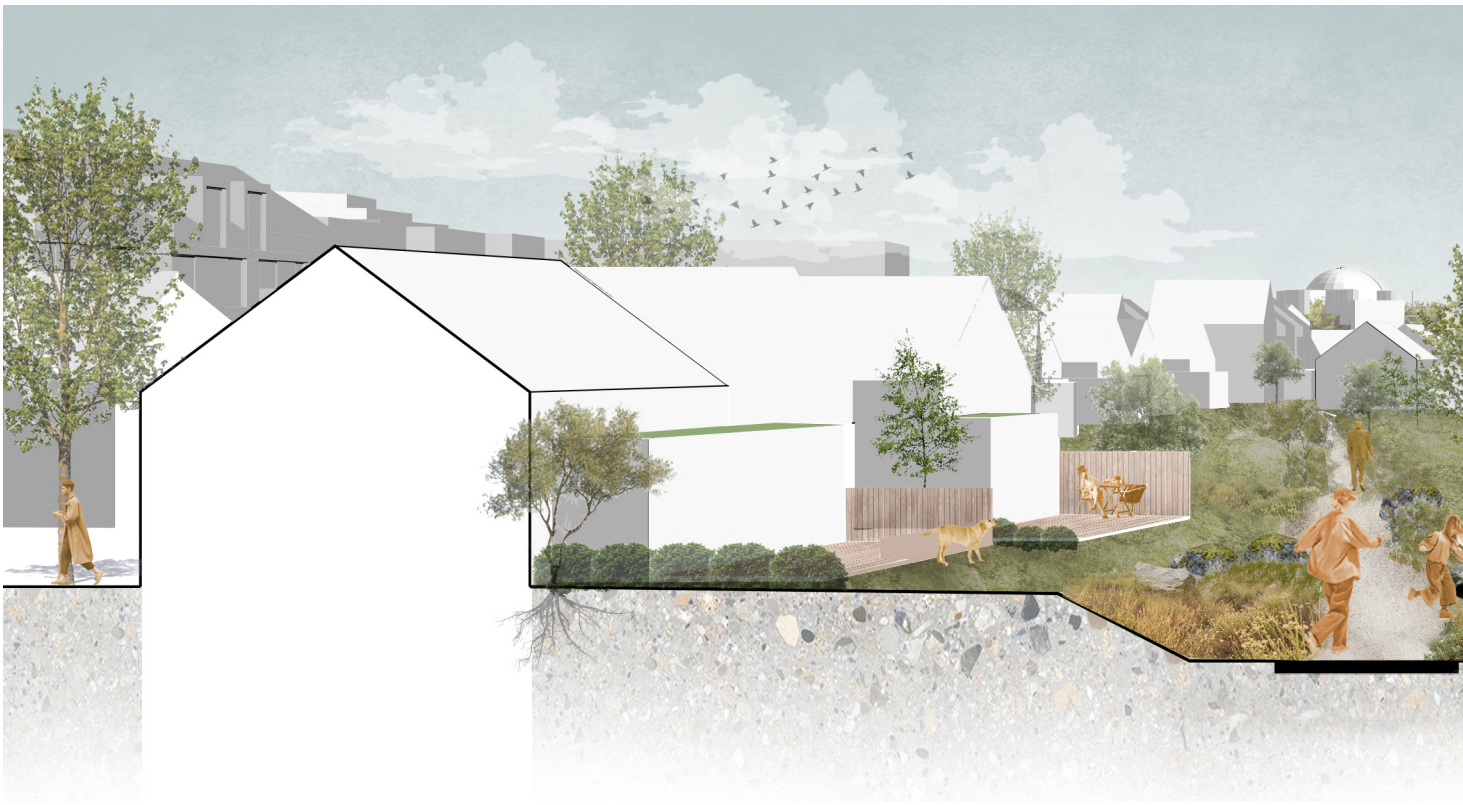


Figure 78: Atmospheric section of an ecological corridor offering views towards Perlan, a landmark building in Reykjavík

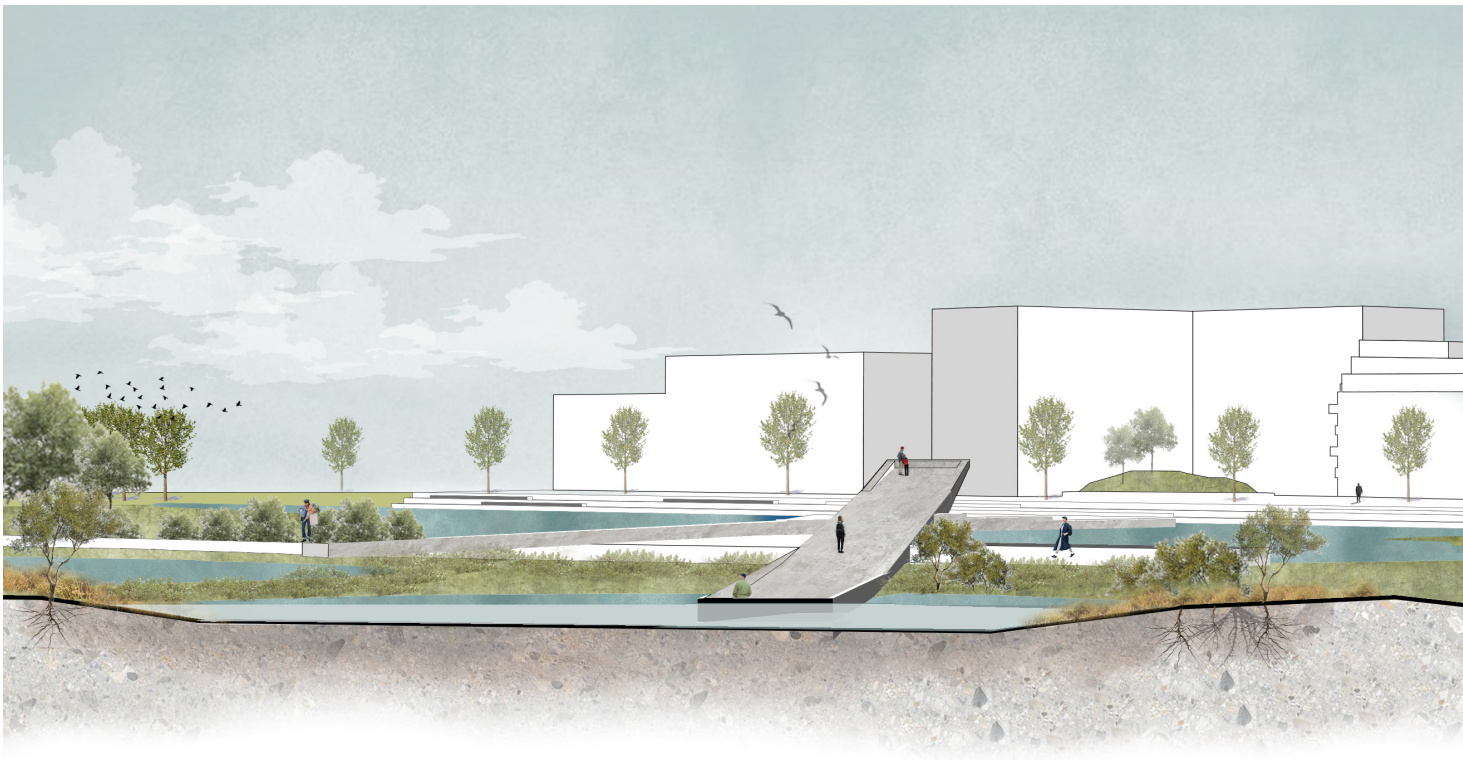
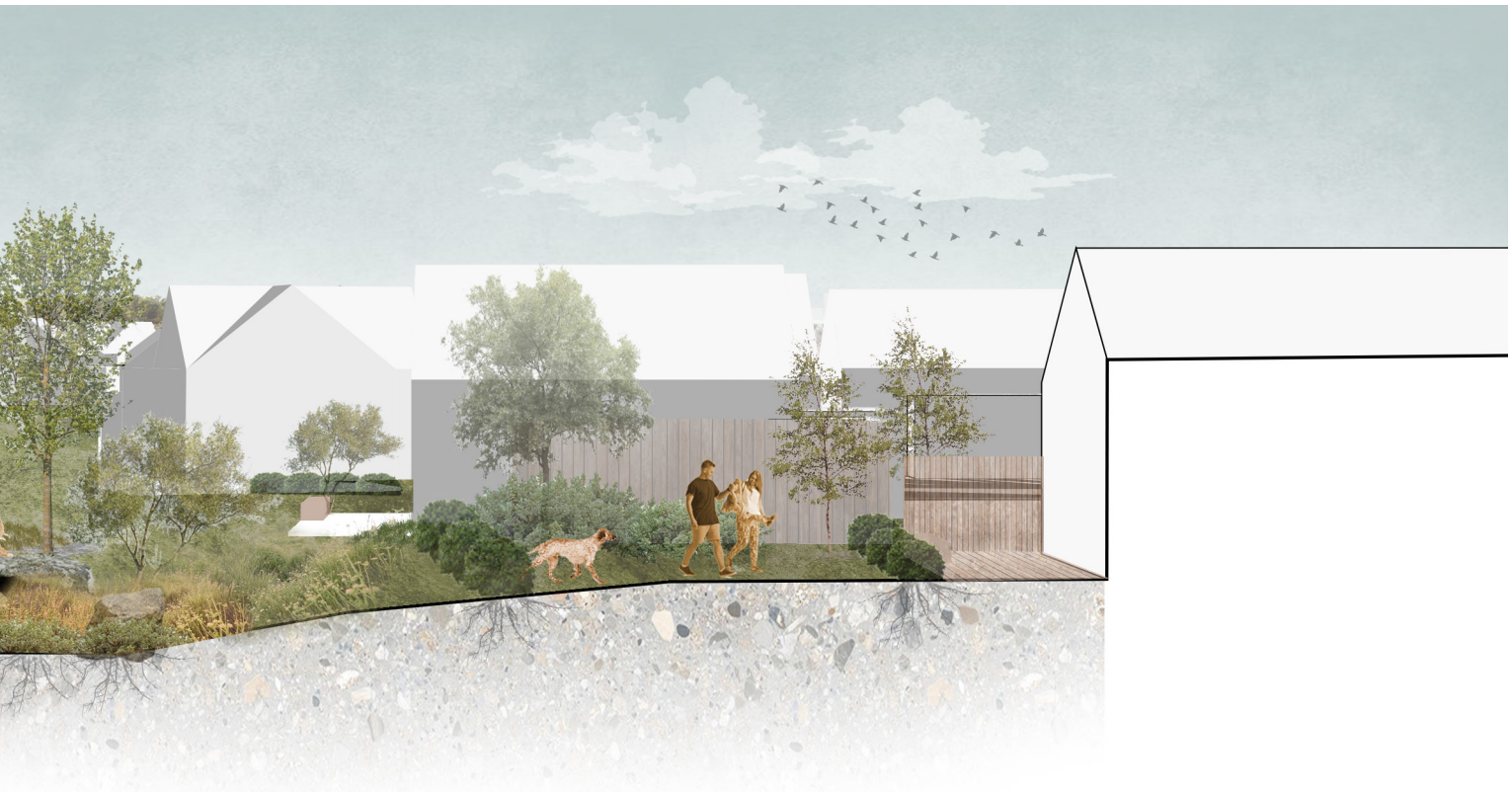


Figure 79: Atmospheric section of central urban and wetland area showing the terraced platforms of the airport



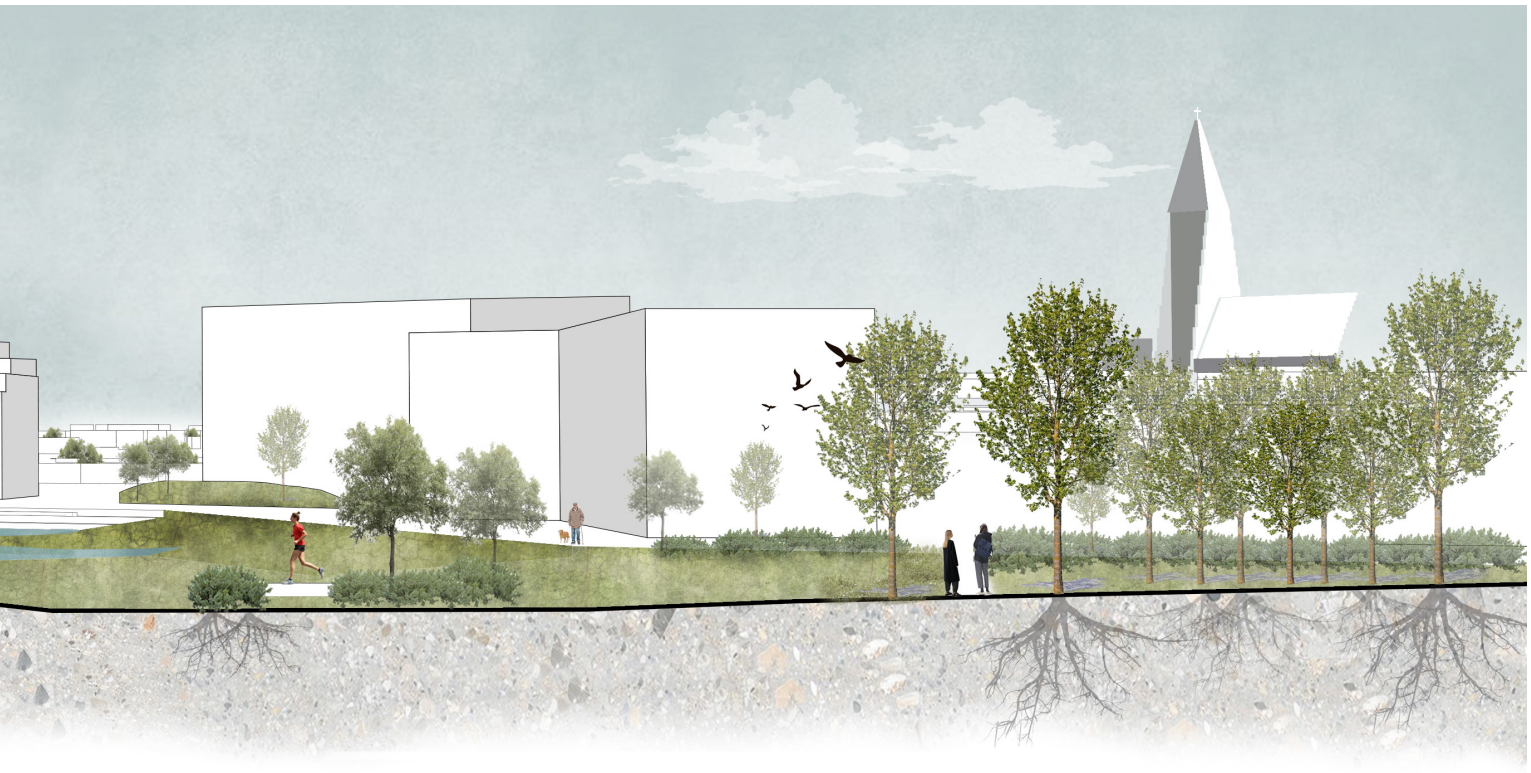


Figure 80: Atmospheric rendering pursuing the spatial and aesthetic qualities of the design

Figure 81: Atmospheric rendering pursuing the spatial and aesthetic qualities of the design

5.0 Synthesis

5.1 Discussion

Throughout this research journey, the primary objective has been to explore the potential of a landscape-based blue-green network to serve as a foundational element for water management, ecological inclusivity, and sustainable urban development in Reykjavík. Guided by this objective, the research questions were formulated to provide a framework for investigating the evolution of Reykjavík's socio-ecological system, understanding the challenges and potentials associated with current dynamics, and exploring how landscape-based approaches can address these challenges effectively and become applicable spatial design.

Delving into the socio-ecological system of Reykjavík, it became apparent how urbanization has affected and shaped the landscape systems, presenting both challenges and opportunities for future interventions. From historical functioning to present-day dynamics, the city has undergone significant transformations, impacting the urban hydrology, ecological health, and overall urban quality.

The investigation further revealed the potential of landscape-based approaches as a crucial tool in addressing these challenges. By leveraging the inherent spatial capabilities of the city and integrating ecological principles into urban design, landscape-based strategies offer innovative solutions for enhancing climate resilience and promoting sustainable development. As the research progressed attention turned to the translation of theoretical concepts and the application of these principles and strategies into spatial landscape architectural design. This phase involved synthesizing theoretical insights of the sponge city principles, principles of nature based solutions influenced by landscape based urbanism and landscape resilience theories with practical considerations to develop design interventions that can effectively integrate water management, urban ecology, and urban development within Reykjavík's landscape context.

Figure 82: Diagram of ecological gradients experienced through different urban typologies

Reflecting on the theoretical framework and the research process that underpins this thesis, it becomes clear how research through design (RTD) guides this thesis. The integration of distinct yet complementary theories, Landscape Resilience and Landscape-Based Urbanism, supported by methodological approaches based on the principles of Nature-Based Solutions and the Sponge-City principles, enriches the approach to creating resilient and sustainable urban landscapes expressed through the spatial design of the blue-green network. Each theory and method contributes a layer of depth to the project, collectively guiding the development of a blue-green network in Reykjavík aimed at enhancing climate resilience. By weaving together these theories and translating their concepts into spatial design the thesis not only formulates a coherent design strategy but also showcases a sophisticated understanding of how diverse theoretical inputs can be harmonized to address specific urban challenges.

The research process started with a combination of researching for the design with a thorough analysis which led on to more research on similar design examples and case studies where existing design principles were derived from. The combination shaped the research phase, research through design (RTD) which allowed me to develop the design concept. After considering the various possible options I was steered towards developing one option further which led me to the creation of the vision plan of the blue-green network. This methodological approach provided me with sufficient research and insights to develop the future vision map for the site. However, it is important to recognize that there is no single correct way to design such a project but this plan demonstrates an option from a landscape point of view with utmost respect to incorporate all aspects.

Urban development requires an interdisciplinary approach, with landscape architecture providing crucial insights into spatial structure, ecological considerations, and water management to create more resilient and sustainable urban landscapes. This thesis demonstrates that by neglecting the use of the landscape as a foundational design element and the utilization of natural resources, such as stormwater, can have significant negative consequences. By integrating landscape architecture into urban development, cities can foster environments that are sustainable, resilient, and enhance the well-being and quality of life for their populations.

Feasibility studies are being conducted on alternative locations for the domestic airport; however, this thesis argues that the current location no longer meets the criteria and needs of modern-day Reykjavík. While filling the wetlands and placing the airport there was once convenient, the city's development and increasing demands has revealed that it is located on valuable land in Reykjavík. It presents significant opportunities for utilizing previously refused resources through water- and ecologically inclusive design and sustainable urban development into more reusable resources to foster resilience and sustainability in the city.

In summary, this research underscores the significance of landscape-based design approaches for increased climate resilience. By establishing a blue-green network as a cornerstone for water management and ecological inclusivity, it lays the groundwork for transformative change that prioritizes the well-being of both human and natural systems within the city. This thesis aligns well with the resilient coastal landscape studio because of the focus on landscape-based design in Reykjavík, a coastal area facing growing challenges from climate change, urbanization, and infrastructure issues. Supported and shaped by theories to develop design concepts and a framework that can adapt to change while maintaining its function, structure, and identity, aiming for a more sustainable future in Reykjavík, Iceland.

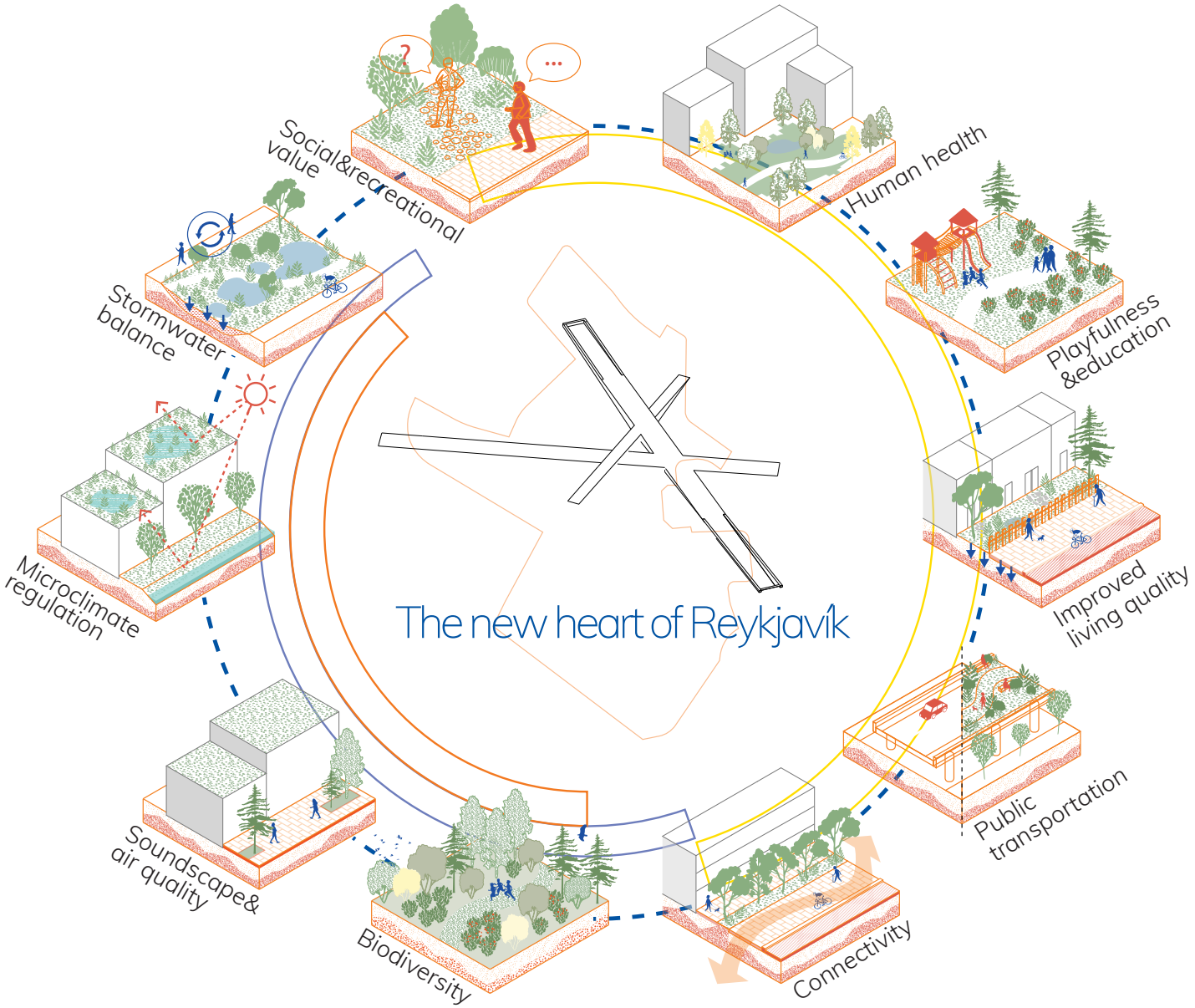


Figure 83: Diagram of the multiple functions of the new heart of Reykjavík; natura, social, cultural

5.2 Conclusion

In conclusion, this research paper has highlighted the significance of adopting a landscape-based approach as a transformative lens for understanding and addressing complex challenges that the city of Reykjavík is facing today. By shifting perspective from a narrow focus on individual, infrastructural components to a holistic view of interconnected systems and ecological processes, new insights and opportunities for sustainable change are unlocked. Important design intervention was to identify, study and develop the ecological gradients of Icelandic flora and fauna along with design implementations of regenerating the local hydrological cycle, which together provides the foundation of the blue green network.

Through case studies, theoretical frameworks, and design applications, landscape-based approaches are embraced to enhance resilience, promote biodiversity, and foster human well-being. As we confront pressing issues such as climate change, urbanization, and ecosystem degradation, the integration of landscape thinking offers a pathway towards more integrated, equitable, and regenerative solutions. By acknowledging the value of landscape properties and embracing their multifunctional capacities, environments can be cultivated that not only sustain life but also inspire creativity, connection, and stewardship. Thus, to continue to embrace the transformative power of landscape-based perspectives, recognizing their potential to shape a more harmonious and resilient relationship between humanity and the natural world.

The development of the blue-green heart of Reykjavík is a well-thought-out strategy that leverages the city's natural and historical assets to create a sustainable urban ecosystem. The detailed focus on regenerating wetlands, establishing ecological gradients and new urban landscape typologies demonstrates a progressive shift towards a landscape-oriented urbanism that respects and enhances the ecological characteristics of the area. The blue-green network that emerged demonstrates how theoretical research can shape practical designs that are innovative yet practical, underscoring the importance of interdisciplinary approaches in urban planning that holistically consider ecological, hydrological, and social factors.

5.3 Outlook

The transition from identifying and detailing the problems of climate change, infrastructure stress and urbanization to proposing a solution by establishing a blue-green network, is thoughtfully developed. Framing the blue-green network not just as a green infrastructure, but as a critical ecological asset for the city of Reykjavík the thesis proposes a paradigm shift from viewing urban development solely through a traditional infrastructural lens to one that integrates ecological and social considerations as the first basis of design. Addressing such complex problems requires a holistic view and deep understanding that encompasses the landscape at its basis, its historical context, and urban development along with current challenges, and future possibilities. The goal to enhance urban resilience through a landscape-based blue-green network is ambitious and illustrates a forward-thinking methodology that could serve as a model not only for Reykjavík but also for other cities facing similar challenges.

Moreover, the integration of a blue-green network in this design strategy is not just an ecological proposal; it is a crucial step towards Reykjavík's ambitious goals of achieving carbon neutrality before 2040. When starting this thesis, the initial focus was on stormwater management in the city of Reykjavík and a thorough study of the existing water infrastructure, a realization occurred that stormwater is currently an underutilized asset that could be transformed into a valuable resource to maintain a healthy urban environment. As the research developed and after some considerations I started looking at the problem from a broader perspective, through an more social-and ecological point of view where I realized that there is an opportunity in Reykjavík's historical center for more than only design interventions for improved water management, but also an opportunity to integrate water management as a part of design strategies for improved urban ecology and overall quality of life in Reykjavík, therefore the blue-green network was established.

Furthermore, the thesis supports the city's aspirations outlined in the municipal plan for the year 2040, which emphasizes sustainable urban development within the existing city boundaries, an increase and improved, accessible green spaces, and better water management for improved urban hydrology. These priorities are vital for improving the quality of life in the city while addressing environmental challenges, therefore, this thesis does not operate in isolation but is a cogent response to future strategies and goals of the city. It seeks to offer practical and innovative solutions to the urgent issues faced by Reykjavík, providing a blueprint for resilient urban landscapes that could serve as a model for other coastal cities globally facing similar challenges. It's a holistic approach, emphasizing the importance of integrating landscape architecture in urbanized areas, that is deeply rooted in ecological sensitivity, resilience theory, and sustainable urban development.

Lastly, this thesis also provides an option for Reykjavík to fulfill the current standard requirements that the European Economic Area, EEA has tightened on wastewater treatment, where separating stormwater from other wastewater could be a crucial factor for such improvements. This marks an interesting time where important decisions need to be made for the future of wastewater treatment in Reykjavík and this thesis projects a forward thinking approach, a landscape-based approach regarding the matter.

Figure 84: Image taken by author overlooking the city from the forest up the hill

6.0 Appendix

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7.0 Images

Figure 2:

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Figure 3:

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