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An urban estuary's transformation: Grønlikaia's "Buffer zone" case study

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Landscape Architecture for Global Sustainability

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Faculty of Landscape and Society
The Norwegian University of Life Sciences

INFORMATION

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An urban estuary's transformation: Grønlikaia's "Buffer zone" case study

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PREFACE

This Masters thesis marks the completion of my Masters degree in Landscape Architecture for Global sustainability.
The 30 ECTS thesis was written for the Institute of Landscape Architecture at the Norwegian University of Life Sciences.

ABSTRACT

Inner Oslofjord is a complex ecosystem in a plight where depletion of natural diversity is ramification of human activity.

This thesis focuses on the area “Buffer zone” in Grønlikaia at the outlet of Alna river to Oslo fjord in Kongshavn nord as a case study area.

Currently, the Alna river’s estuary at Kongshavn nord, is a closed harbor that is not suitable for biodiversity. The challenges in the area at Alna’s outlet are quite intertwined that makes it complicated and extremely vulnerable habitat and onerous for biodiversity.

Fjordbyen is a waterfront development project in the centre of Oslo aimed at freeing up the areas facing the sea for sustainable urban development with recreation, housing and industry in a way that opens the city up to the fjord. Bjørvika is one of the areas in fjordbyen and Grønlikaia is the last major development area in Bjørvika.

Hav Eiendom, in collaboration with the Oslo Havn, invited prequalification for the parallel assignment for the development of the entire Grønlikaia in February 2022. Grønlikaia was devided into five sub-areas. I have chosen to focus on the sub-area ”Buffersonen”.

The objective of this thesis is to explore this urban estuary area focusing on its current ecological state and analyze existing design proposals for the sustainable development of Gronlikaia’s buffer zone in Kongshavn north. The research aims to identify key issues and possibilities for improvements and answer the research question: How can the estuary of Alna river and its surrounding area (Buffersonen) be transformed into a fjord landscape that optimizes the area’s ecosystem and participates in nature restoration at Oslofjord and at the same time contributes to human wellbeing?

In addition, the thesis aims to acquire knowledge about the history and fjord’s ecosystem, estuary and restoration of such ecosystems to Increase biodiversity, facilitate human-nature interaction and enhance the connection between ecosystems in the fjord and on land .

ACKNOWLEDGEMENTS

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PROJECT AREA

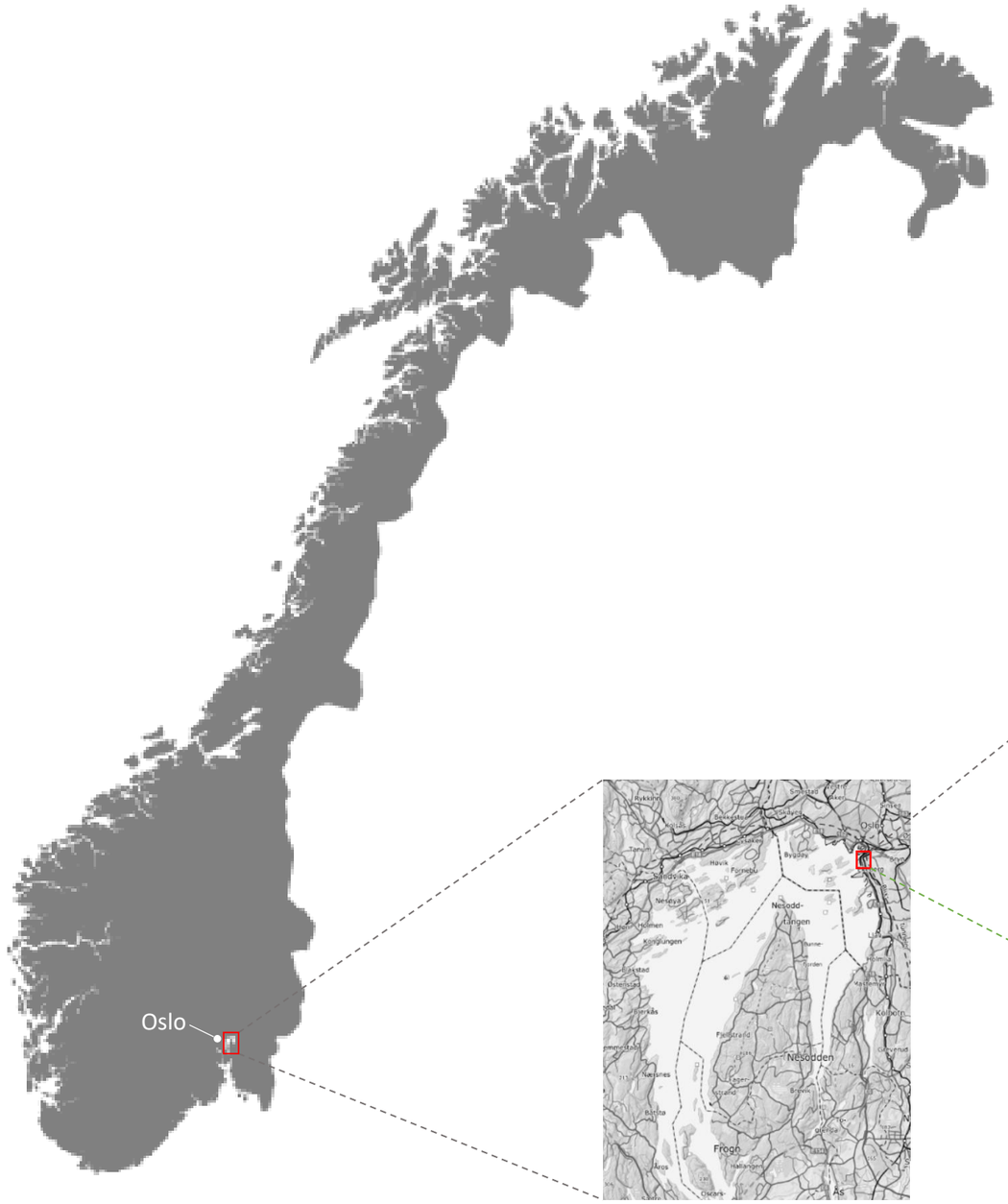

Figure 4. Location of the case area

INTRODUCTION TO THE CASE AREA

The inner Oslofjord is a highly intricate marine ecosystem that has been adversely impacted by anthropogenic activities resulting in the depletion of natural diversity. Industrial emissions, urban run-off, and waste disposal have led to a surge in environmental pollutants on the seabed of the inner Oslofjord. These contaminants include metals from wastewater, microplastics, and environmental toxins such as chemicals from industries and constructions that are transported by water flowing through the city and eventually discharged into the fjord and its seabed. This pollution significantly contributes to the degradation of natural diversity by bringing effluent including nutrients and diminishing the access of sunlight to the seabed which are significant factors contributing to the deterioration of marine life in the inner Oslofjord.

Grønlikaia, a former quay area situated between the green Ekebergskråningen and the Oslofjord, is a relatively unknown location to many people despite being located adjacent to Sørenga. However, Grønlikaia is the next major development area in Bjørvika, with plans to transform the current closed container port into Oslo's new fjord district. The Grønlikaia plan is divided into five sub-areas with different qualities.

The Alna river is part of the area in Grønlikaia which is called "Buffer zone and Kongshavn north".

The challenges in the area at Alna's outlet are quite intertwined, making it complicated and extremely vulnerable habitat and onerous for biodiversity. The mixing of fresh water from Alnaelva with saline water from the fjord has further intensified the ecological burden. Additionally, the alarming pollution level in Alnaelva's water carries extra nutrients from urban waste and sewage into the fjord water, promoting the growth of unwanted species which are taking over the original species in the fjord's ecosystem.

I will investigate the buffer zone area at the outlet of Alna river to Oslo fjord in Kongshavn north , study and analyse the existing design proposals for the area and try to address the abovementioned issues and contribute to the design of a fjord landscape with a holistic approach that optimizes the area's ecosystem and participates in nature restoration at oslo fjord while creating a recreation area for human wellbeing.

Figure 5. Grønlikaia, Photo: Hav Eiendom

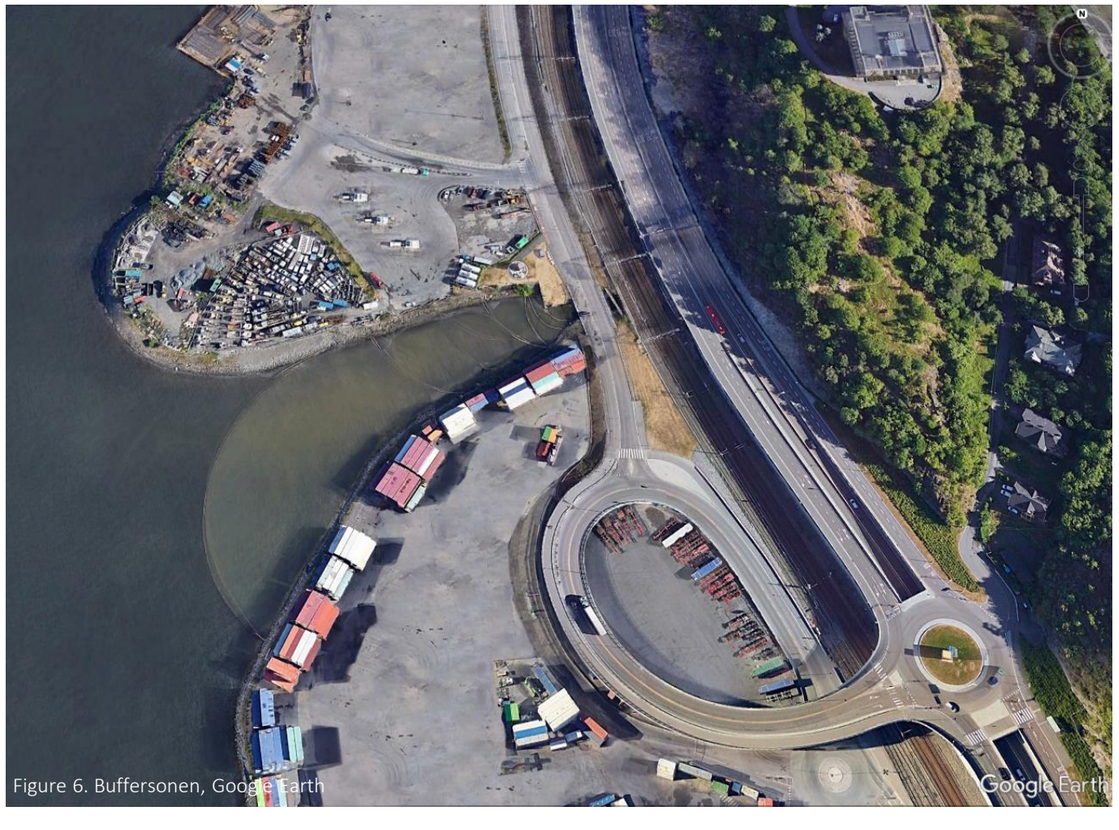

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Figure 7. Buffersonen, 2023

Figure 8. signs in the case area, 2023

ALNAELVAS UTLØP

Alnaelva is Oslo's mother river, but in 1922 it was culverted and flowed out here. Closing rivers and streams was common in Oslo until the 1980s as a measure to reduce the stench from wate water and make areas available for industry, roads and homes.

Sources of Pollution

Pollution in Alna is a fact. The challenges along Alna include runoff from dense surfaces, roads, car workshops, washrooms, oil tanks, horse farms, golf courses, sports facilities and also diffuse emissions and point emissions from waste water, small industry, waste landfills and contaminated land.

Pollution damages biological diversity in the river and affects life in the Oslofjord. Oslo municipality has plans and strategies that will contribute to the improvement of the Alnaelva, but this is a comprehensive task that requires a lot of effort from politicians and voters in order to be realised.

Figure 9. Buffersonen, 2023

Figure 10. Buffersonen, 2023

SCOPE

- **Geographical**

The case area is Grønlikaia's buffer zone located at the outlet of Alna river to Oslo fjord in Kongshavn north.

- **Thesis definition**

This thesis studies the urban estuary at the outlet of Alna river to Oslofjord in Kongshavn north focusing on its current ecological status, and looks into the design proposals for development of Grønlikaia's sub-area "Buffer zone" offered by three teams chosen by Hav Eiendom and Oslo Havn (team Asplan Viak, team Norconsult & team Aart) and studies and analyzes them to identify key issues and possibilities for improvements in order to transform this landscape into a fjord landscape that optimizes the area's ecosystem and participates in nature restoration at Oslofjord which also helps human wellbeing with focus on ecology and biodiversity.

RESEARCH QUESTION

How can the estuary of Alna river and its surrounding area (Buffersonen) be transformed into a fjord landscape that optimizes the area's ecosystem and participates in nature restoration at Oslofjord and at the same time contributes to human wellbeing?

- **Goal**

The goal of this master thesis is to study and analyse the site and existing design proposals for development of Grønlikaia's buffer zone at the outlet of Alnaelva to Oslofjord in Kongshavn nord in order to identify main issues and contribute to the design of a fjord landscape with a holistic approach that optimizes the area's ecosystem and participates in nature restoration at Oslo fjord while also creating a recreation area for human wellbeing.

- **Sub-Goal**

Acquire knowledge about the history of the area and Alna river, fjord's ecosystem, estuary and restoration of such ecosystems.

METHODOLOGY

The methodology of this thesis is based on literature review, document study, historical study and site survey.

The **literature review** provides theoretical information about marine ecosystems, estuaries, species in the area and sustainability.

A **document study** of existing guidelines and ongoing plans, feasibility studies and design proposals for the area was done to get an overall understanding of ongoing plans.

Historical maps, documents and photographs were reviewed. They contributed with valuable insights into how the areas had changed overtime and how it used to be when it was not as affected by human activities.

Site surveys were conducted to observe the atmosphere in the case area, seasonal conditions, users and access, non-human interactions, and local flora and fauna.

THESIS STRUCTURE

Introduction: This chapter presents an introduction to the project area, scope, research question, methodology and structure.

Background: This chapter puts the thesis in a local, regional and global context. Presenting current information on the applicable international, national, regional and local guidelines.

Theory: This chapter covers the literature review within marine ecology and estuary ecosystems which forms the basis of my knowledge.

Case Area: This chapter presents my analysis of the case area and its current status and provides important knowledge of local conditions and historical context.

Design Proposals: This chapter gives an overview of current design proposals for the case area and presents my analysis, comments and contribution for possible improvements.

Conclusion: This chapter presents the conclusion of the thesis and suggestions for further work.

Figure 11. Buffersonen, 2023

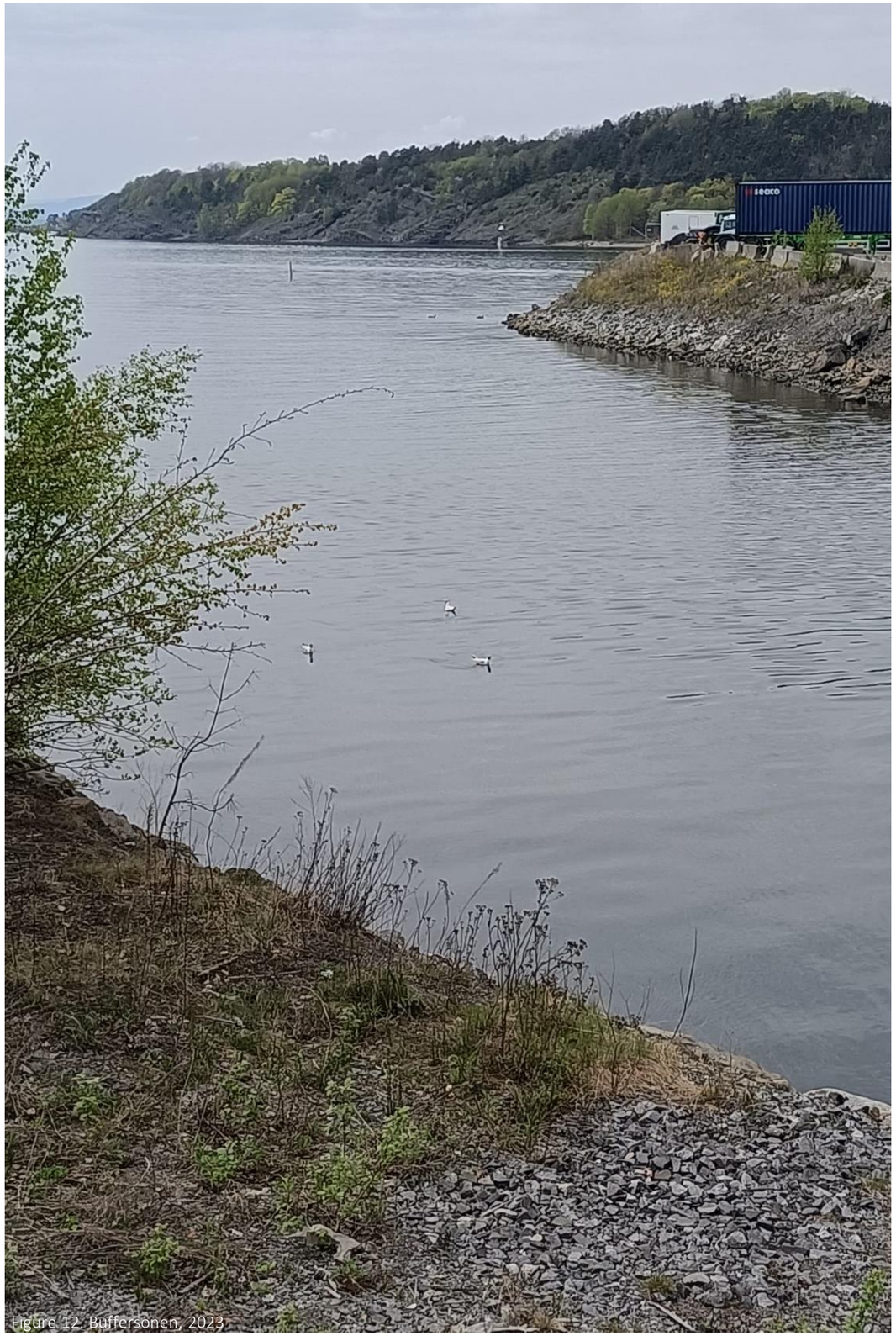


Figure 12. Buffersonen, 2023

02. BACKGROUND

Introduction

Climate change

Urbanization and loss of biodiversity

International and national guidelines

Fjordbyen

Grønlikaia

INTRODUCTION

The impacts of human activities on the Earth's system have been profound and far-reaching (Steffen et al., 2006).

The Oslofjord that is located in the south-eastern part of Norway and is the country's most populous area has suffered from pollution during the 20th century.

The Oslo fjord is divided into two parts: the Inner Oslo fjord and the Outer Oslo fjord. The Inner Oslo fjord stretches north from Drøbaksundet towards Oslo city, and further wraps around the peninsula of Nesodden towards Bunnefjord. At the narrowest point of the fjord, the Drøbak Sound connects the inner Oslofjord and outer Oslofjord. This narrow (1600m) and shallow (19.5m) sound limits the water exchange between the inner and outer Oslofjord (Staalstrøm et al., 2012).

Urbanization, land-use changes, and climate change have resulted in ecological challenges in Oslo fjord. Large areas of the fjord have a bad chemical status and a moderate ecological conditions (Miljødirektoratet, 2019). During the 20th and 21st centuries, several action plans have been produced to enhance the fjord's status, but the situation is still not optimal.

The United Nation's Decade on Ecosystem Restoration 2021-2030

The UN Decade on Ecosystem Restoration aims to prevent, halt and reverse the degradation of ecosystems on a global scale. Healthy ecosystems are important for reversing the climate disaster, increasing the security of food and water supply, and biodiversity. The element of biodiversity is primarily the emphasis of this thesis. Restoring nature is important for biodiversity and also for climate change. Healthy ecosystems are essential for life on Earth and Ocean, and coastal ecosystems are crucial. (United Nations Environment Programme, 2021)

CLIMATE CHANGE

Climate change is impacting sea temperatures. This results in storm surge, sea level rise and changes of ecosystems below water. Marine ecosystems purify water and are important during storm events as they mitigate the energy of the storms. They are also important in controlling sediments and filtering nutrients.

Climate change engenders more and intense rainfalls, soaring temperatures and surging sea levels. Since 1985, the average air temperature in Oslo has been warmer than normal, and the trend is on an upswing. The precipitation patterns have also undergone a marked shift towards heavier downpours, especially since the turn of the century.

Increased temperatures and more rain impact the physical conditions in the Oslofjord. Winters have become warmer and rainier, which increases the volume of drainage. Intense and heavy rain triggers flooding, which, in turn, affects the circulation of the fjord . (Arvnes, 2019)

As climate change ushers in a warmer climate, the risk of invasive species rises, as they find new habitats further north. The pacific oyster is a local example of this. Hence, it becomes imperative to create robust ecosystems with local vegetation.

URBANISATION AND LOSS OF BIODIVERSITY

Today, the built infrastructure is expanding at the quickest rate in history (Zu Ermgassen et al., 2019) and ecosystems are negatively impacted by human activity. As a result, extreme biodiversity loss is connected to widespread urbanization (Living Planet report, 2020). Natural habitat fragmentation, which reduces habitat size and quality, is directly linked to human impacts on land use, such as, agriculture, infrastructure and urbanization.

The population of the Oslo-region is rapidly expanding. In 2050, there will be two million people living in the fjord's vicinity, according to estimates. (Arvnes, 2019). This results in more pressure both on the fjord itself and on areas connected to the fjord.

The Oslofjord area has most inhabitants and the most species in all of Norway. However, biodiversity is threatened by a variety of factors, including change in land use, pollution, climatic changes, and invasive species. There is now less public access to the beach zone due to increased development and construction (Klima- og miljødepartementet).

Large industrial and agricultural sectors discharge to the fjord, which increases the amount of nutrients in the sea water(Arvnes, 2019). This means a higher risk of ecosystem disruption and contamination. In addition, due to black water, seaweed and algae receive less light, which significantly impacts their habitats negatively.

The most important factors limiting biological diversity in the inner Oslofjord are terrain and growth surface characteristics, light access into the water-masses, nutrients, oxygen and environmental toxins.

The Oslo fjord region has the highest number of endangered species in the country (Arvnes 2019). 90% of Norway's endangered species are threatened by various sorts of land use changes, including deforestation, demolition, degradation and cultivation. Fisheries, shipping, industry, and marine litter are additional variables that have a detrimental effect on biodiversity and habitats. As a result, ecosystems change and are destroyed, biological diversity is diminished, and vulnerable species are put under more stress. (Norwegian environment agency, 2020)

INTERNATIONAL GUIDELINES

Figure 13. UN sustainable development goals

• UN sustainable development goals:

The United Nations Sustainable Development Goals encompass an assemblage of 17 global targets devised to expedite the realization of a more sustainable future for all. They address an array of exigent global challenges, including poverty, inequality, climate change, environmental degradation, justice and peace. These guidelines developed in 2015, recognize that the elimination of poverty and other forms of deprivations must be combined with strategies that bolster health and education, reduce inequalities, and galvanize economic growth, all while tackling climate change and working to preserve our oceans and forests in order to foster healthy living and well-being (United Nations, n.d).

• European Landscape Convention

The European Landscape Convention of the Council of Europe is the first international accord dedicated exclusively to addressing all aspects of the European landscape(Council of Europe, n.d).
Its objective is to achieve harmony between economic activities, social needs and environmental considerations, while taking into account the cultural aspects of the landscape.

• New European Bauhaus:

The New European Bauhaus is an interdisciplinary and creative initiative that links the European green deal to our living spaces and experiences. It encourages everyone to work together to envision and create a future that is pleasing to our eyes, brains, and souls, one that is both sustainable and inclusive. Places, practices, and experiences that are:
•**Enriching,** influenced by art and culture, responding to requirements beyond functionality.
•**Sustainable**, in harmony with the environment, nature, and the earth.
•**Inclusive**, promoting conversation amongst people of different ages, genders, and cultures (European Union, n.d).

NATIONAL GUIDELINES

• The Public Health Act (2011)

The Public Health Act seeks to promote equal public health through social development. The municipalities are in charge of advancing public health by providing an overview of local trends and public health issues. Gaining an overview of available recreational activities, their absence, and the environmentally friendly mobility of cyclists and pedestrians. Therefore, municipalities efforts to promote public health should include planning for green structures (The Public Health Act, 2011).

• The Nature diversity Act 2009

The purpose of the Act aims to safeguard the diversity of biological, geological, and landscape entities, alongside their intricate ecological processes, by means of conservation and sustainable use, ensuring that the environment provides a basis for human activity, culture, health, and general well-being, not only in the present but also in the future, including a basis for Sami culture(Nature diversity Act, 2009)

• Planning and building Act 2008

Section 1-8 Projects, etc., are prohibited along the river system and coastline. Special attention must be paid to the natural and cultural environment, landscape, outdoor recreation, and other features of public interest within the 100-meter zone along the seashore and river systems.

• Outdoor recreational act 1957

This Act aims to protect the natural foundation for outdoor leisure, and to defend the public's right of access to and travel through the countryside, as well as the right to spend time there, etc, to ensure that the availability of outdoor recreation possibilities as a leisure activity that is healthy, environmentally responsible, and promotes wellbeing is preserved and increased. (The Outdoor Recreation Act, 1957).

FJORDBYEN

Fjordbyen, a large-scale urban development project in Oslo, seeks to open up the city to the fjord by freeing up existing sea-facing areas for housing, recreation, and industry. The project spans almost 10 kilometers of coastline from Kongshavn in the southeast to Frognerkilen in the west and is divided into ten development areas. These areas include Sydhavna, Grønlia, Bjørvika, Vippetangen, Akershusstranda, Rådhusplassen, Aker brygge, Tjuvholmen, Filipstad and Frognerstranda. (Oslo kommune, n.d)

The concept of Fjordbyen emerged in January 2000 when the Oslo City Council resolved to integrate the city with the fjord by releasing former port areas for urban development. The goal is to create attractive public spaces that are inclusive and accessible for everyone.

In recent years, Fjordbyen has transformed large parts of Oslo's harbor areas from industrial and container zones into new city districts. As a result, the fjord town is now alive with tourists, residents, workplaces, bathers, and cultural activities. The people of Oslo now feel closer to the water, and the Fjordbyen project has greatly enhanced the city's livability.

Fjordbyen's development is driven by a strong desire to create sustainable and future-oriented urban environments. The municipality intends to release as much of the sea-facing areas as possible for recreational areas, housing, and industry, integrating the fjord into the city.

Moreover, Fjordbyen seeks to address environmental and sustainability issues, including water quality and biodiversity. The project includes measures to improve water quality, such as reducing nutrient loads and enhancing habitats for fish and other aquatic species. Additionally, Fjordbyen aims to be a zero-emission and low-carbon community, with an emphasis on green mobility and energy efficiency.

Fjordbyen's innovative approach to urban development has gained recognition and attention worldwide. The project serves as a model for sustainable urban development and has inspired similar initiatives in other cities.

Fjordbyen is a significant urban development project that seeks to integrate Oslo with its natural surroundings, create sustainable urban environments, and enhance the city's livability. Through this initiative, the municipality aims to create attractive public spaces that are inclusive and accessible for everyone, while addressing environmental and sustainability challenges.

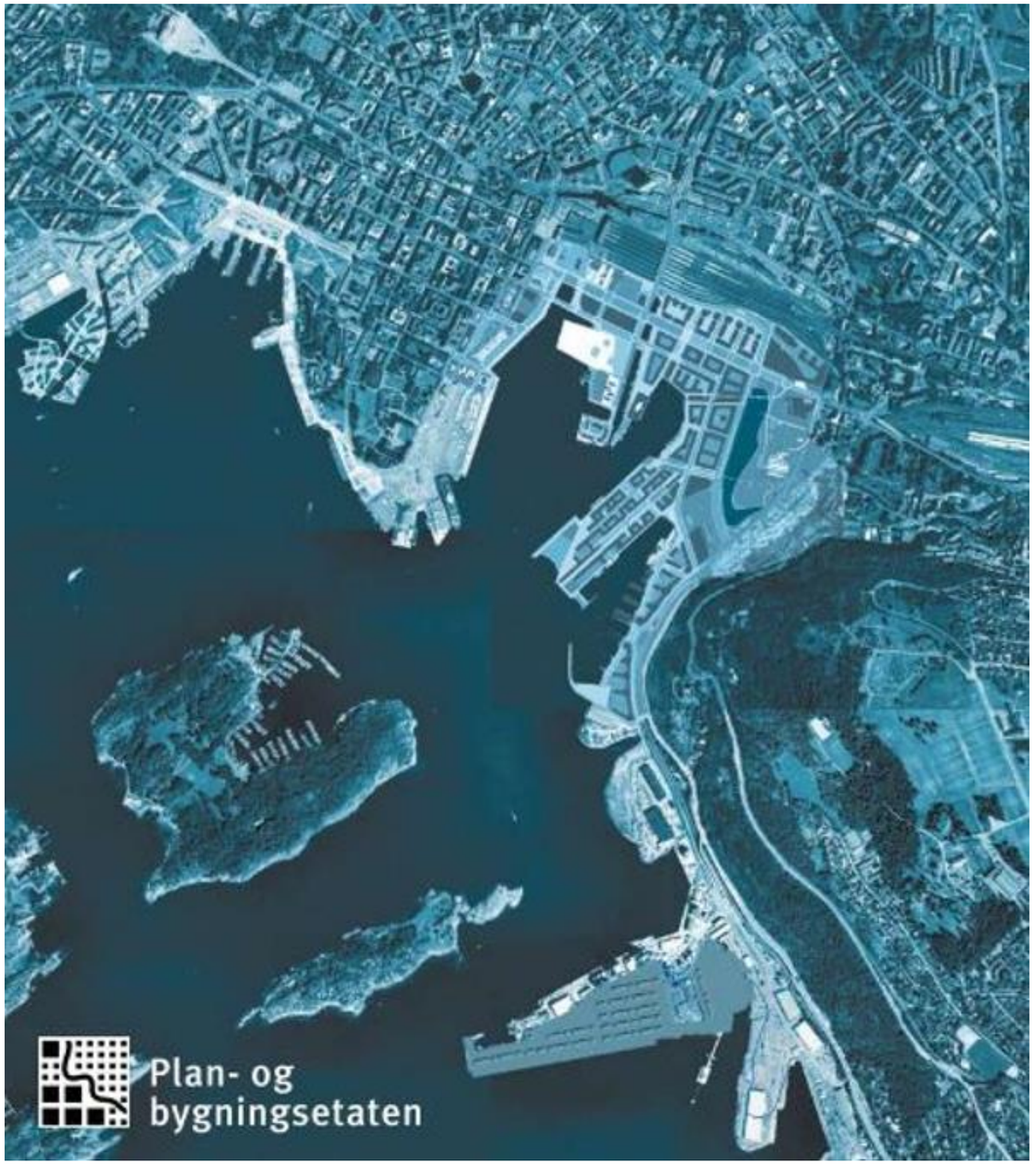


Figure 14. Fjordbyen, plan og bygningstaten, 2006

GRØNLIKAIA

One of the biggest urban development projects in Oslo is Grønlikaia, which is regarded as the final significant development area in Bjørvika.

Grønlikaia is an artificial landform on fill masses located at the foot of Ekebergåsen.

The plan for Grønlikaia is divided into sub-areas with distinct characteristics and identities. The place names are drawn from the history of Grønlikaia.

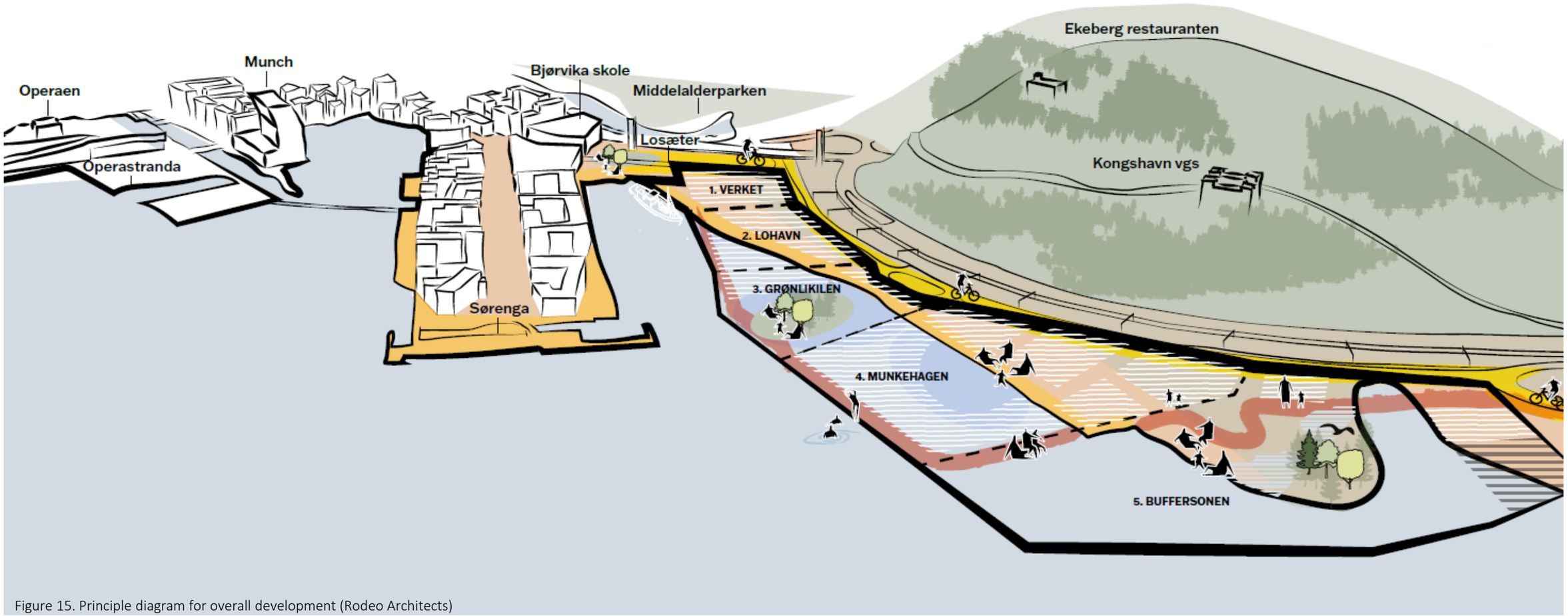


Figure 15. Principle diagram for overall development (Rodeo Architects)

Figure 16. Eelgrass flower shoot (Zostera marina). photo: Eduardo Infantes

03. THEORY

Estuaries

Marine ecology

Marine Natural environments

Key species

Alien species

Estuarine food web

ESTUARIES

Estuaries are partially enclosed bodies of water where fresh water inflow from land dilutes salt water, resulting in brackish water with a salinity that lies between fresh water and normal seawater.

The term "estuary" comes from the Latin word "aestuarium," which means a tidal inlet of the sea and is itself derived from the word "aestus," which means tide. An estuary has been defined in a variety of ways. The most widely accepted definition is: "a semi-enclosed coastal body of water, which has a free connection with the open sea, and within which seawater is measurably diluted with freshwater derived from land drainage“. (Pritchard, D. W. ,1967)

Estuaries have been referred to as the "nurseries of the seas" because they offer a secure environment for fish, birds, and other species to raise their young. Additionally, estuaries help by filtering sediment and contaminants from water before it enters the ocean. They are also important because they act as a buffer between the sea and the land, which can lessen the effects of flooding and storm surges.

Humans and marine life both benefit from estuaries. Muddy intertidal areas are deposited in the estuary habitat as a result of the steep salinity gradient and high turbidity levels that it experiences. For many people on the earth, this area is the closest thing they will ever see to a natural habitat. Although estuarine habitat has been exploited and damaged by mankind, it continues to be one of the planet's most resilient habitats, retaining its appeal for species despite industrialisation and land claims. It is a habitat that has the potential to offer special ecosystem services that will benefit both the sea and people (McLusky and Elliott, 2004).

There are several classifications of estuaries, and the one in this thesis can be categorized as a salt wedge estuary, where freshwater from the river flows over the saltwater in the fjord, and the salt wedge moves back and forth with the tides .The fresh water flows out along the surface, while the saltwater flows in at depth, resulting in the formation of a wedge-shaped lens of seawater moving along the bottom. Depending on the level of mixing that occurs, the surface water may remain mostly fresh throughout the estuary, or it can become brackish.

Figure 17. Buffersonen, 2023

Salt-wedge Estuaries

Salt-wedge estuaries are known to be the most stratified, or least mixed, of all estuaries. Salt-wedge estuaries occur when a fast-moving river meets weak tidal currents in the ocean. The circulation of water in these estuaries is determined by the force of the river pushing freshwater out to sea rather than tidal currents transporting seawater upstream. As freshwater is less dense than saltwater, it sits atop the seawater, creating a sharp demarcation between the two water masses. A layer of saltwater forms a wedge on the bottom while freshwater floats on top. Though some mixing occurs at the boundary between the two water masses, it is typically slight. The location of the wedge varies according to weather and tidal conditions (NOAA, 2021)

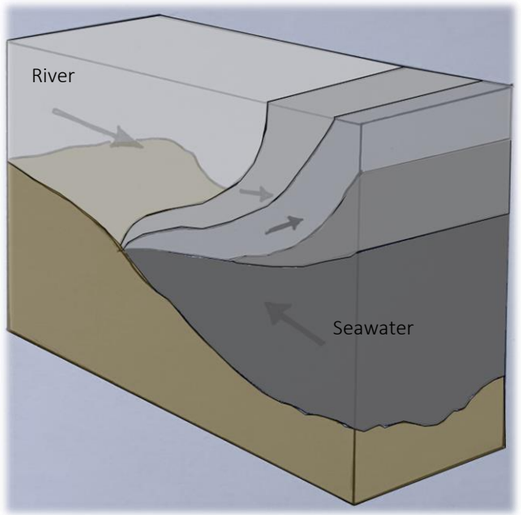


Figure 18. Illustration of salt-wedge estuary

MARINE ECOLOGY

Tide

In marine ecosystems such as estuaries and the beach zones, tides are a fundamental ecological element. The occurrence of tides is determined by the lunar cycle and local topography (Direktoratet for naturforvaltning, 2013). The tides typically occur twice a day, resulting in low water twice a day. This means that flora and fauna in the tidal zone must endure challenges such as flooding, drainage, and even freezing. The extent of tidal variation varies regionally, with the Oslofjord having a relatively small difference of approximately 40 cm between high and low tide (Ryvarden, 1997). Additionally, the conditions of the wind and air pressure have impacts on the tide.

Salinity

In estuaries, the most important factor is salinity and variation in salinity is nowhere more noticeable than in estuaries. Salinity fluctuations occur both horizontally and vertically, as well as seasonally. These variations result from the tide, evaporation, and the amount of freshwater supply.

Eutrophication

For more than 50 years, eutrophication has been recognized as a serious threat to coastal marine ecosystems all over the world (Ryther and Dunstan, 1971). Increased supply of nutrients to the ecosystem results in more phytoplankton production and can lead to a decline in the quality of the surface water (Nixon, 1995). Moreover, sinking plankton biomass can further contribute to oxygen consumption, leading to reduced oxygen levels in deeper basins (Cloern, 2001; Staalstrøm, 2015). Eutrophication may also result in an increased occurrence of toxic algal blooms (Heisler et al., 2008).

MARINE NATURAL ENVIRONMENT

Hard bottom habitats

Hard bottom habitats are the parts of the seabed made up of rocks and hard structures and provide complex textures for species like seaweeds and sponges to attach. However, these habitats are susceptible to anthropogenic threats such as dredging and damage from fishing activities, which can have profound implications for their ecological integrity and biodiversity (Ryvarden, 1997).

Hard bottom habitats provide complex physical structures for attachment and colonization by a variety of marine species. These habitats are known to support high biodiversity and productivity, as they offer numerous niches and microhabitats for a wide range of organisms, such as seaweeds, sponges, corals, and various invertebrates.

Soft bottom habitats

Sediments such as mudflats, beaches, shoals, holes, and sand make up soft bottom habitats. The sediments, which typically become exposed during low tide periods, are composed of clay, silt, sand, and gravel with grains smaller than 16 mm. These habitats serve as vital foraging areas for birds and fish, contributing to their ecological significance.

The biodiversity and productivity of soft bottom habitats are intricately influenced by various factors, including depth, light exposure, sediment size, and temperature. (Ryvarden, 1997). For instance, sediment size and composition play a crucial role in determining the types of organisms that can thrive in soft bottom habitats, with different species adapted to specific sediment types. Moreover, soft bottom habitats are known to serve as important foraging areas for a variety of marine organisms, including birds and fish, due to the availability of food resources and shelter.

KEY SPECIES

Key species that are also referred to as structuring species can generate biological diversity, as other species will emerge if the key species are successfully established. It is imperative to promote indigenous species through the utilization of local geotopes, both aquatic and terrestrial, as a means of facilitating their establishment.

ALIEN SPECIES

Aliens, non-native, or nonindigenous, foreign species are those that occur outside of their natural range. Alien species impact ecosystems in various ways, such as displacing indigenous species or transmission of parasites and diseases.

Pacific oyster (*Crassostrea gigas*)

The Pacific oyster, *Crassostrea gigas* (Figure 19), is an example of invasive species that was introduced to Scandinavia and farmed in several locations in the 1980's and early 1990's. Though feral populations failed to establish, a bio-invasion of Pacific oyster commerced in 2007 (Wrange et al. 2010), and the species has now colonized most of the Scandinavian coast. The Scandinavian populations may already have adapted to regional environmental conditions (Sussarellu et al. 2015), and reproduction in new areas may be facilitated by warm summers. The dispersal of Pacific oyster larvae via water currents and their attachment to suitable substrates further contribute to their expansion.

The razor-sharp shells of the Pacific oyster can prohibit public access and negatively impact the quality of bathing spots along the coast.

Figure 19. Pacific oyster (*Crassostrea gigas*). Photo: Vivian Husa.

ESTUARINE FOOD WEB

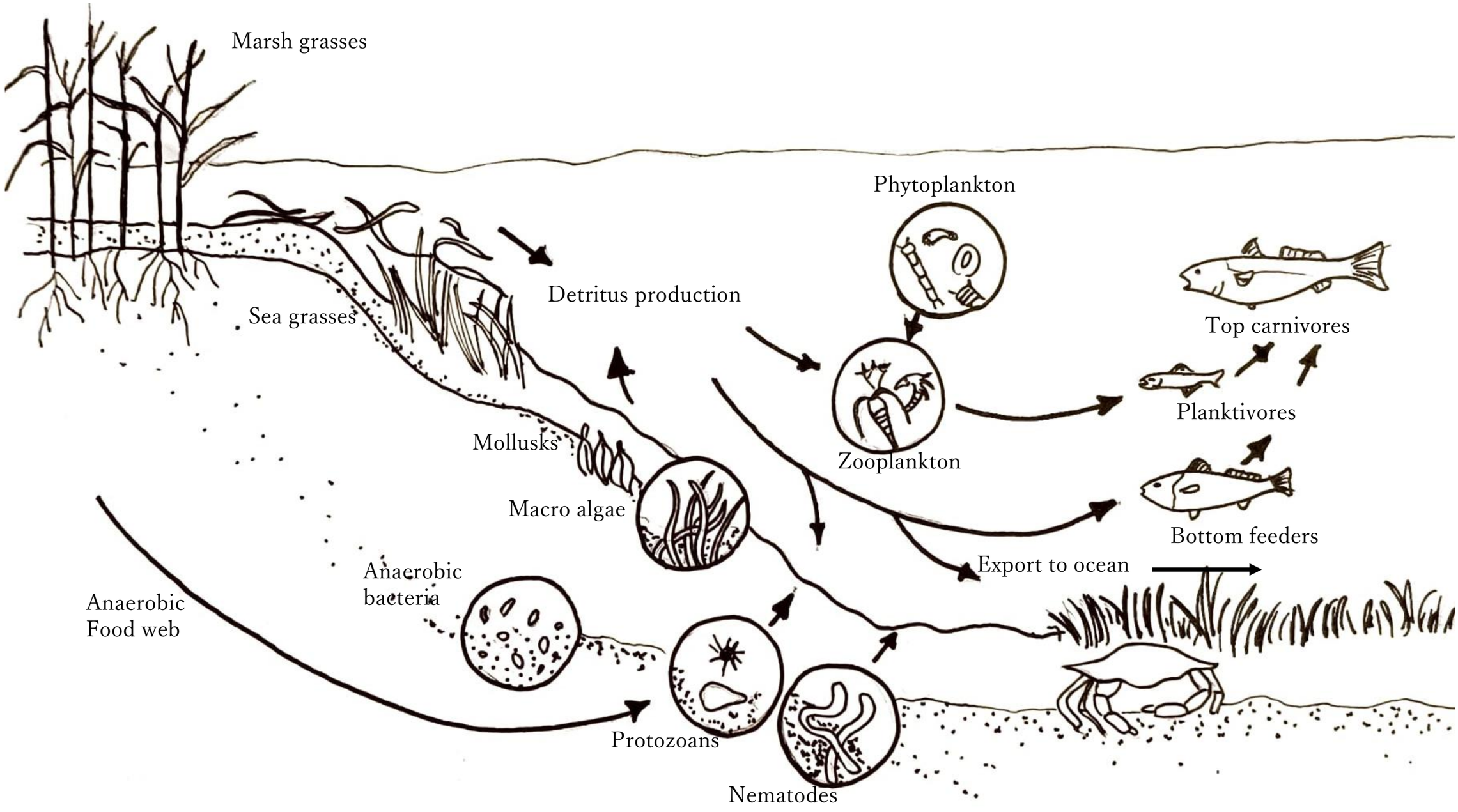


Figure 20. Illustration of estuarine food web

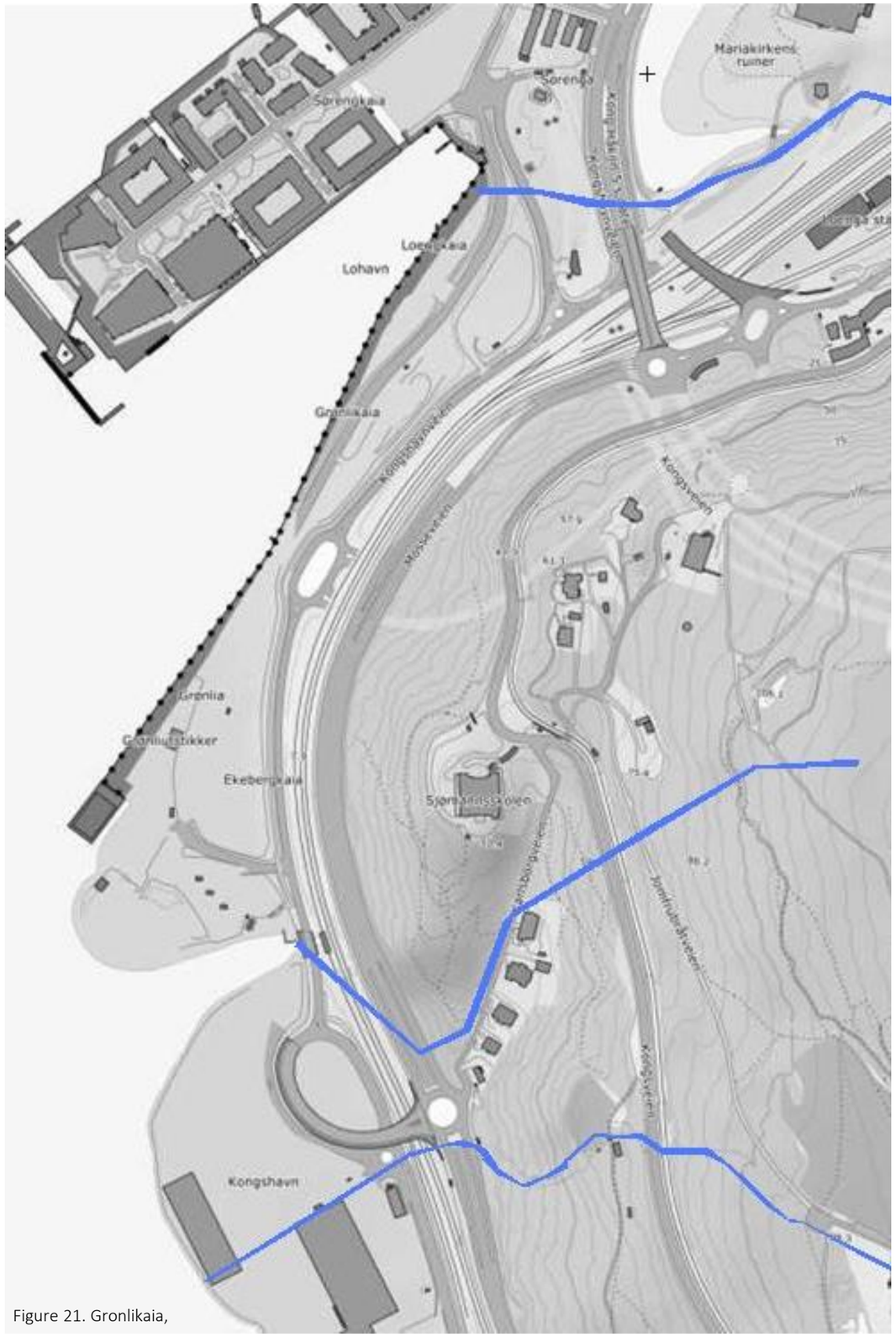


Figure 21. Gronlikaia,

04. CASE AREA

The Oslo fjord

Inner Oslo fjord

Alna river and its estuary

Historical context

Figure 22. Buffersonen, 2023

THE OSLO FJORD

The Oslofjord is located in the south-east of Norway. Stretching about 100km inwards from the strait of Skagerrak towards Oslo, Norway's most populated city, the Oslo fjord is a micro-tidal fjord. The fjord is divided into two sections, the Outer Oslo fjord and the Inner Oslo fjord (Braarud and Ruud 1937). The fjord consists of several basins that are separated by shallow sills, which restrict free water exchange. The boundary between outer and inner Oslofjord is constituted by a sill that is about 20 m deep, situated in the north end of the Drøbak Sound. The inner Oslofjord comprises two primary basins: Vestfjord located on the western part of the fjord and Bunnefjord located on the eastern part. These basins are divided by another sill, approximately 50m deep, that runs between the peninsulas Nesodden and Bygdøy.

According to Gade (1968), the water masses of the fjord are divided into two layers: the upper brackish layer and the lower homogenous almost-marine layer, typically holding salinities of less than 30 and above 31, respectively.

The salinity and temperature of the fjord undergo considerable annual fluctuations, with low temperatures and high salinity during winter and high temperatures and low salinity during summer. quently, the thickness of the surface layer varies from being almost non-existent during winter to as much as 20m thick in summer (Gade 1968).

In the inner Oslofjord, the freshwater influence is mainly governed by the large rivers, such as Glomma and Drammens River, mounding in the outer fjord, due to low discharge from the rivers directly mounding into the inner fjord, including Alna.

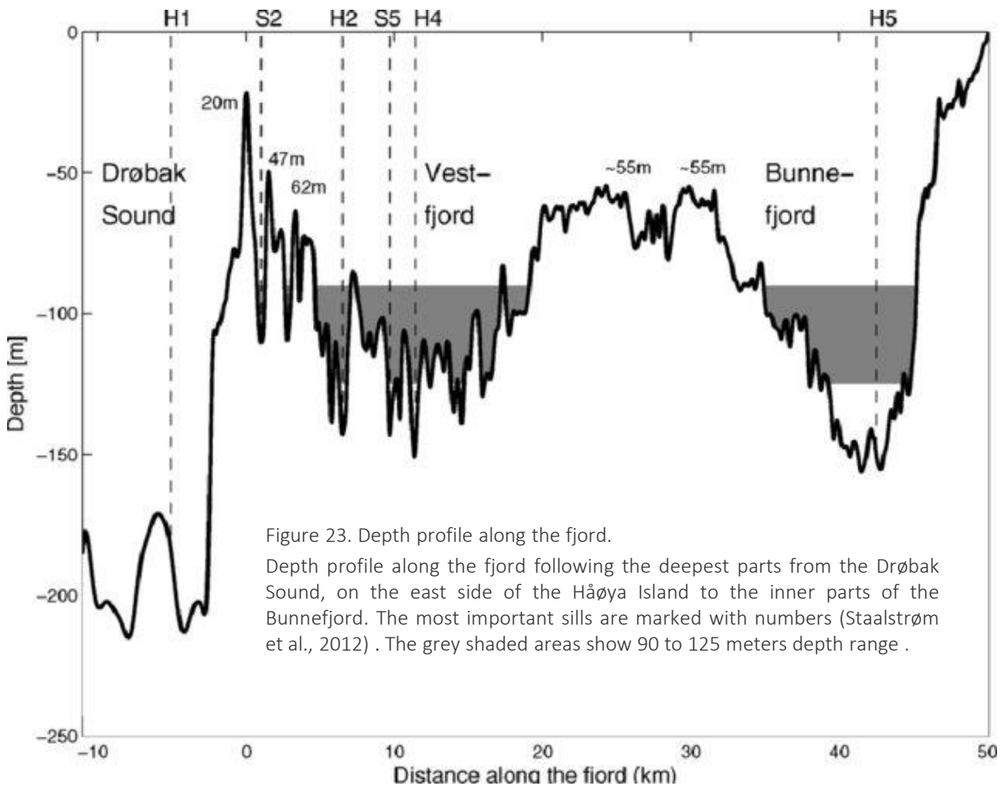


Figure 23. Depth profile along the fjord.

Depth profile along the fjord following the deepest parts from the Drøbak Sound, on the east side of the Håøya Island to the inner parts of the Bunnefjord. The most important sills are marked with numbers (Staalstrøm et al., 2012) . The grey shaded areas show 90 to 125 meters depth range .

Pollution history: The Oslofjord's contiguous land area has undergone momentous demographic expansion, primarily centered around Oslo city, resulting in the emergence of approximately 760,000 residents in the adjoining municipalities who rely on the fjord for wastewater disposal. Concurrent with this population growth, the industrial sector has also burgeoned, with the establishment of sawmills along the rivers in the 16th century, followed by a substantial proliferation in the mid-19th century. This era witnessed the creation of pulp mills, textile factories, breweries, hardware and chemical plants, all of which utilized the rivers as open sewers, thereby engendering significant pollution. During the last 50 years, majority of these industries have been dismantled.

In 1910 and 1911 the first wastewater treatment plants went into operation. Other small treatment plants were built the following years. These employed crude technology to rinse the effluent (Arnesen 2001), and the sludge was often disposed of in the fjord, just a few kilometers away from the harbor. During the 1920s and 30s, the pollution situation was a topic of discussion amongst scientists, engineers, and the public, due to water's greenish-grey color and bad odor. As the harbour area was a popular recreational location, public health was the main concern (Arnesen 2001).

In the 1930s to 50s, scientists raised concerns about the increasing algal populations caused by nutrient loading, but the engineers at the Oslo Sewer Authority failed to recognize the connection and focused solely on organic matter content. It wasn't until the 1970s that nutrient removal became the top priority, but by then, nutrient loading had already caused anoxic conditions to appear in the Bunnefjord below 70m water depth. (Arnesen 2001).

Since the advent of nutrient treatment in the 1980s, the Oslofjord's gradual improvement in response to eutrophication has been evident. However, despite these efforts, conditions of dysoxia and localized anoxia in the benthic waters continue to persist (Arnesen 2001).

Inner Oslofjord

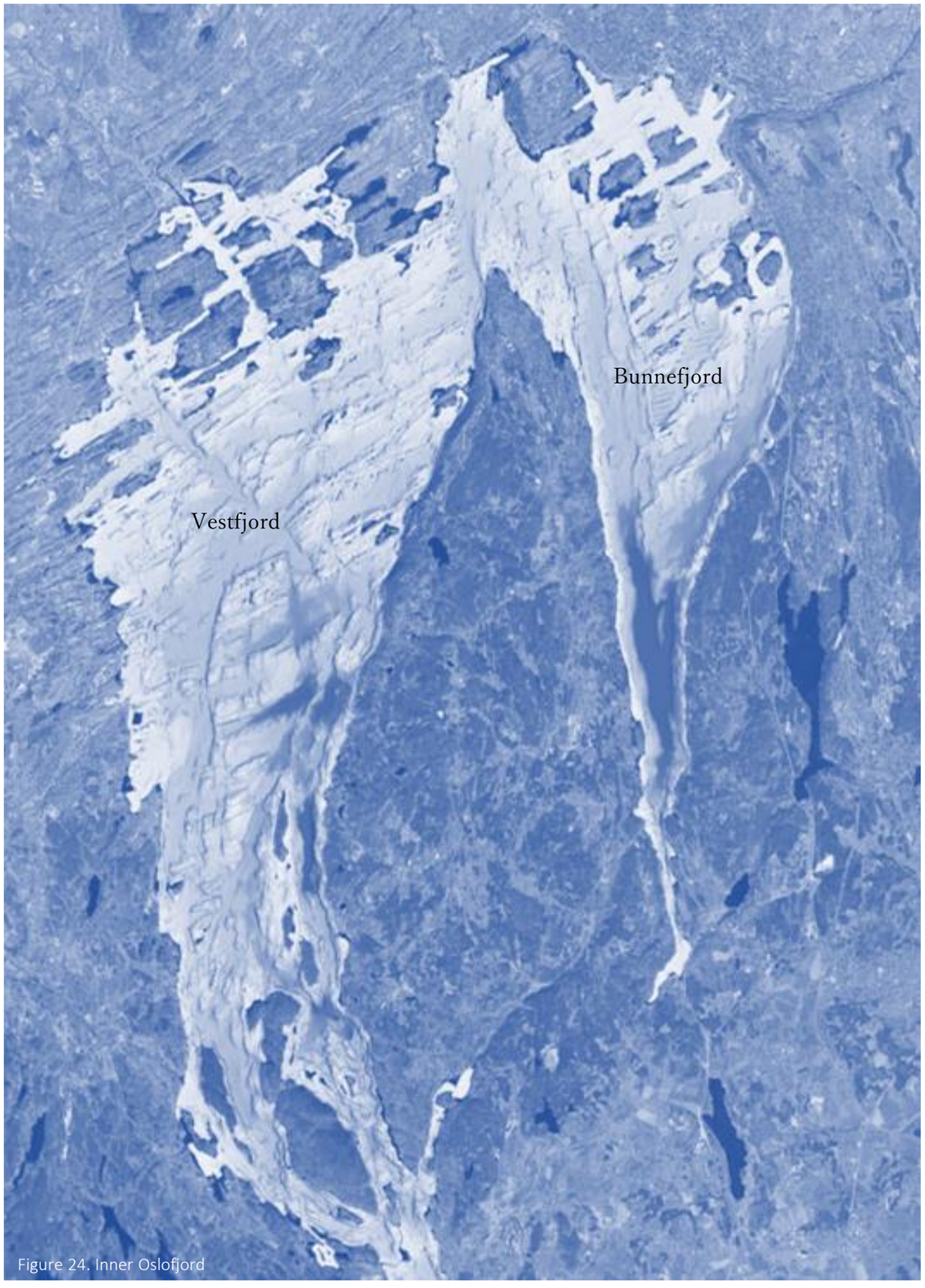


Figure 24. Inner Oslofjord

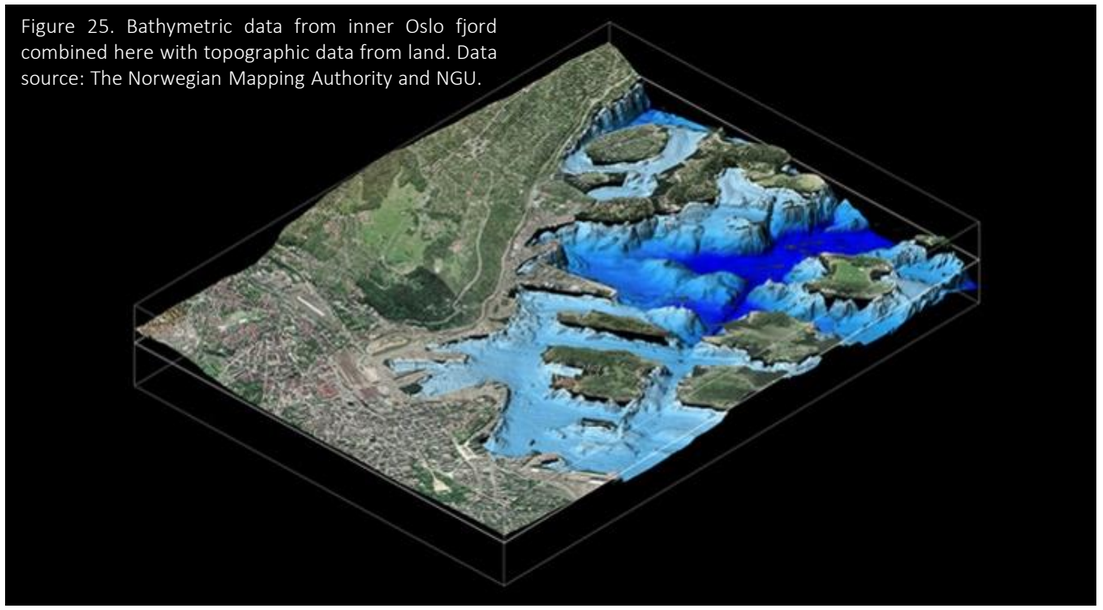


Figure 25. Bathymetric data from inner Oslo fjord combined here with topographic data from land. Data source: The Norwegian Mapping Authority and NGU.

The Oslo Inner Fjord is a complex marine ecosystem. It is a region of high ecological diversity, with distinct physicochemical gradients, salinity gradients, and nutrient dynamics. The fjord's unique hydrodynamics, including strong tidal currents and stratification, play a crucial role in shaping the fjord's ecosystem.

The Oslo Inner Fjord is home to a wide array of marine species, including fish, plankton, benthic invertebrates, and seabirds. It serves as an important spawning and nursery ground for several commercially important fish species, such as cod, herring, and mackerel. The fjord's nutrient-rich waters support a productive food web, with complex interactions among various trophic levels.

Human activities, including urbanization, industrialization, and shipping, have resulted in environmental pressures on the Oslo Inner Fjord. These activities have led to changes in water quality, habitat degradation, and alterations in biodiversity patterns. Efforts are underway to monitor and mitigate these impacts through various conservation measures, including habitat restoration, pollution control, and sustainable resource management.

The Oslo Inner Fjord is also a valuable site for scientific research and monitoring, providing valuable data on the dynamics of marine ecosystems, the impacts of human activities, and the effectiveness of conservation measures. Understanding the fjord's ecological processes and responses to environmental changes is critical for informing management and conservation strategies in this unique and dynamic marine ecosystem. Further research is needed to comprehensively understand the fjord's ecological dynamics and support evidence-based decision-making for its sustainable management.

Figure 26. Map of Oslo's rivers. Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA. (https://www.arcgis.com/apps/mapviewer/index.html)

ALNA RIVER AND ITS ESTUARY

At a length of 15 km and a catchment area of 69 km², the Alna River is the longest river in Oslo (NIVA, 2018). Originating from the Alnsjøen lake in the north, the river flows through the east of Oslo before discharging into Oslofjord in the Bjørvika neighbourhood in the Sentrum district. The Alna river has been tunnelled through Ekebergåsen as part of renovating the Old Town and to facilitate the railway facility that is now Oslo Central Station. Lohavn used to be the river's original outlet, where the river had abundant space for water dynamics and wide edge zones on each side. It is believed that the historic natural river banks along the fjord were characterized by salt marsh vegetation.

In 1922, the lower section was forced underground through a series of pipes by Kværnerbyen culvert (NIVA, 2020). Since World War II, much of the river was covered up and forced through culverts to facilitate greater urbanization and serve as a sewage disposal system for large housing developments that were built. Furthermore, 80% of the Alna's tributaries are closed, which exacerbates the poor hydrological and ecological conditions in the Alna. (NIVA, 2020). Due to the highly urbanized catchment area, the Alna is one of the most polluted rivers in Norway (NIVA, 2018), with high levels of phosphorus and nitrates. Most of the pollutants come from urban surface runoff, point and diffuse discharges from wastewater, industries, landfill, and contaminated ground caused by older industries (NIVA, 2020).

Today, the Alna river emerges through a culvert under the motorway system between the Kongshavn and Sydhavna infills. The river's edge zone and outlet have been greatly diminished.

The outlet on the Sydhavna side is plastered with large boulders. The embankment on the Kongshavn side forms a steep slope with a height difference of nearly 5 meters between the water's edge and the highest ground; and the filling houses a fuel station where oil spills have been observed on the ground and on the surface of the water.

Brackish water areas, such as at Alnaelva's outlet, where river water mixes with sea water,, are called estuarine areas. Although these areas are typically considered to be less species-rich than purely marine sea areas, they are crucial for biodiversity, including for commercial species caught for food consumption. Estuaries are commonly referred to as the sea's nursery, due to the fact that they serve as the breeding ground for many of marine organisms. These regions are in constant flux due to the varying depth and the fluctuation of physical variables such as salinity and temperature which are heavily influenced by the water flow from the river and the tidal cycle. The estuarine ecosystem encompasses a wide range of habitats such as tidal beds, tidal marshes, kelp forests, oyster reefs, and eelgrass beds.

However, human activities and development have had such a profound impact on the local environment that many of the natural species' habitats have vanished.

The lack of a natural shoreline along the fjord, buildings, floating marinas and wharves, transportation and port infrastructure have disrupted the habitats for species in the area around Grønlikaia.

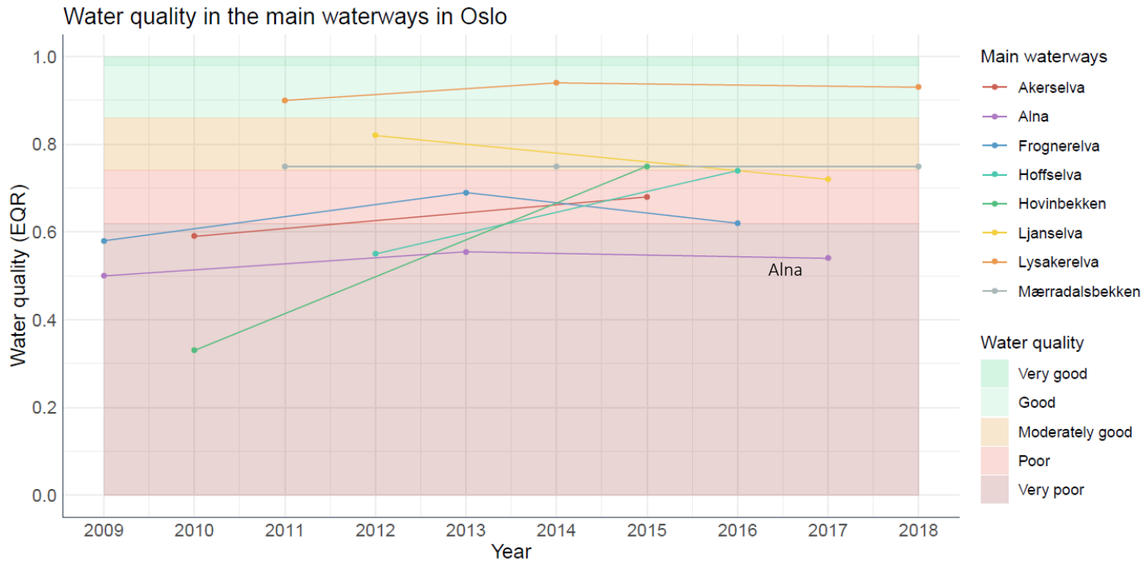


Figure 27. The numbers are in EQR which stands for Ecological Quality Ratio that is a quality coefficient for a given waterway. Data source: Agency for Water and Sewerage Works (oslo.kommune.no)

The coastal waters along the Norwegian coast are increasingly experiencing darkening, which can be attributed to the influx of humic substances and particulate matter from the land. This phenomenon leads to reduced light availability, hindering the photosynthesis process of algae and eelgrass plants. Climate change exacerbates the situation, as it results in intensified precipitation events and, in turn, amplified sediment runoff and siltation of the seabed. Such sedimentation can create unfavourable conditions for filter-feeding organisms, including mussels and oysters. Therefore, to ensure optimal habitat conditions for marine life, it is crucial to minimize the influx of pollutants and particulates by implementing appropriate management practices to mitigate the effects of sediment runoff.

HISTORICAL CONTEXT

Figure 28. Oslo, approx. year 1300 Source:WRL: NATURRESTAURERING I URBAN HAVNEFRONT

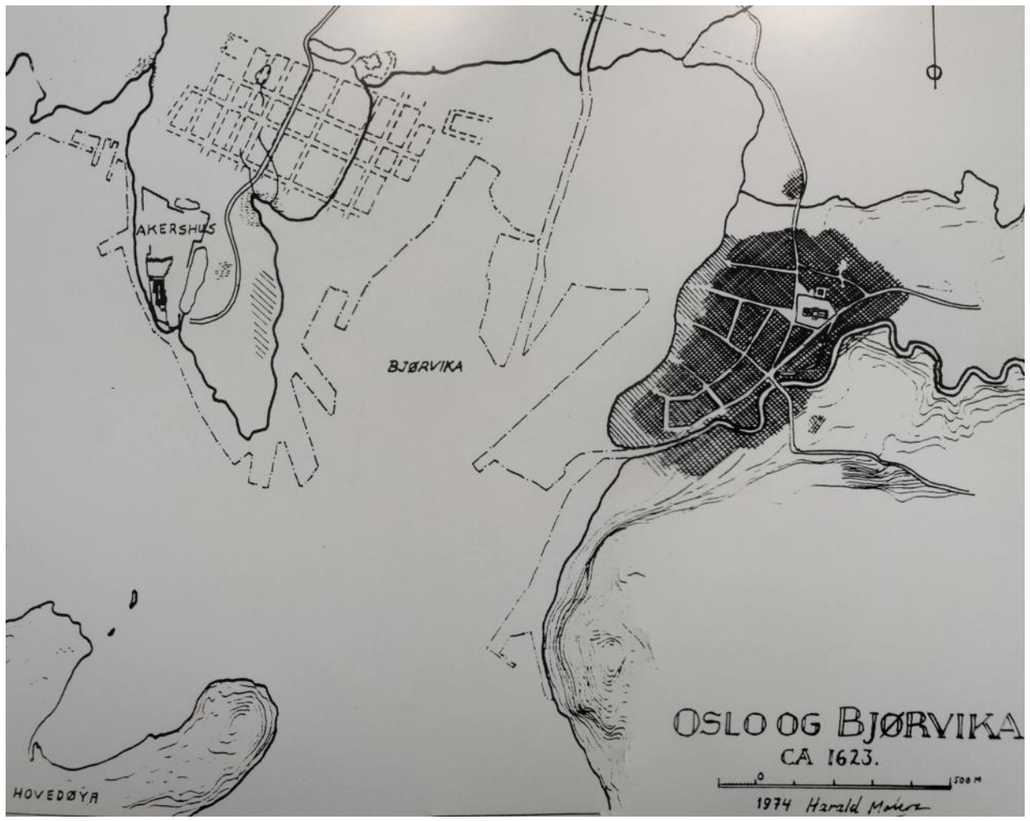


Figure 29. 1623 Map with 1947 waterfront dashed in. Source: Notes from Norway

Figure 30. Oslo in the 17th century . Source:WRL: NATURRESTAURERING I URBAN HAVNEFRONT

Long before settlers began to establish themselves along its banks, the Alna River has been around for thousands of years. Perhaps the earliest settlers in Oslo did not settle down exactly by the Alna, but a city ultimately developed near the river's mouth and became the capital of Norway in 1314. Therefore, it is possible to think of the Alna's outlet as the cradle of the capital. (The Municipality of Oslo Application for Candidacy to the Landscape Award of the Council of Europe 2016-2017)

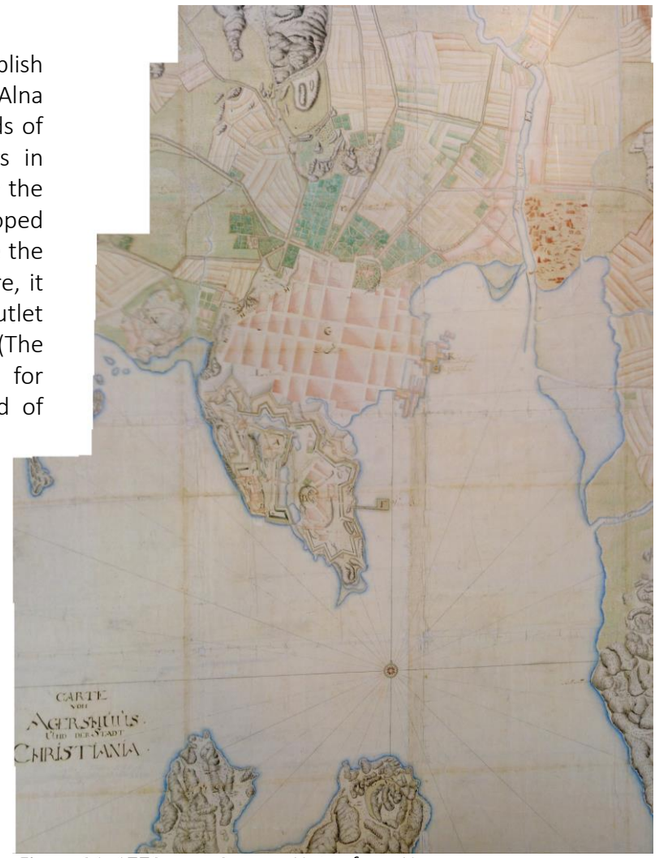


Figure 31. 1770 map, Source: Notes from Norway

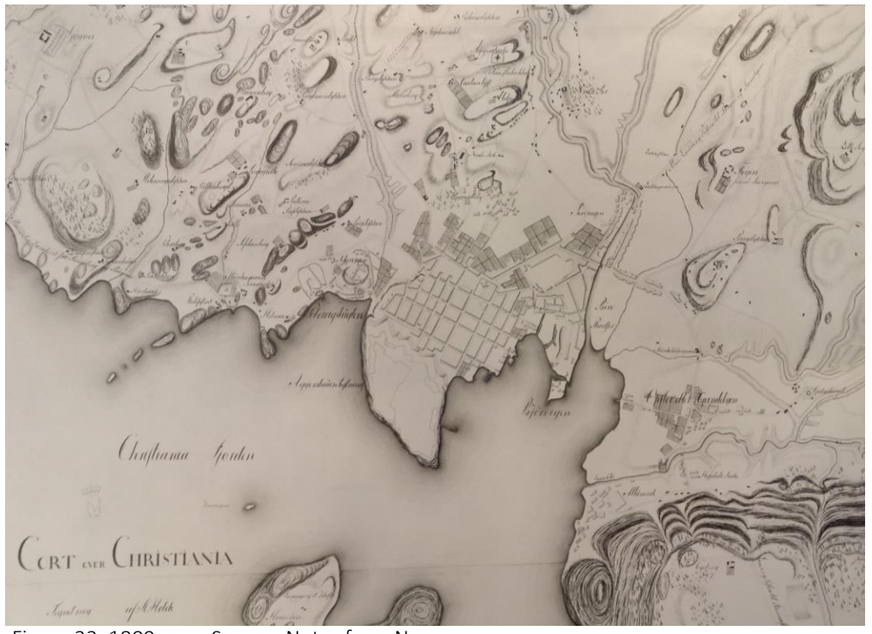


Figure 32. 1809 map. Source: Notes from Norway.

Figure 33. 1858 map. Source: Notes from Norway

Figure 34. 1920 map.
Source: Notes from Norway

Figure 35. Massive development of Oslo harbor from Frognerkilen in the west to Sjursøya in the east throughout the 20th century. Map from 1980. Source:WRL: NATURRESTAURERING I URBAN HAVNEFRONT

Oslo's history began at the mouth of Alna river. In 1922, the lower part of the river was tunnelled through Ekeberg from the Kværner area down in the Lodalsøkket to the outlet in the Oslofjord between Grønlikaia and Kongshavn.

In 1927, Lake Alnsjøen was dammed as a source of drinking water, and with this Alns' water level was reduced.

In 1948, the culvert was extended eastwards so that the waterfalls from Svartdalen and down into Kværnerdumpa in Lodalen, the so-called Kværnerfossene, were also drained. Until the mid-1980s, more and more of the river was put underground.

Figure 36. Alna river's lower course around the beginning of the 19th century, before railways and industry changed the landscape

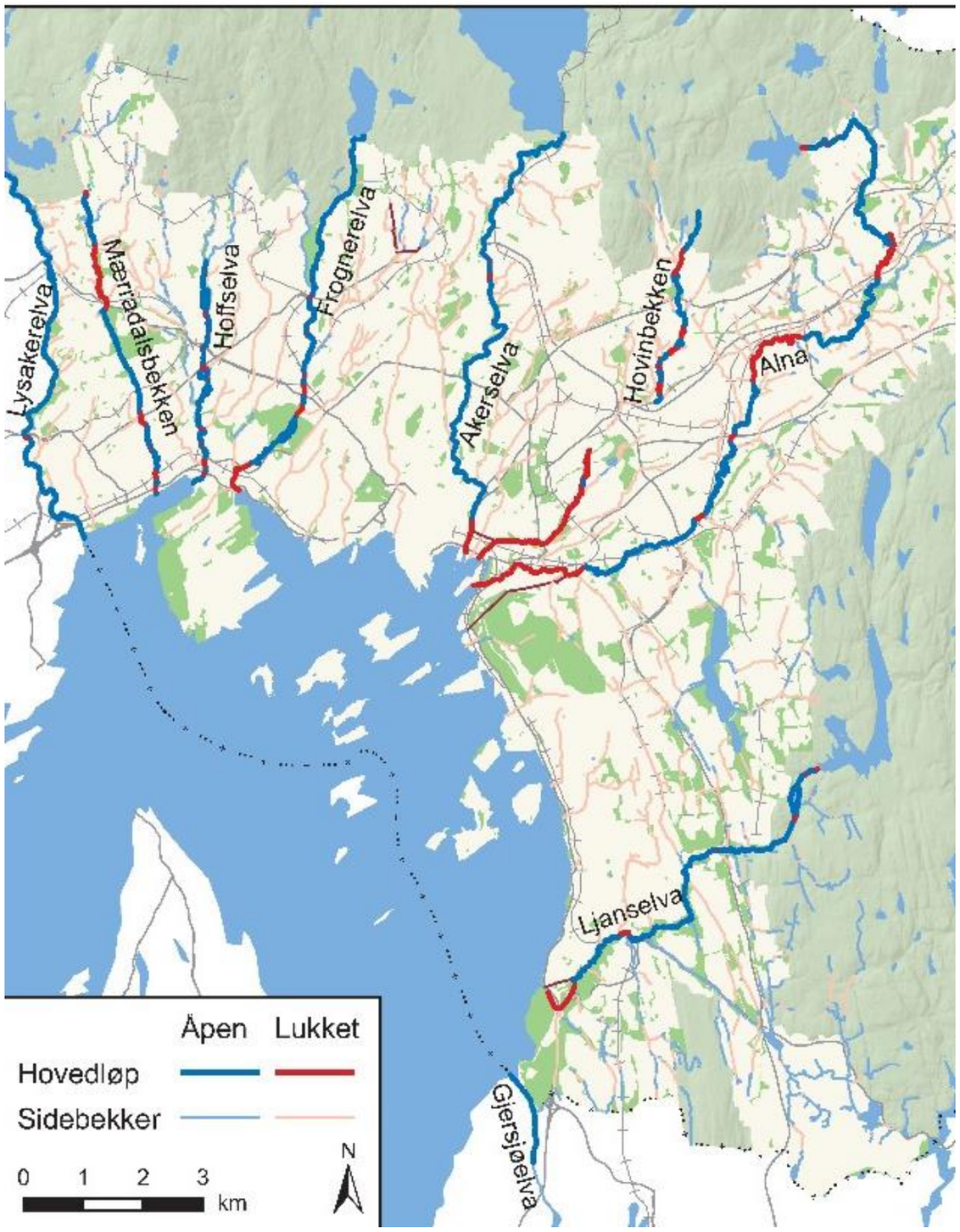


Figure 37. The city with the rivers and streams, Source: Oslo Elveforum.

Timeline

Alna's outlet was the hearth for the establishment of the city of Oslo around the year 1000. The river was larger at this time and the width of the outlet was around 70 meters and the water level was around 3 meters higher than today.

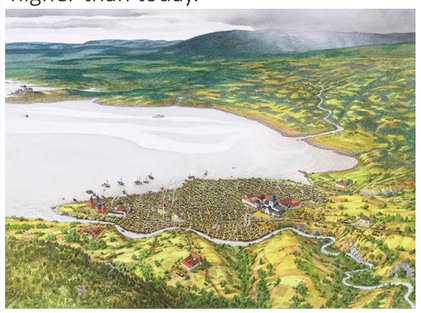


Figure 38. Medieval Oslo. Illustration: Karl-Fredrik Keller

Towards the end of the 13th century, the expansion of Oslo began also on the south-east side of Alna.

The first brickworks connected to Alna was built down on Øra by Duke Håkon around 1290 as the clay by the river was good.

From the 16th century, Alna became a power source for sawmills, and in the 18th century as many as 10 sawmills were established from Kværner to Grorud.

Industrialization in the 19th century

Figure 39. 1887. Photo: Axel Lindahl, © Nasjonalbiblioteket.

In 1922 the river that flows further west, originally to Sørenga on the east side of Bjørvika, was laid in a culvert to Kongshavn, around 900 meters south of the original outlet

Figure 40. Photo: Hans Høydalsvik (2020)

The pollution of the river increased with the development of industry and housing so in 1992, Oslo municipality started "Aksion Alna", with hiking trails along the river, cleaning and other measures.

In 2000, in connection with the millennium anniversary, it was decided to highlight this area of the former outlet which is strongly linked to the city's history, by recreating the water mirror in Middelalderparken that shows Alna's original outlet.

Figure 41. Photo: Helge Høifødt

Figure 42. Buffersonen, 2023

Alna River Discharge

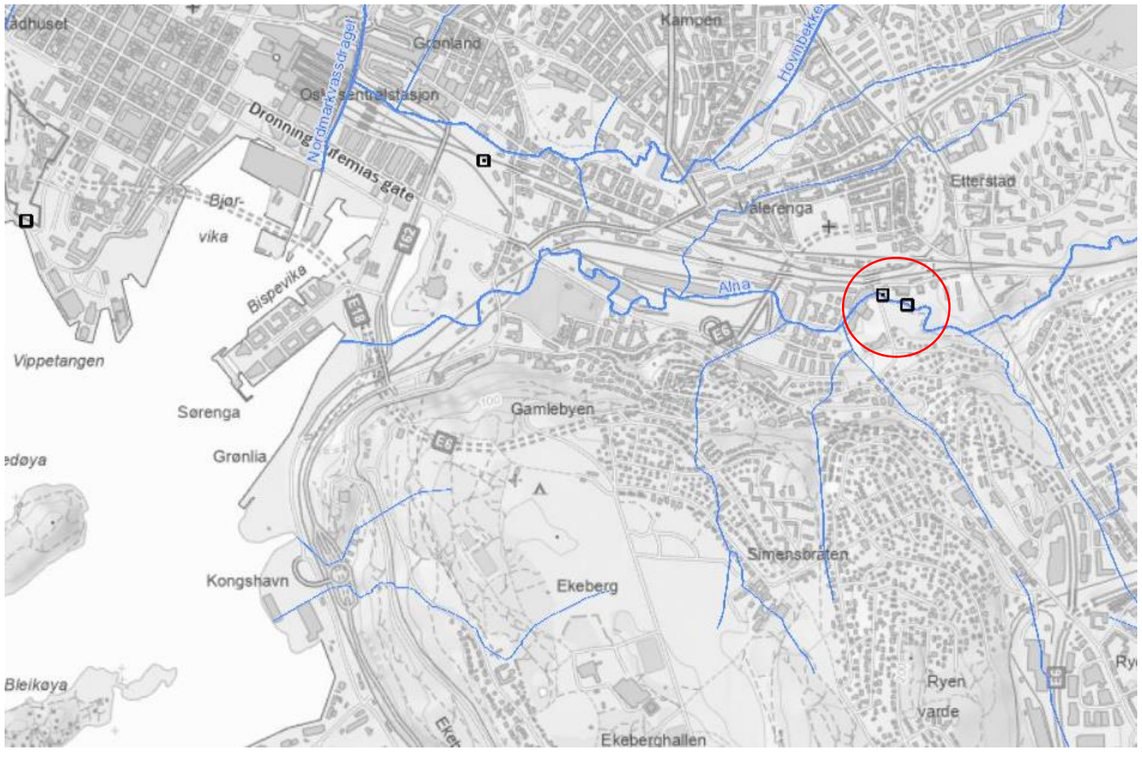
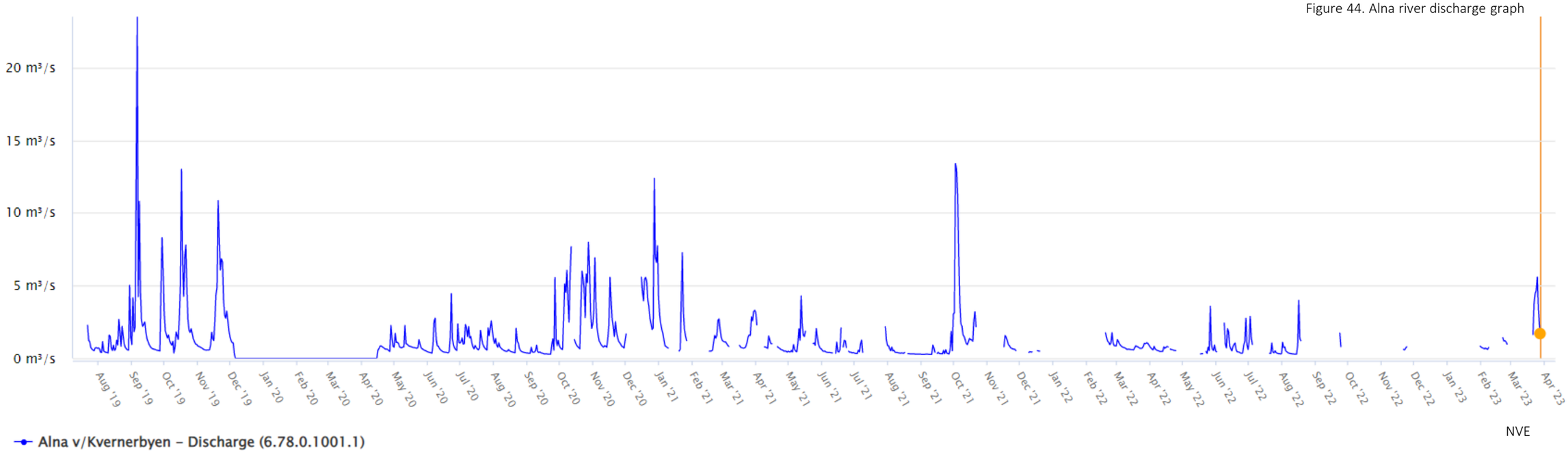


Figure 43. Hydrological measuring station
(The station is located in Oslo and is active. It has been in service since July 2019).

Figure 44. Alna river discharge graph



NVE

Combined sewer system (CS)

The impacts of climate change and urbanization are placing additional stress on wastewater networks, which are already facing challenges due to aging infrastructure. Planning and maintenance are made more challenging by climate change since it is more difficult to predict future needs. For instance, a 20-year return period rainfall event in Norway is predicted to rise by 27–46% by 2100, depending on the duration of the rainfall (Dyrrdal & Førland 2019).

According to climate change predictions rainfall events will occur more frequently and more intensely, there will be more freeze-thaw cycles and more of the winter's precipitation will be in the form of rain. Droughts will occur more frequently during the summer. Urbanization further exacerbates the situation. In 2018, 55% of the global population were residing in urban areas. By 2050, This percentage is projected to increase to 68% (United Nations 2019).

Oslo, the capital of Norway, is also witnessing rapid urbanization, with a projected population increase of 25% by 2040 compared to 2019 (City of Oslo 2020). Urbanisation results in increased impervious surfaces, leading to both greater stormwater runoff and faster response time, which in turn heighten the risk of sewer network overload. In recent years, a significant number of precipitation-related damages have been registered in Norway, with total insurance payments amounting to EUR 700 million between 2008 and 2020, and 30% of these damages are directly linked to the wastewater network, as reported by Finance Norway's database (Finance Norway 2020).

The wastewater network in Oslo is extensive, spanning 2,250 km and averaging 47 years in age (City of Oslo 2020). Approximately 57% of the network in Oslo comprises a combined sewer system (CS), which combines domestic sewage and stormwater runoff in the same pipe. However, these systems are ill-equipped to handle increasing volumes of stormwater, resulting in heightened risks of sewage overflow and infrastructure damage. Consequently, this contributes to potential threats to human health and the environment.

The network contains 218 CSO that discharge into the waterways of the city and Oslo Fjord. (J. Kvitsjøen et al., 2021)

57 percent of the sewage system in Oslo consists of combined sewers, while 43 percent consists of separated sewers. The oldest parts of the sewage network are combined systems, while constructions post 1965 are mainly separated systems. (Application Form for the European Green Capital Award 2019)

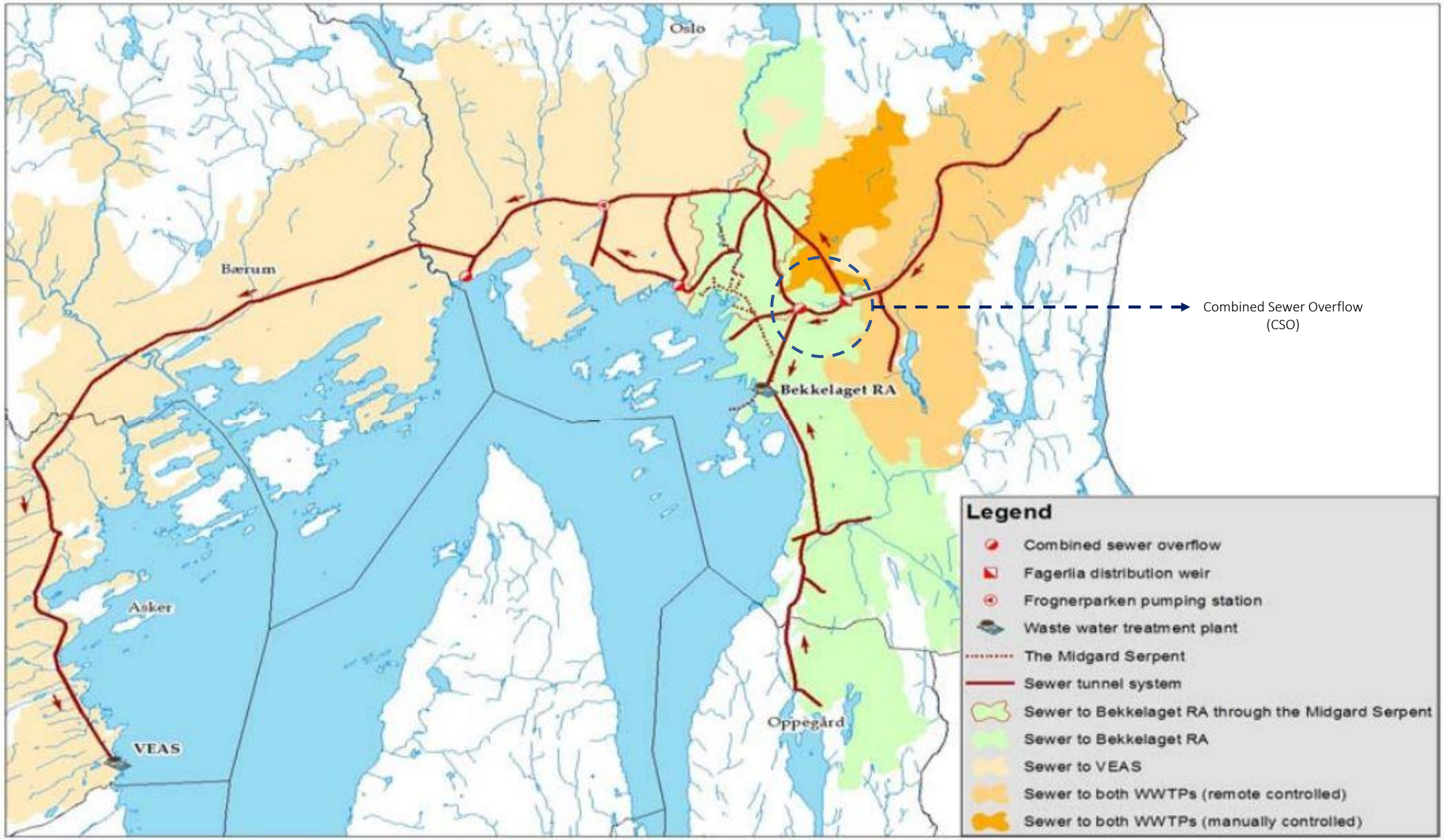


Figure 45. The map shows the sewage system in the city. Source: Application Form for the European Green Capital Award 2019

Precipitation and CSO

Precipitation shows an increasing trend through the last 120 years. The largest annual change have occurred between the two most recent normal periods.

The figures show the increase in precipitation which would put the existing strained stormwater management infrastructure under significantly more pressure. This results in the risk of increased incidences of combined sewer overflows (CSOs).

It is therefore very important to mitigate CSOs occurring as much as possible, as the changing climatic conditions suggest that if nothing is done, then extreme flood events (and hence CSOs) are expected to increase in frequency.

Figure 46: Average mean annual precipitation in Norway 1901-2020. The horizontal lines represent the consecutive 30 year average (normal) values 1901-1930,1931-60, 1961-90 and 1991-2020. Met report 2021

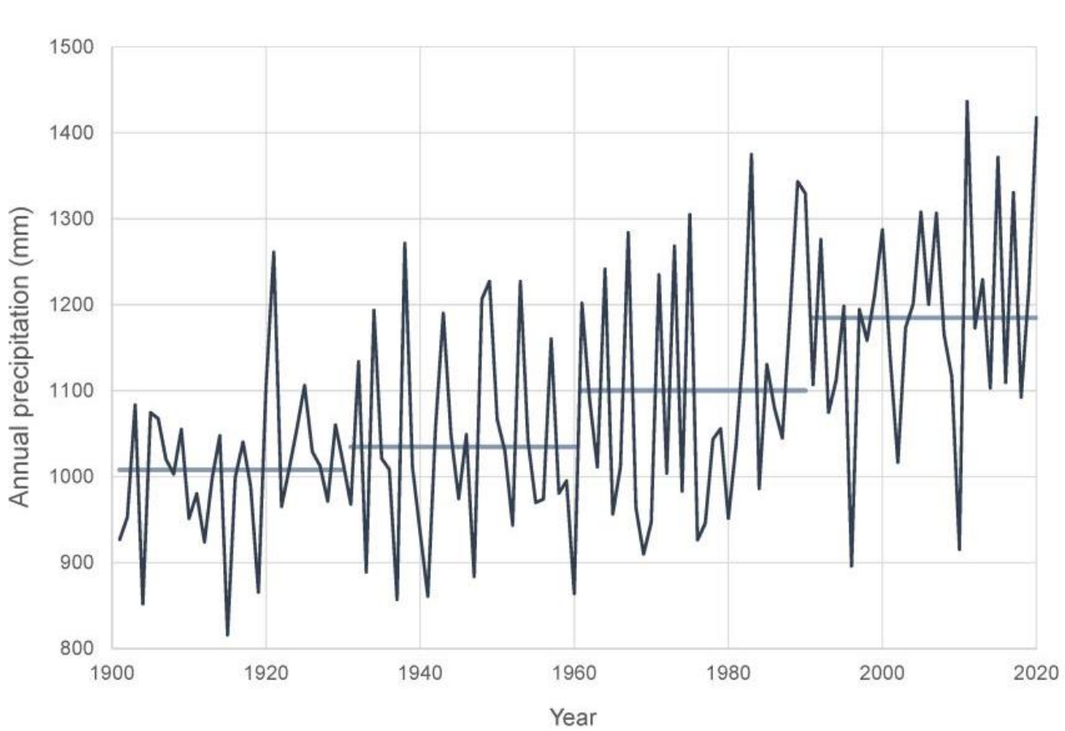


Figure 47. Precipitation annual trends with significance of trend per decade, Norway, from World Bank (2021)

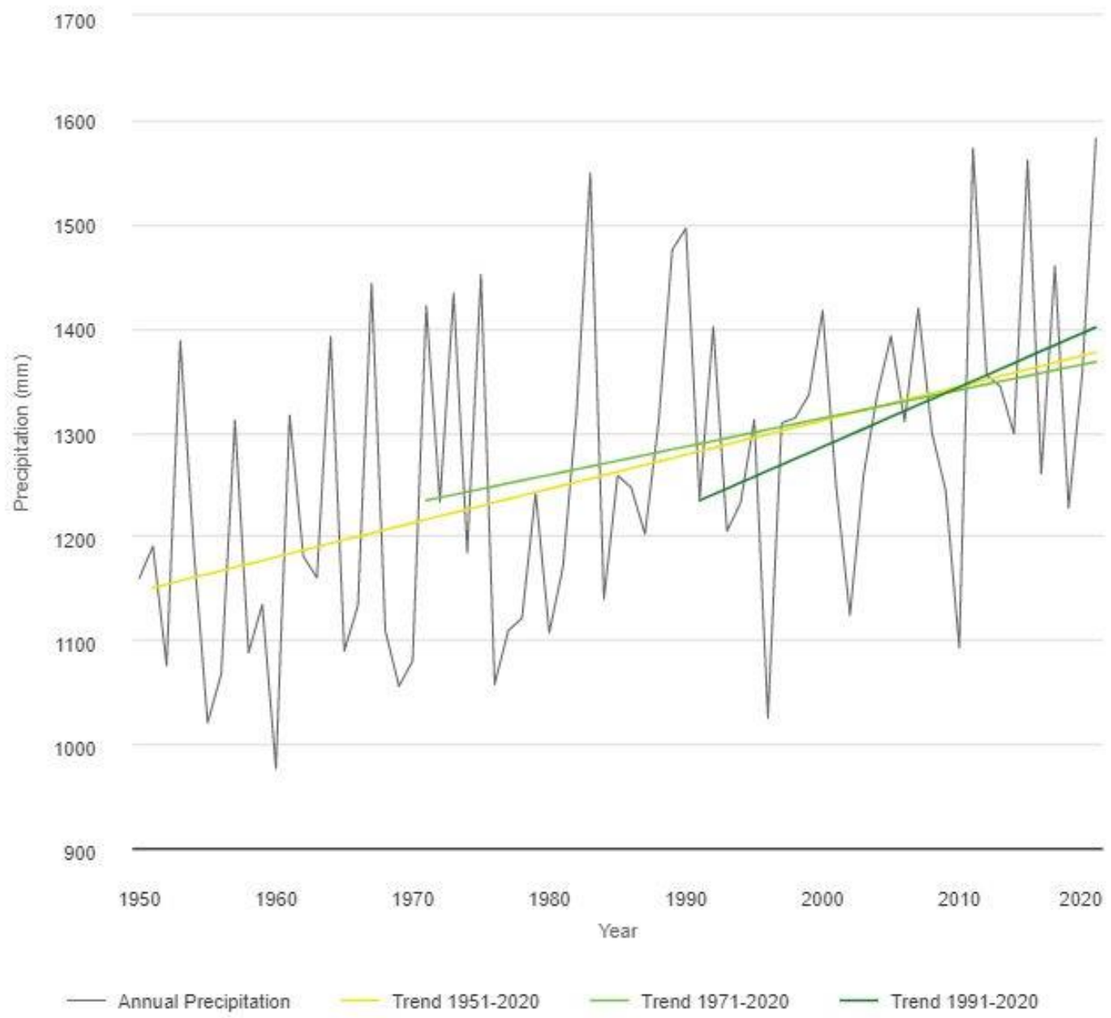


Figure 48. HIstorical orthophoto,(Norge i bilder)

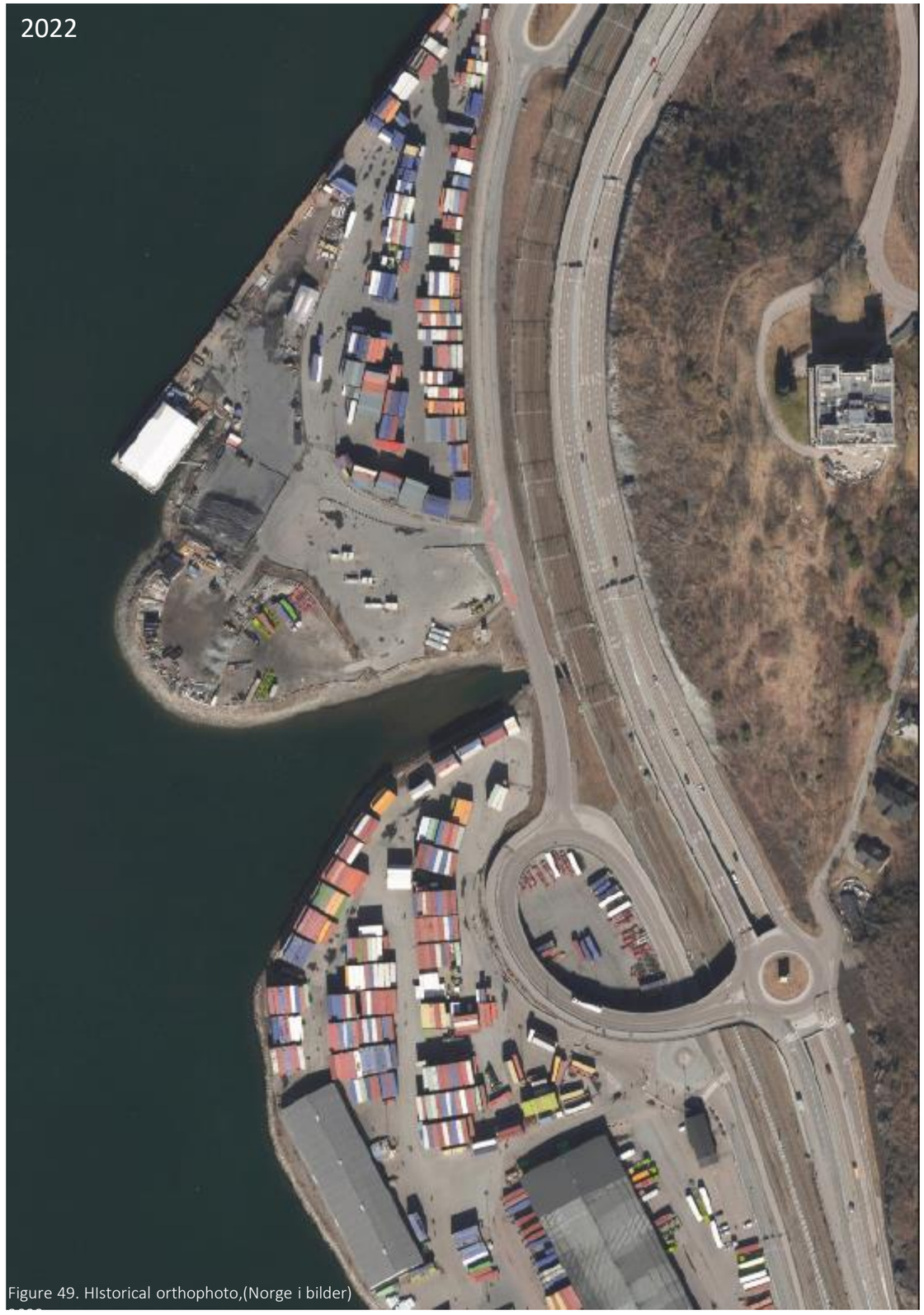


Figure 49. HIstorical orthophoto,(Norge i bilder)

Figure 50. illustration, Team Asplan Viak, 2022

Figure 51. illustration, Team Norconsult, 2022

Figure 52. illustration, Team AART, 2022

05. DESIGN PROPOSALS

Team Asplan Viak
Asplan Viak
MAD Arkitekter
Biota Naturkompetanse
NaturRestaurering AS
Gjenbrukbar AS
Rådgivende biologer AS

Team Norconsult
Norconsult
Urbaniq

Team Aart
AART Architects
Edit AS
Hydrateam
Morten Bergan, Pandion Energy
Benjamin Kupilas, NIVA
Maja Karoline Rynning, TØI

In February 2022, Hav Eiendom, and Oslo Havn (Oslo port authority), jointly announced the prequalification process for the parallel assignment concerning the development of the entire Grønlikaia. The plan for Grønlikaia is divided into sub-areas.

In case of Grønlikaia, instead of approaching a few selected architectural firms, Hav Eiendom invited all architect and landscape architect offices to apply, culminating in a total of 118 unique applications that were subsequently evaluated based on their competence, references, and understanding of the task, with an emphasis on their approach to social and ecological sustainability, a crucial element in the development of Grønlikaia (Hav Eiendom, 2022).

The outcome was a well-curated team composition that ranges from large, established offices to newer and emerging firms.

For the fifth sub-area called “Buffersonen” which is the topic of this thesis, three teams were selected (Team Aart, Team Asplan Viak and team Norconsult) to give their design proposals for the buffer zone to function as a buffer between the city and the port operations in Sydhavna, with great emphasis to be placed on nature restoration.

These teams have addressed the issues in this area in a very inclusive and comprehensive way.

In this chapter I have looked into these three design proposals for the buffer zone area. I will analyse each design proposal and mention about any possibly not covered problem and will try to have a small contribution to the possible improvements.

Hav Eiendom and Oslo Havn have an ambitious vision for the "buffer zone" around Alna river’s outlet with nature restoration above and below water forming an integral part of the Harbor Promenade's design towards the city (Hav Eiendom, 2022).

It has been important to work with the landscape both above and below water in order to best create an urban area in social and ecological interaction with the fjord.

The primary function of the zone in south of Alna is to creat space for urban outdoor activities and nature restoration on land and at sea.

Summary of the recommendations from Hav Eiendom and Oslo Havn for Buffersonen/ Kongshavn Nord:

1. Masses should be handled locally to the greatest extent possible and large new fillings are not recommended.

2. The buffer zone must have a real buffer effect.

3. It is advised that construction within the buffer zone should be regulated as an area reserve for the city.

4. The buffer zone will be an important supplement for outdoor recreation areas in Grønlikaia and a significant public space for the whole city.

5. The buildings at Kongshavn Nord should function as a visual and noise buffer.

6. It is advised to restore nature with a focus on life in a saltwater environment.

7. The creation of life at the end of the Harbor Promenade is crucial for both safety and wellbeing.

8. The development of the buffer zone ought to strengthen Kongshavnveien and the impression of close proximity to Ekeberg.

9. The buffer zone must be seen in connection with the design of Munkehagen and the emergency harbour. (Hav Eiendom, Oslo Havn, 2022)

Design Proposal by Team Asplan Viak

Figure 53. The island landscape, new buildings and Ekebergåsen, Team Asplan Viak, 2022

credit : Oslo Havn, Hav Eiendom and Asplan Viak

Design proposal by Asplan Viak

The proposed development endeavors to establish an urban ecological priority area, where an innovative island landscape at the outlet of the Alnaelva will nurture ecological diversity above and below the water surface.

Their approach is to establish a nature-rich, circular, energy-plus area that caters to the benefits of the fjord, natural diversity, and the community at large.

The buffer zone will serve as a verdant public space, strategically designed to address both the ecological and social needs of the urban environment. Moreover, the buffer zone will primarily function as a buffer between the forthcoming urban and residential development and the perpetual industrial port operations in Sydhavna/Kongshavn.

The objective of the scheme is to sculpt a fresh landscape that optimizes the area's ecosystem while simultaneously promoting sustainable urban and residential development and port operations.

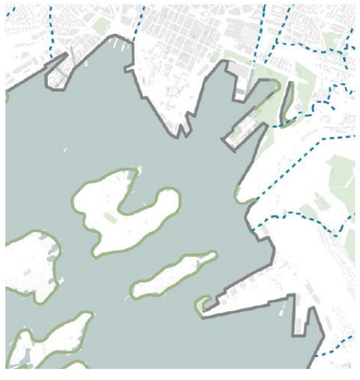
Based on their astute analysis, the buffer zone is ideally situated with optimal solar conditions, and its picturesque landscape space facilitates a good visual contact with the entire inner Oslofjord. The strait located between Bleikøya and Hovedøya forms a distinctive landscape space, directing the gaze westward, in line with the typical direction of the Oslofeltet.

The project intends to establish nature for nature's sake, representing a unique urban example of the distinctive Oslofjord nature that reinforces the protected areas in Ekebergskråningen and the islands in the Oslofjord.

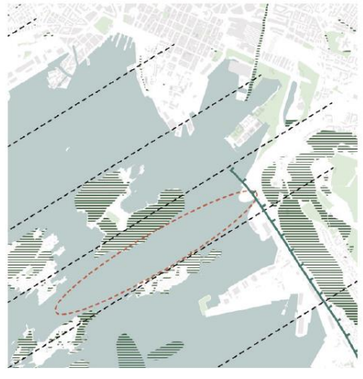
The seabed in the buffer zone is elevated to approximately -2.5 in order to provide good access to light in the bodies of water. This would enable the establishment of a shallow saltwater area with rich beach vegetation and marine underwater beds (eelgrass etc.) which has enormous potential to serve as a nursery for marine life and carbon capture. (Asplan Viak, 2022).

Figure 54. Overview image of development of Grønlikaia's sub-area "Buffer zone" in Kongshavn north. Illustration: Asplan Viak

Figure 55. Analysis illustration, Asplan viak, 2022. (Oslo Havn, Hav Eiendom and Asplan Viak)



Lack of natural beach zones is an important cause of loss of marine life in Oslofjord. (Asplan Viak, 2022)

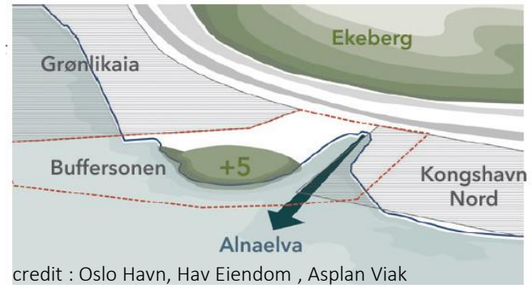


The plot is located between Ekebergskråningen and the island landscape in the Oslofjord. The main area direction in the Oslofeltet forms a clear landscape space between Hovedøya and Bleikøya (Asplan Viak, 2022).

The development of Grønlikaia will create a new beach zone. The area will form a real buffer between the future urban and residential development on Grønlikaia and industrial port activity (Asplan Viak, 2022).

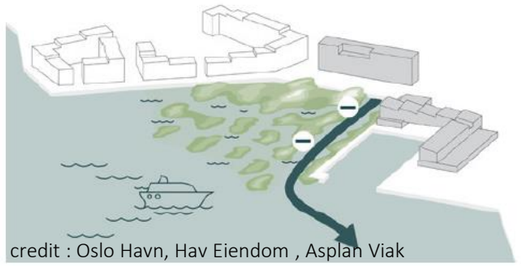
Concept

Figure 56. Concept illustration, Asplan viak, 2022

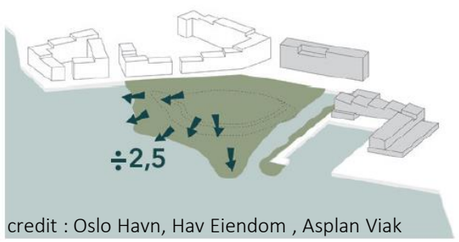


credit : Oslo Havn, Hav Eiendom , Asplan Viak

The buffer zone is located at the outlet of Alna river (Asplan Viak, 2022).

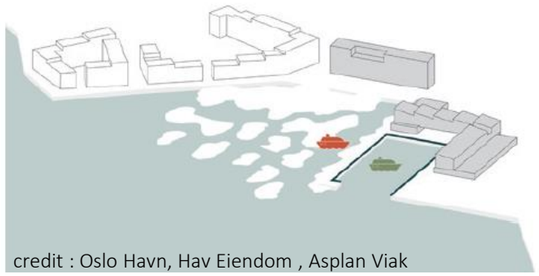

credit : Oslo Havn, Hav Eiendom , Asplan Viak

The archipelago optimizes the extent of natural beach zones, offers protection against wave action and diverts Alna's contaminated water to the south (Asplan Viak, 2022).

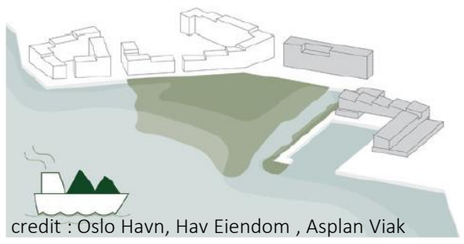


credit : Oslo Havn, Hav Eiendom , Asplan Viak

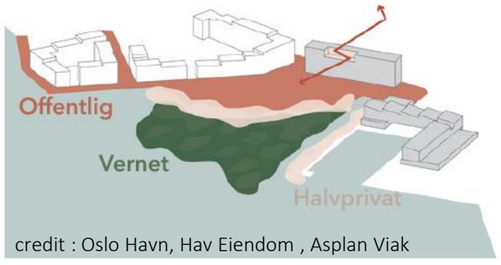
The archipelago is made up of already-existing excess masses and creates a shallow saltwater basin with beach vegetation and marine underwater beds (Asplan Viak, 2022).


credit : Oslo Havn, Hav Eiendom , Asplan Viak

In order to avoid wave movement and potential conflict with the Alna river, the harbor basin is separated from the surrounding natural area.(Asplan Viak, 2022).


credit : Oslo Havn, Hav Eiendom , Asplan Viak

Local materials are transported to create multi-layered, richly diverse Oslofjord environment, both above and below the water (Asplan Viak, 2022).



credit : Oslo Havn, Hav Eiendom , Asplan Viak

The island landscape maintains a balance between accessibility and protection in a natural way (Asplan Viak, 2022).

Contaminated water from the Alnaelva is discharged in a controlled manner into the fjord to the south.

The Alna outlet is shielded from the emergency harbor and is designed with two-sided green banks and a deep break that separates the water currents from the shallow saltwater areas.

The building is organized so that it functions as a noise, dust and visual screen against Mosseveien and the railway in the east and the harbor areas in the south.

The new island landscape is shaped according to the main stroke direction of the Oslofeltet with kinship to the other islands in the fjord.

The islands have characteristic "catamaran shapes" where shallower soft-bottom areas form tidal basins between the islands. At the same time, the islands create channels that direct the polluted water from the Alnaelva towards the south to avoid washing out the marine underwater beds (Asplan Viak, 2022).

Figure 57. Alnautløpet seen towards Ekeberg. Illustration: Asplan Viak


credit : Oslo Havn, Hav Eiendom and Asplan Viak

In order to prevent erosion and wave action, team Asplan Viak has recommended that the archipelago be protected by a seawall/ jetty of loose masses up to elevation -1 as protection against waves and larger boats entering the area. (Asplan Viak, 2022).

The island group is shaped based on the redistribution of existing clean surplus masses from the buffer zone and Grønlikaia. It is considered that the top masses are contaminated, but the largest masses in the area are clean masses that can be reused. In case of a requirement to add masses, it is suggested that suitable masses can be transported on barges. In order to establish a natural top cover and indigenous vegetation, circular soil mixtures and suitable local masses of lump lime are transported from the region. (Asplan Viak, 2022).

It is costly, both environmentally and financially, to fill in masses in the sea to create new beaches and shore zones. In addition, fillings can pose a risk to existing structures in the sea due to adverse side pressure. However, their assessment is that the Buffer Zone area is best suited for such filling as it is not dependent on existing pile structures and can accept settlements over time in the island landscape. (Asplan Viak, 2022).

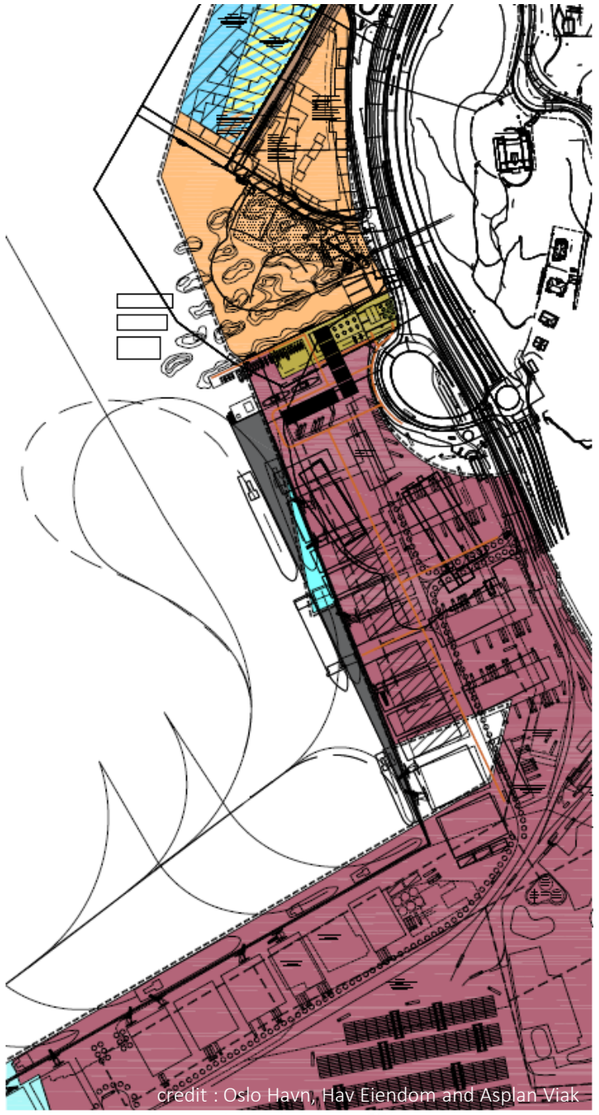


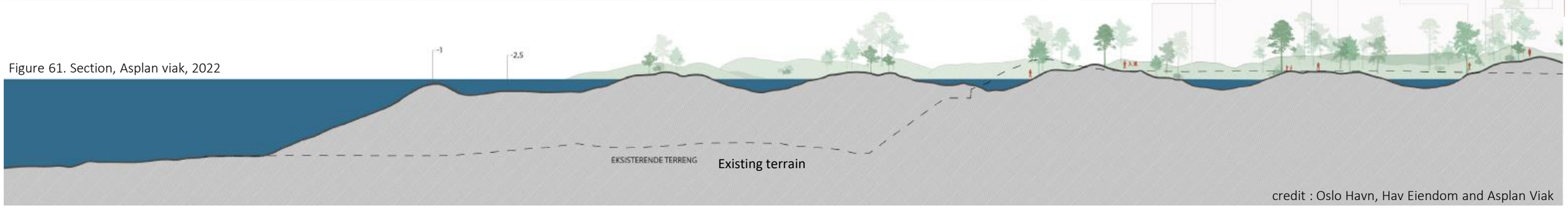
Figure 58.illustration, Asplan viak, 2022

Figure 59. Section, Asplan viak, 2022

credit : Oslo Havn, Hav Eiendom and Asplan Viak

Figure 60. Landscape plan. Illustration: Asplan Viak
credit : Oslo Havn, Hav Eiendom and Asplan Viak

Figure 61. Section, Asplan viak, 2022



credit : Oslo Havn, Hav Eiendom and Asplan Viak

Hydrology:
This proposal posits that according to the measuring station at the entrance to the tunnel the water flow is relatively smooth and it will be difficult to create a naturally functioning "delta area" based on the modest discharge of the Alna river and sediment transport. The fjord's hydrodynamics and currents significantly exceed those of the Alna, thus conferring the fjord's dominance over the adjacent coastal zone. Consequently, the buffer zone ought not to be construed as a delta, but rather as a shallow saltwater area (Asplan Viak, 2022).

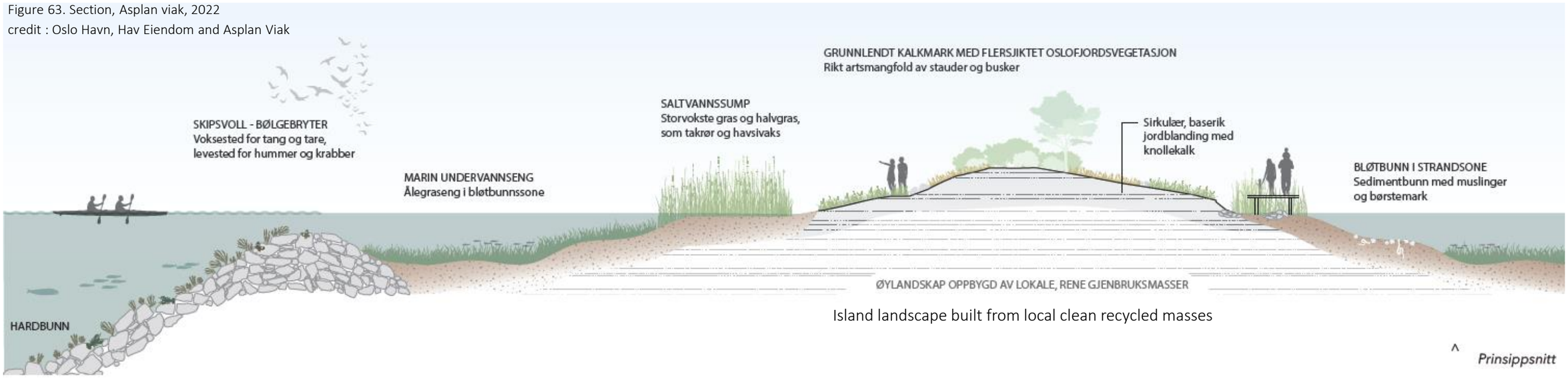
Any cleanup strategies in the outlet of the Alna are deemed impracticable and neither technically nor economically feasible due to large amounts of water and insufficiency of available space. Therefore, their recommendation is to direct the contaminated fresh water out into the fjord as far south as possible, away from shallows and active zones on Sørenga and Grønlikaia to reduce negative envirinmental impact. (Asplan Viak, 2022)

Marine biology:
The shallow saltwater basin between the islands will form a suitable habitat for aquatic organisms and will provide a secure haven for marine underwater beds, small birds for foraging and nesting. This undisturbed area will support the growth of key species, including eelgrass and sugar kelp at Grønlikaia. Eelgrass can be established on soft bottoms, whereas sugar kelp needs stone or rocky bottoms. Clams such as mussels and flat oysters filter the water and offer a rich food source for seabirds, lobsters and crabs. (Asplan Viak, 2022).

Natural diversity:
The proposed action of raising the fjord's bottom will create new areas with base-rich soil, which in turn will provide more abundant resources and larger habitats for species from the red-listed habitat type of open shallow limestone ground. Additionally, the establishment of underwater marine beds and algae is made possible, which has the potential for carbon storage in these habitats up to 40 times greater than in forests. This action will thus greatly contribute to the natural diversity (Asplan Viak, 2022).

Figure 62. The islands with a view towards the Oslofjord. Illustration: Asplan Viak
credit : Oslo Havn, Hav Eiendom and Asplan Viak

Figure 63. Section, Asplan viak, 2022
credit : Oslo Havn, Hav Eiendom and Asplan Viak



Island landscape built from local clean recycled masses

^ *Prinsippsnitt*

DISCUSSION

Design ingenuity:

The design recommended by Asplan Viak exhibits a range of commendable features, including its holistic approach, ecological conservation, sustainable development, sustainable material use, carbon storage potential, positive economic contribution, social benefits, and innovation, making it a noteworthy and commendable proposal for the urban ecological priority area at the outlet of the Alnaelva.

The design takes a holistic approach, considering ecological, social, economic, and hydrological factors in an integrated manner, showcasing a comprehensive and sustainable approach to landscape design to create a sustainable and resilient urban landscape that benefits both humans and the environment.

The proposal strikes a balance between environmental conservation and human development, facilitating sustainable urban and residential development, as well as continued port operations, showcasing a responsible and forward-thinking approach.

The design proposal minimizes negative environmental impact of polluted water on nearby areas by suggesting controlled discharge of contaminated water from the Alnaelva into the fjord to the south. Directing the fresh water from Alnaelva to the south has the advantage of creating more of a saltwater basin and salinity variation will be less as it won't get affected by the amount of freshwater flow.

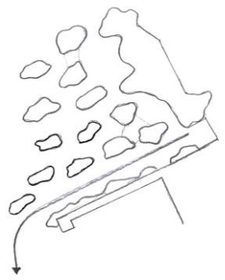


Figure 64.

The green island landscape also provides a visual connection to Ekeberg.

The design promotes the use of local masses and circular soil mixtures for natural top cover and indigenous vegetation, reducing environmental and financial costs, and showcasing a sustainable material use approach. The proposal's potential for local handling of excess mass from other sub-areas in the development can contribute positively both economically and environmentally.

The design's emphasis on creating underwater marine beds and algae provides potential for carbon storage, contributing to climate change mitigation, and showcasing a forward-thinking approach to environmental sustainability. The proposal raises the seabed to create a shallow saltwater area with rich beach vegetation and marine underwater beds, contributing to ecosystem restoration and providing a breeding ground for marine life.

Figure 65.

It also acknowledges the hydrology of the area, considering the smooth water flow of Alnaelva and the strong water masses and currents of the fjord, resulting in a design that aligns with the natural hydrological conditions of the area. The design utilizes landscape elements such as tidal basins, channels, and beach vegetation to prevent erosion, manage water flow, and create a functional and aesthetically pleasing landscape design

The proposal acknowledges the challenges of creating a naturally functioning "delta area" based on the modest water flow and sediment transport of the Alnaelva, and instead designs the buffer zone as a shallow saltwater area that complements the fjord's water masses and currents.

Indigenous vegetation, reducing environmental and financial costs, and showcasing a sustainable material use approach.

The proposal's potential for local handling of excess mass from other sub-areas in the development can contribute positively both economically and environmentally, showcasing a responsible and environmentally-conscious approach.

The design raises the seabed to create a shallow saltwater area with rich beach vegetation and marine underwater beds, contributing to ecosystem restoration and providing a breeding ground for marine life

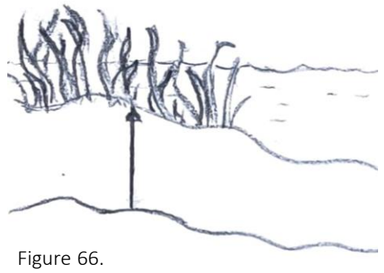


Figure 66.

The proposal provides recreational opportunities for the local community can have positive social benefits, promoting community engagement and well-being.

The Islands in this proposal can also serve as stepping stones or corridors for species movement, enhancing ecological connectivity. The archipelago optimizes the extent of natural beach zones, protects against wave action and diverts polluted water from Alna to the south.

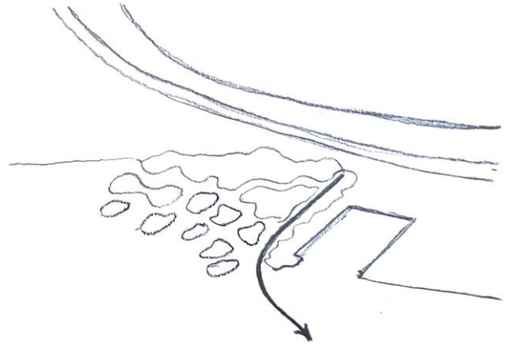


Figure 67.

This design proposal includes construction underwater that facilitate marine natural diversity.

Figure 68.

DISCUSSION

Identifying overlooked aspects and factors:

Although the design proposal is quite inclusive and comprehensive there are still some points which were overlooked in this proposal.

- Nothing is done about the pollution of Alna river and the design proposal is just directing the contaminated water away.

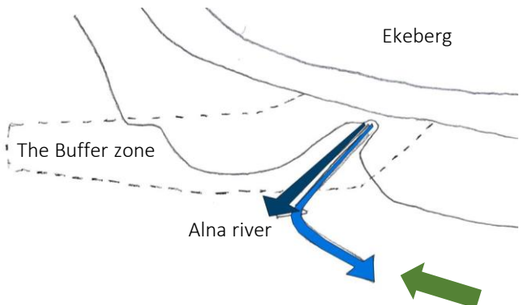


Figure 69.

- The islands will not have sufficient growth depth for larger vegetations like trees and in case of saltwater flooding vegetation on land could get affected.

Figure 70.

- Terrain processing at sea is very extensive in this proposal and the design doesn't follow the recommendation of the client that existing, filled-in mass should be left undisturbed to the greatest extent

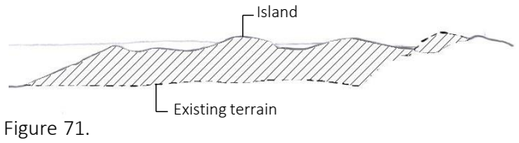


Figure 71.

Design Proposal by Team Norconsult

Figure 72. illustration, Team Norconsult, (2022), credit : Oslo Havn, Hav Eiendom and Norconsult

Design proposal by Norconsult

Fjordgartneren:

The "Fjordgartneren" initiative is a proposed concept that aims to harness the landscape both above and below water. Specifically, the concept entails creating a sloping terrain that extends below water to an elevation of -0.4, thereby generating compact and well-defined outdoor areas on land for both people and animals along the fjord. Moreover, this approach reintroduces a much-awaited tidal zone in the inner harbor basin, providing Oslo's harbor promenade with a floating zone and portal at either end. The initiative seeks to revive marine life and fauna in the air, on land, and below water, effectively creating biotopes that are inviting and conducive to sustaining life (Norconsult, 2022).

3xH (head, hands, heart) strategy:

The strategy is based on both global and local social sustainability and ecological sustainability. how these are connected and influence eachother. The strategy is founded on the understanding that these components are interconnected and that they influence one another. It involves using our heads to comprehend new goals and strategies so that we can actively and consciously use our hands for innovation and creation while opening our hearts to change, love, and concern for the fjord and its future (Norconsult, 2022).

As part of this initiative, Oslo will get Norway's first fjord gardener who will have the fjord garden as his base and will work across the rest of the fjord.

The fjord gardener's job description is based on 3xH strategy and includes children and young people, artists, politicians and researchers. All are invited to take part as fjord gardeners, contributing to taking care of both the landscape and life under water (Norconsult, 2022).

Some of the important components of the concept are traditional Norwegian coastal architecture, a tidal zone, artificial islands and the establishment of a natural water purification filter.

Taken together, these components position the Fjordgartneren as a forward-thinking and future-oriented initiative that prioritizes nature restoration, distribution of accessible and inaccessible nature on the islands, and the reclamation of the critical biological value of the coastal zone to Oslo's inner harbour. Architecture is a storyteller and carrier of identity in this proposal.

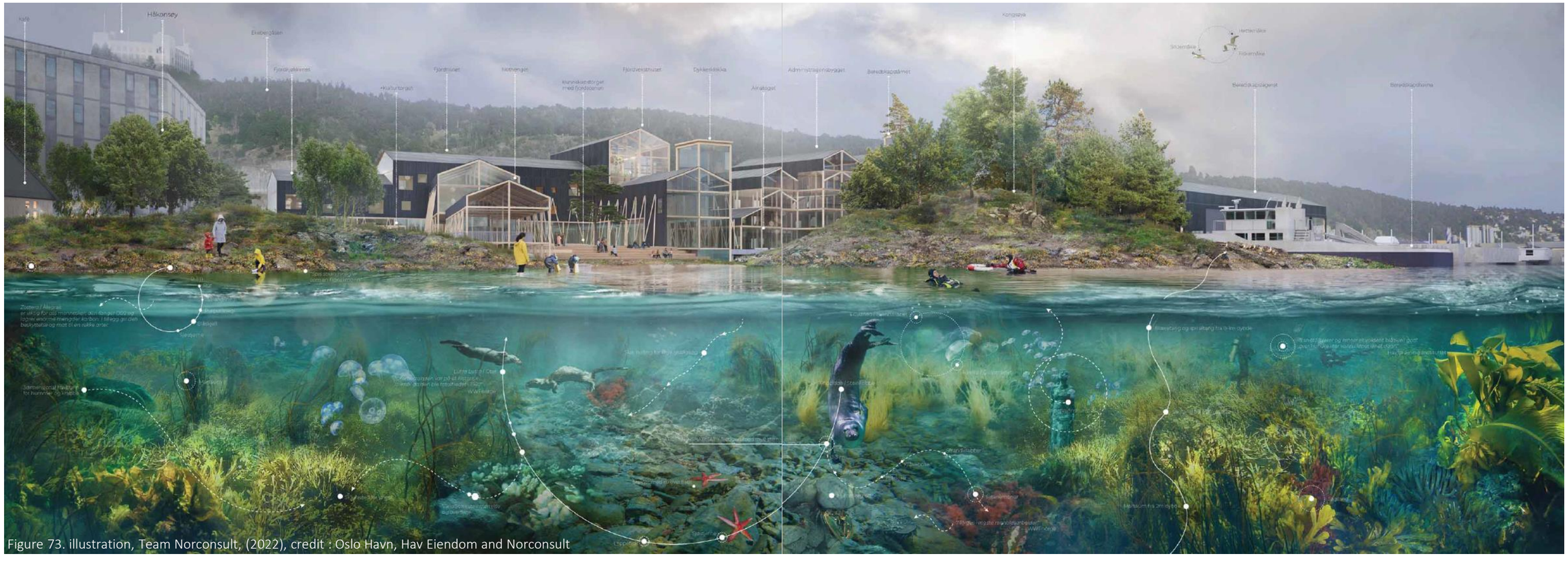


Figure 73. illustration, Team Norconsult, (2022), credit : Oslo Havn, Hav Eiendom and Norconsult

Fjord life for the people:

The demand for local social arenas is enormous; and the solution offered in this proposal is an accessible gathering place where people can convene, acquire knowledge, and engage in recreational activities without incurring charges (Norconsult, 2022).

A pool for swimming lessons is designed as a meeting place at the far end of the pier in transition to the residential districts. This is not a sea bath, but a heated pool, which accommodates those who wish to refine their swimming skills and to get used to swimming all year round in Nordic water conditions, while also offering an enjoyable experience for people of all ages and physical abilities (Norconsult, 2022).

Fjordveksthuset also features a medium-sized greenhouse for the community. The greenhouse's primary purpose is not botany but rather to serve two crucial roles in social, ecological, and economic aspects: During the prolonged and dark winter, the fjord greenhouse welcomes us indoors to strengthen ourselves mentally and socially through light, sea views, experiences in interaction with the fjord, togetherness and playing (Norconsult, 2022).

Moreover, the Fjordveksthuset has an outstanding view of the sea garden and the fjord. The house will be high-tech and contain an educational teaching facility for water purification, solar energy plant and environmental station to deal with marine waste (Norconsult, 2022).

Figure 74. illustration, Team Norconsult, (2022). credit : Oslo Havn, Hav Eiendom and Norconsult

The treatment laboratory for Alnaelva:

Today's treatment facilities near the Oslofjord have a weakness in their cleaning procedure: they do not remove the nutrients before releasing the water into the fjord. As a result, the Oslo Fjord becomes extremely nitrogen-rich and algae blooms and litter are an issue. Via the local treatment plant at Grønlikaia, Norconsult proposes to do more than what the municipal plants do. They plan to establish an educational exhibition that will fully show the effort required to purify water once it has been contaminated. Under the Fjordveksthuset an educational cleaning process for the river water will be established. A pipeline from the channel upstream ensures a partial flow into it. A glass floor between that and the first floor will give a good overview of the cleaning process of dirty river water. The process of getting clean water in the fjord may be seen by students in school classes, who can learn about it. . The water must pass through a number of chambers in order to obtain pure water. (Norconsult, 2022).

To get clean water, the water travels through different chambers:

1. grate: a grate ensures that the biggest fragments and trash are separated.

2. Sand trap: in this chamber the water must pass through a sand filter.

3. Biological purification with bacterial control takes place.

4. The process of hemical purification in which chemical substances take the pollution to the bottom.

5. Furthermore, the water will be pumped to an outdoor facility at Alnatorget.

6. The water is directed through open passages to submerged chambers containing wetland trees and plants. The plants are subsequently given nutrient-rich water. The nutrients in the water are absorbed by plants.

7. water can be directed into different biological chambers for further purification. Levers that direct the water toward additional filtration and a number of biological compartments can be operated by kids and young people.

8. The last chambers output is clean water. (Norconsult, 2022).

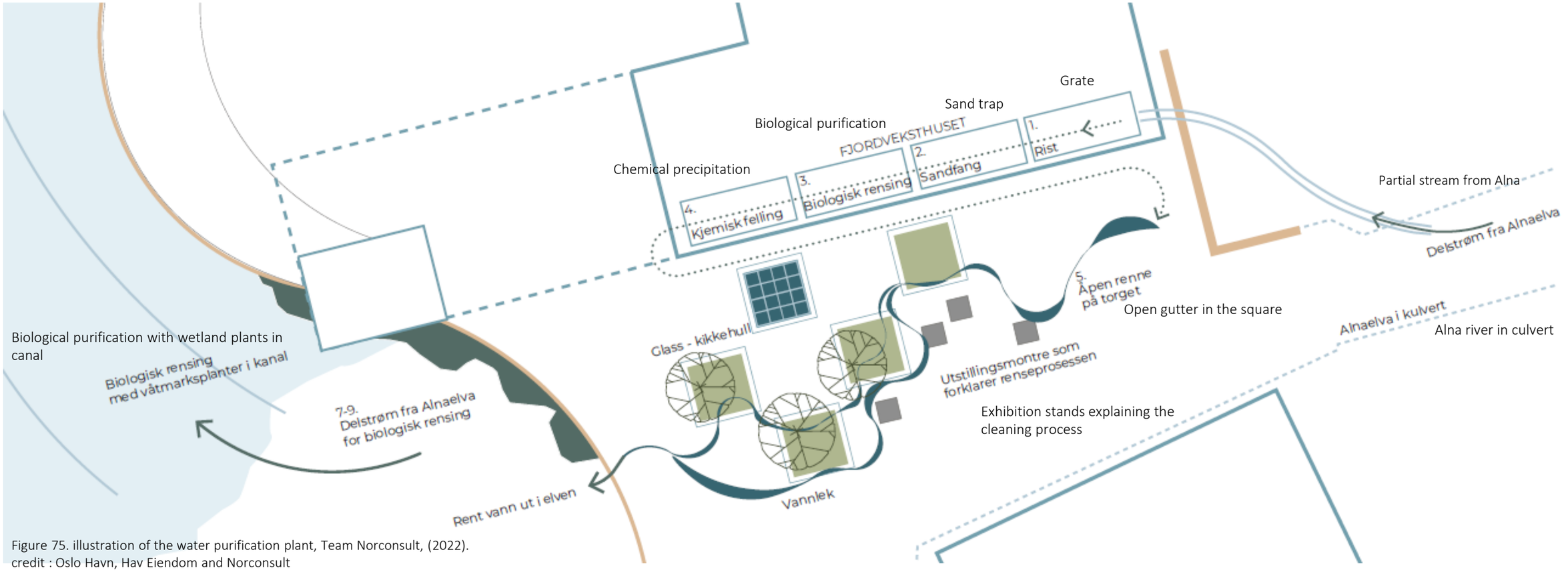


Figure 75. illustration of the water purification plant, Team Norconsult, (2022).
credit : Oslo Havn, Hav Eiendom and Norconsult

7 arenas for fjordgartneren:

Oslo’s inner fjord basin will have a spot to experience the tidal zone. By lowering the terrain from the generally regulated elevation of +3 to an elevation of -0.4 ,a dedicated riparian landscape is established for exploration and investigation of life in the fjord. The idea behind fjordgartneren is to create a location where the fjord's native plants and animals are given priority, but where visitors are also welcome. (Norconsult,2022)

1 Fjordpromenaden: The fjord promenade continues as a promenade through the Fjordgartner, which consists of expansive fields of greenery with Oslo’s native plants. Although this urban area is furnished, it must also have lots of room for people to walk around, interact, and enjoy the fjord.

2 +Kulturtorget: The culture square serves as a meeting place for the various cultures in Oslo. The square is conceptualized as a place where cultures are linked to the sea. Sea food can be the main theme. The square will also have its Fjord kitchen where visitors can learn to cook and taste dishes based on the sea inspired by recipes from all over the world.

3 knowledge square with the fjord scene: The stage is where concerts, lectures and presentations are held in a blue context. By inviting schools and kindergartens and other groups , you will be able to teach them from the stage but also invite them down to the shore garden where they can actually experience the condition of the fjord with their own eyes and hands.

4 Renseportalen - Alnatorget: Alnatorget is situated above the outlet of Alna river to the fjord. The furnishing at Alnatorget recreates the outlet visually and experientially. There are various plants in plant beds and pools to filter the water for nitrogen from the Fjordveksthuset. There are also peepholes down to the river.

5 High tide and low tide in fjaerehagen: At high tide the area is less accessible to people and more of a peaceful place for flora and fauna. The area is divided into different zones where it will be possible to study various habitats and methods to reestablish underwater landscapes. The landscape will become more accessible during low tide. Then there are opportunities to discover and look into what is hidden in the changing landscape. In the winter, this will be a location where it is safe to move around and go exploring on the ice.

6 Håkonsøy: Håkonsøy is situated at the first green buffer against the residential areas in the north. The island is a gathering area where everyone is welcome to sit down. The island is accessible for free and has a simple café in the historic house that is being relocated there. The Oslo islands' native vegetation will make up the island biotope, where visitors can swim, grill, and enjoy a picnic. The terrain leads down to the fjord on a number of different paths.

7 Kongsøya: As the second green buffer, Kongsøya is situated to the south between the shore towards Håkonsoy in the north and the Alnaelva’s mouth into the fjord. With higher ground, greater flora, and more trees, the island is primiraly for wildlife. (Norconsult, 2022)

Figure 76. illustration, Team Norconsult, (2022). credit : Oslo Havn, Hav Eiendom and Norconsult

On the east side of Fjordgartneren, islands have been created as terrain embankments with vegetation between the buildings and the road. The vegetated terrain embankments will serve as a noise buffer against the road.

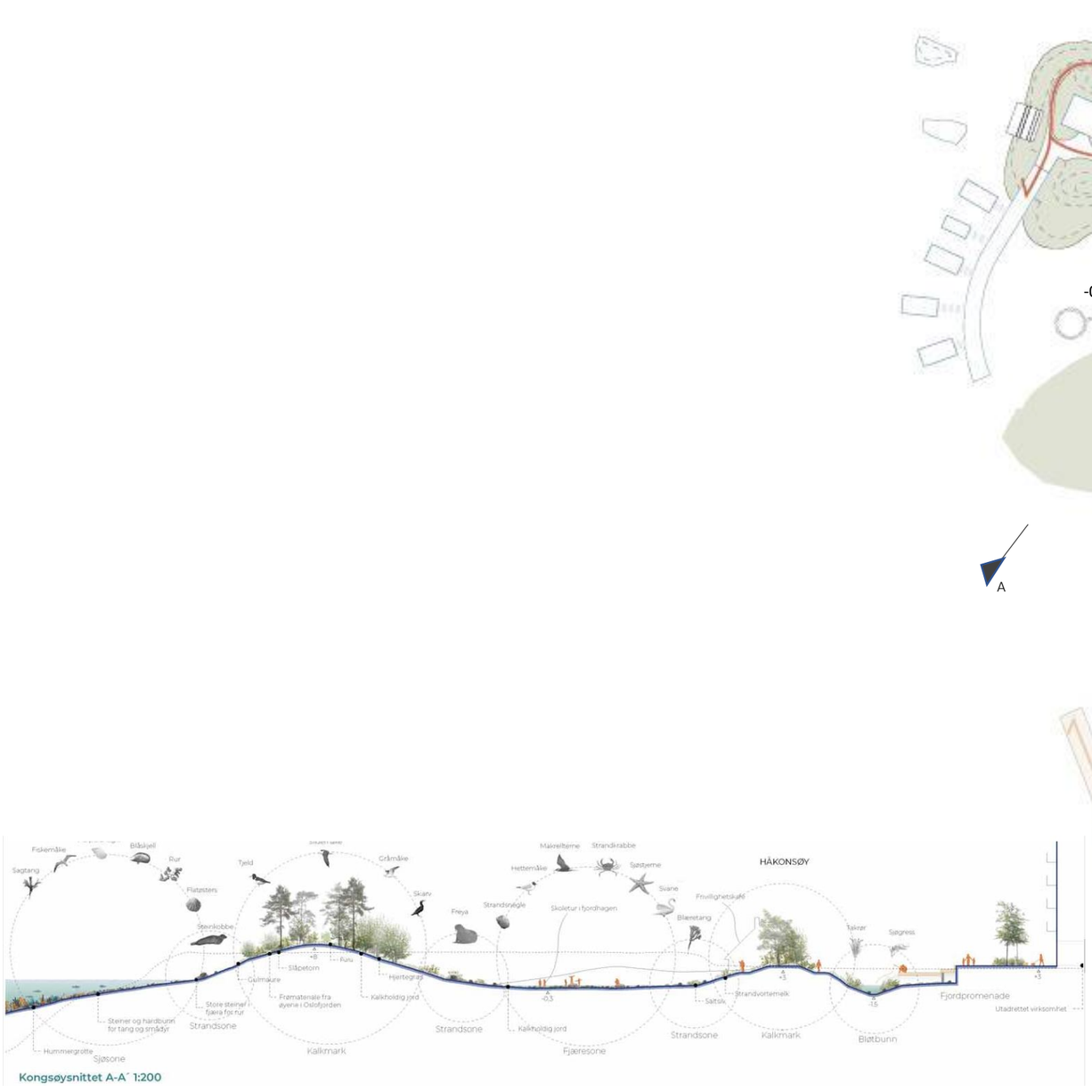


Figure 78. Section A-A, Team Norconsult, (2022). credit : Oslo Havn, Hav Eiendom and Norconsult

Figure 77. Mobility, Team Norconsult, (2022). credit : Oslo Havn, Hav Eiendom and Norconsult

DISCUSSION

Design ingenuity:

The design proposal by team Norconsult is quite commendable when it comes to landscape architecture in an urban context; by designing landscapes in several dimensions, both above and below water, as well as ensuring both user-friendly and sustainable solutions now and for the future.

Hav Eiendom and Oslo Havn have commissioned the Fjordgartneren as an illustration project for the Buffer zone at Grønlikaia and Norconsult's team will design the buffer zone at Grønlikaia.

The concept presents two islands with an intermediate tidal zone, where one island is not accessible to the general public. The zone between the islands will increase the water area useful for biodiversity.

Figure. 79

The island which is not accessible to the public, is primarily for wildlife and has a terrain hight of elevation +8 and more vegetation and trees as it is a buffer against the hectic and noisy activity in the emergency harbour. The hight also ensures good elevation above the sea level and flood target and is suitable for the establishment of root systems for larger plants as trees. Typical vegetations that is found on the islands of oslo fjord will be established and local fauna will thrive.

Figure. 80

With holistic solutions Fjordgartneren concept will create future sustainable solutions in the coastal landscape. Traditional Norwegian coastal architecture, a tidal zone, artificial islands and the establishment of a natural water purification filter are some of the important components of the concept.

The Fjordgartneren is future-oriented and an example of a project where nature is given greater scope.

The proposal is laudable for emphasizing nature restoration, distribution of accessible and inaccessible nature on the islands and taking back the important biological value of the coastal zone to Oslo's inner harbour.

The concept proposes a naturally soft landscape in sloping terrain that extends below the water to elevation -0.4, creating compact and defined outdoor areas on land for people and animals along the fjord. This soft landscape design allows for the reintroduction of a tidal zone in the inner harbor basin, providing opportunities for marine life and fauna to thrive.

It also proposes the creation of social arenas, such as a pool for swimming lessons, Fjordhuset for administrative functions and other fjord-related activities, and Fjordveksthuset with a medium-sized greenhouse for people to gather, learn, and experience the fjord in a social, ecological, and economic perspective.

The educational exhibition and treatment laboratory for Alnaelva, showcases the process of water purification from dirty river water to clean water. This provides an educational opportunity for school classes and visitors to understand the importance of water purification and environmental conservation and allows people to see what it takes to clean the water after polluting it.

Promotion of cultural exchange through the fjord promenade and culture square is another unique feature of the proposal.

The proposal is close to the existing terrain, and island measure relates to the delimitation of existing infill, which reduces the need for mass interventions and infill at sea.

Overall, the Fjordgartneren design proposal is unique and innovative due to its integrated approach to landscape design above and below water, its holistic 3xH strategy, the concept of a Fjord Gardener, focus on social sustainability and accessibility, educational and interactive elements, and emphasis on nature restoration and cultural identity. These features make it a compelling and forward-thinking design concept for Oslo's inner harbor.

Identifying overlooked aspects and factors:

Although the proposal demonstrates a strong alignment with ecological sustainability, resilience to climate change, social and cultural relevance, technical feasibility, and aesthetic and functional qualities, the following points have been overlooked:

- It is very expensive to purify water at the outlet. Cleaning the water upstream too can be considered because that's where the pollution comes from.
- Combined Sewer Overflow (CSO) is another point which was not covered in this proposal and can affect the project. It is crucial to consider CSO as the changing climatic conditions suggest that extreme flood events (and hence CSOs) are expected to increase in frequency.

Design Proposal by Team Aart

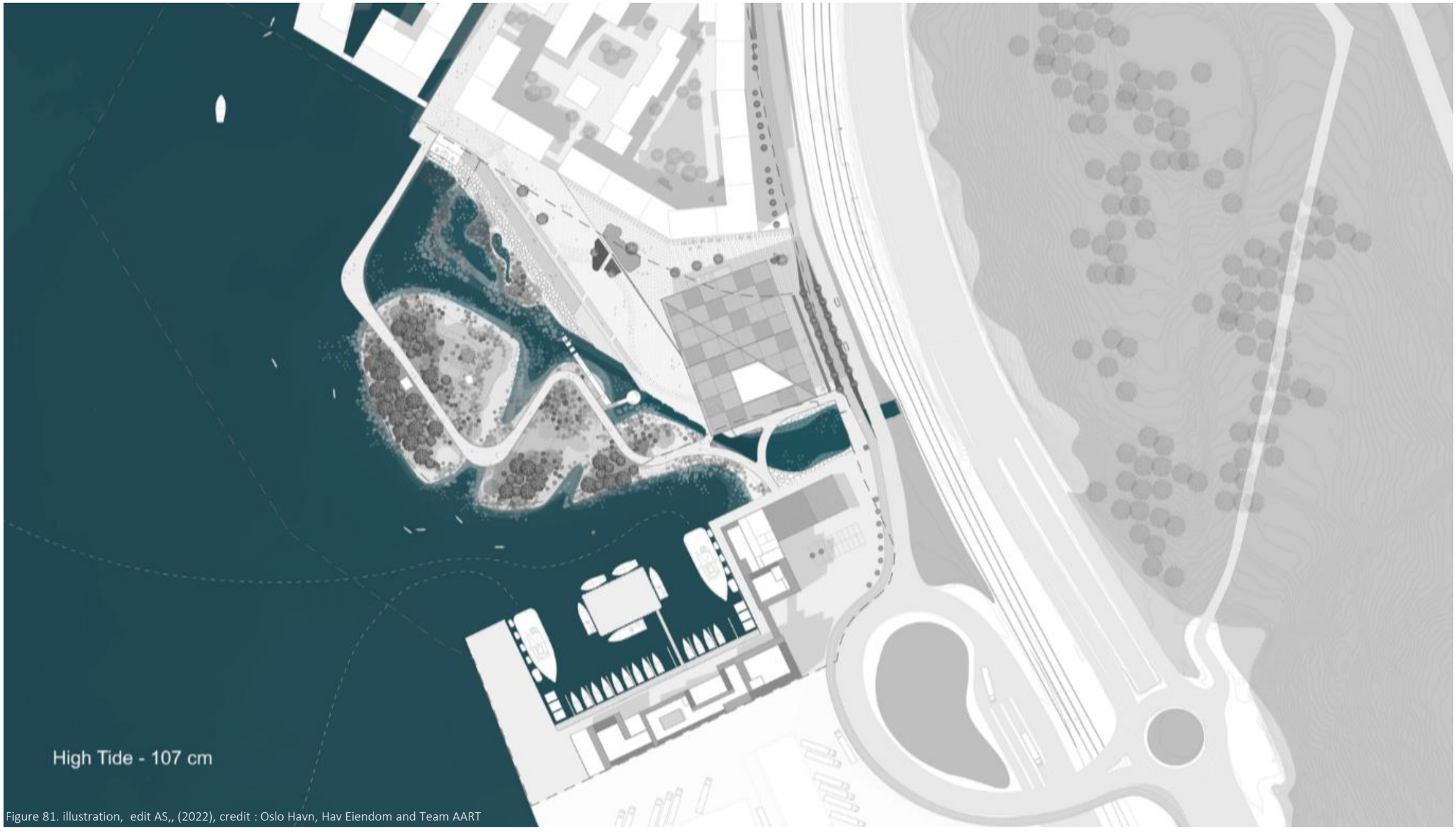


Figure 81. illustration, edit AS,, (2022), credit : Oslo Havn, Hav Eiendom and Team AART

Kongshavnfjordpark — A centre for marine knowledge:

The project proposes to create a marine knowledge centre called Kongshavnfjordpark. The starting point is the proximity to the fjord, the missing Alna river delta, and the underlying geology. From this a naturum for the city emerges which is a center to welcome visitors to a natural area(edit. AS, 2022). The Swedish concept of Naturum is to create a doorway to nature that is worth visiting, with the goal of educating the public and motivating visitors to go outside and independently explore nature. Naturums should provide exhibitions, scheduled events, and outdoor nature interpretation on their property or nearby.

The landscape uses the existing condition as a starting point and gives it shape using the cut and technique. The topography within the park will be built using all non-polluted excavated materials (edit. AS, 2022).

The new river channel will help to create the Kongshavn dyke which will work in three ways; 1. a new, beautiful, and biodiverse river delta will be created within the park as a result of the Kongshavn dyke re-directing the river water towards the park, 2. due to the currents from the river it will be easier to manouver in Kongshavn, and 3. since sedimentation will not occur in Kongshavn less dredging will be required, improving the environment for marine life.

When Kongshavn is built, it will need to be dredged; this material can be used to keep the excavated material flowing locally by being used in the new riverbed and along the islands. (edit. AS, 2022)

Furthermore, the former river delta of Alna is situated beneath the new Verket development. Although the first layer is most likely contaminated, there may be valuable, very fertile sedimentary deposits beneath this that can be recycled into the new river delta at Kongshavn. (edit. AS, 2022)

Figure 82. illustration, edit AS,, (2022), credit : Oslo Havn, Hav Eiendom and Team AART

Ten Recommendations for the site by team Aart:

1 Restore the mouth of the Alna River and create a delta linking city, port, river and sea.

2 ICON - Norway's first "Naturrum" and marine knowledge centre; restoring and re-establishing the river delta and creating landscapes that can adapt to climate.

3 Using local resources and materials as a pilot project on site landscape and structures.

4 create nature-based solutions for cleaning and monitoring the river upstream instead of establishing costly solutions downstream.

5 Demonstrate the hidden phenomenon that lies in the underlying geology.

6 Be patient and allow the landscape to be shaped over time giving the city's population green fingers.

7 Create a neighbourhood both under and above water which has people and nature as co-habitants.

8 Design the landscape and the structures such that activities and programs are carried out both inside and outside, enabling participation from all age groups.

9 Create a team that can advance the vision with the help of users and leadership.

10 combined play and education throughout the park. (Team AART, 2022)

Figure 83. Photo: Falck Ytter, Oluf Vilhelm, Oslo's city archive

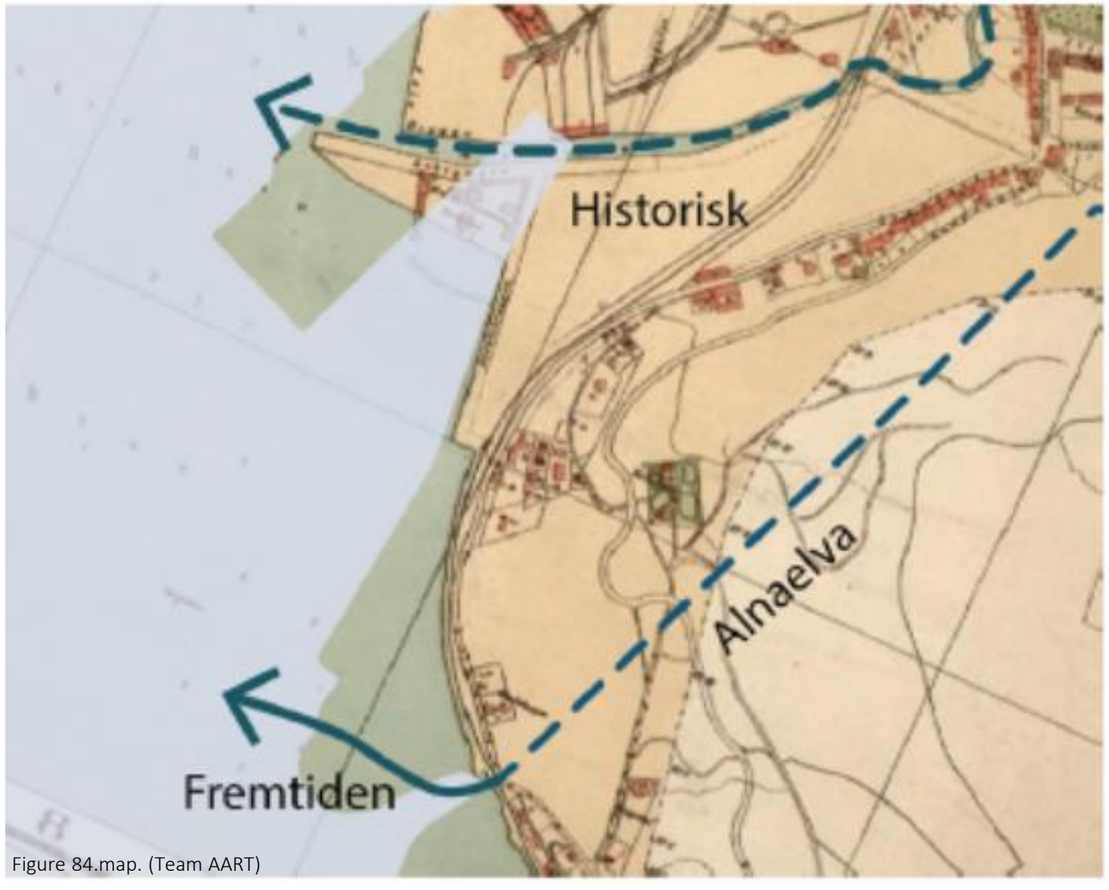


Figure 84.map. (Team AART)

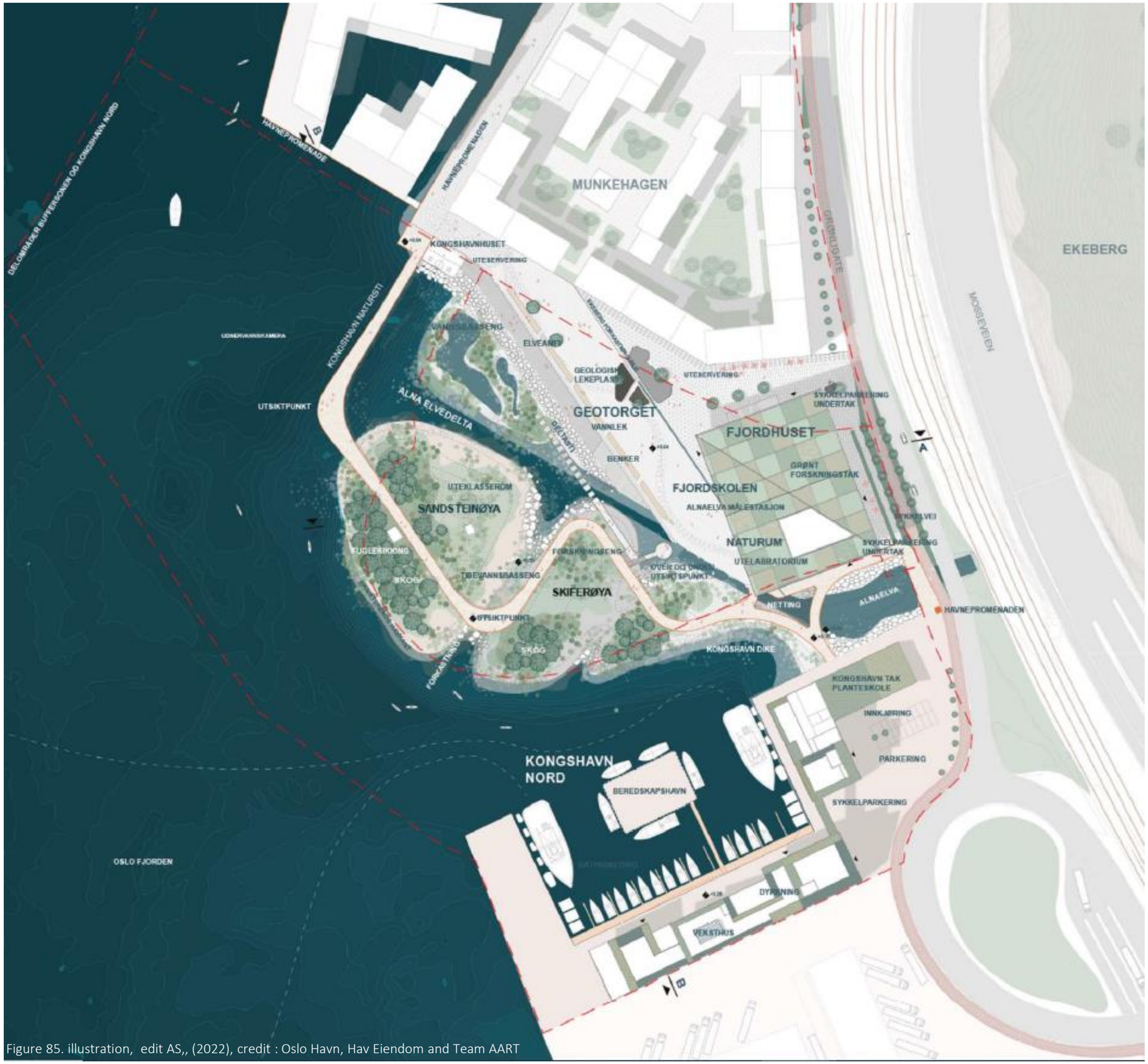


Figure 85. illustration, edit AS,, (2022), credit : Oslo Havn, Hav Eiendom and Team AART

The new river delta is designed as a dynamic landscape that changes with the tides and fluctuation in river water volumes, and to minimise potential dredging of the emergency port.

Alna has persistently suffered from deleterious impacts of pollution, however, the establishment of Kongshavn Fjordpark is anticipated to catalyze a paradigm shift in this regard.

Instead of a costly cleaning infrastructure at the river mouth, which would be of limited effectiveness downstream, the project intends to utilise simpler technologies to instill stewardship over the river. Proposals entail the placement of small monitoring devices upstream throughout the river which transmit feedback loops to a small monitoring station located within the Fjordhus that can be visually accessible to the visiting public. Strategically located near industrial and commercial zones, these monitoring devices are expected to make it easier to hold them accountable for pollution discharges into Alna. (Team AART)

The proposal by team AART suggests twisting of the river's outlet and establishing a new delta.

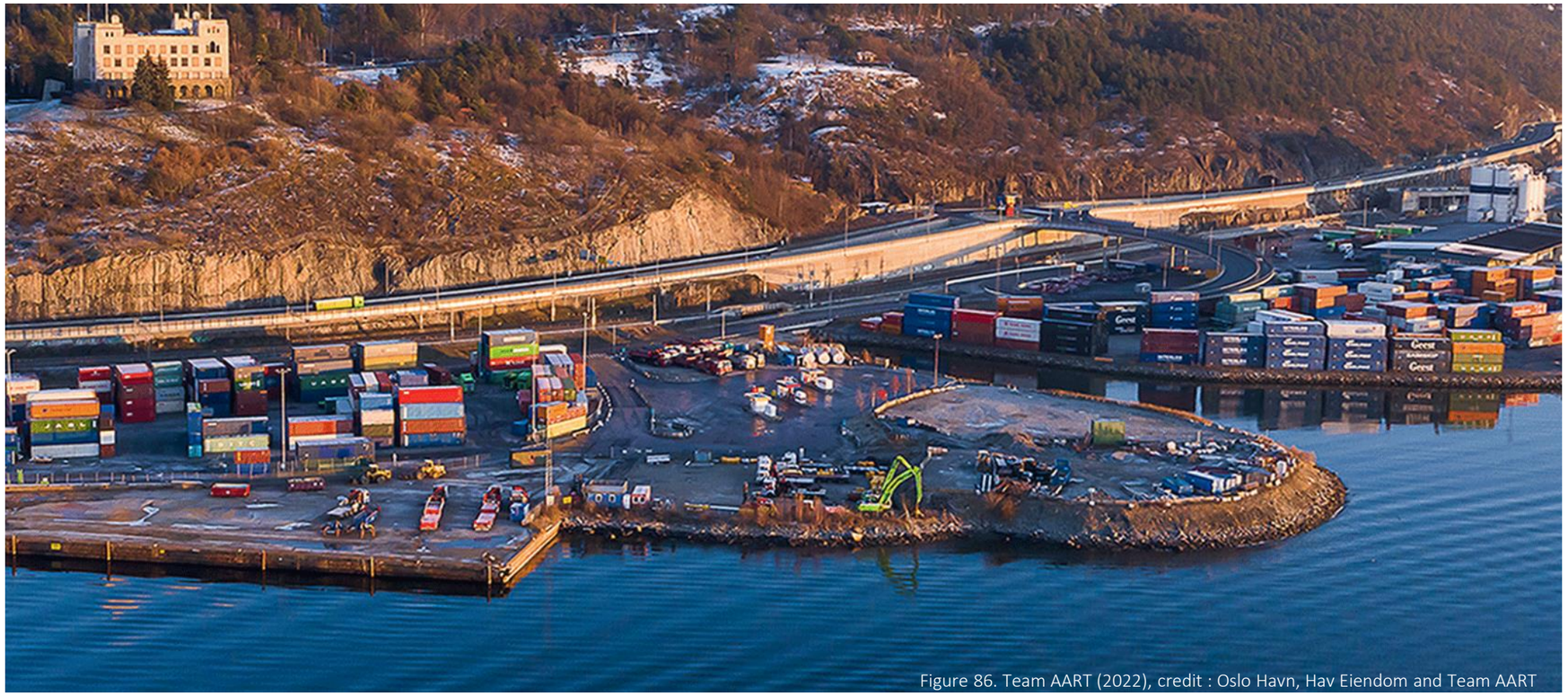


Figure 86. Team AART (2022), credit : Oslo Havn, Hav Eiendom and Team AART

Figure 87. illustration, edit AS,, (2022), credit : Oslo Havn, Hav Eiendom and Team AART

DISCUSSION

Design ingenuity:

The proposal highlights the importance of dynamic landscape planning, minimizing dredging impacts, promoting pollution monitoring and stewardship, prioritizing ecological restoration, and serving as a catalyst for positive change in addressing pollution. sustainable and innovative approaches in the design and management of river deltas, with a focus on environmental resilience, biodiversity conservation, and community engagement.

a holistic approach that takes into account various aspects such as geological features, aesthetics, ecological balance, and contextual relevance. This integrated approach shows an appreciation for the complexity of the site and the need to consider multiple factors in the design process.

Restoring the mouth of Alna river and creating a delta highlights the importance of reconnecting the river with the sea, which can have positive impacts on the city, port, river, and the surrounding ecosystem. It emphasizes the need for ecological restoration and creating linkages between different natural elements.

The idea of "Naturrum" and marine knowledge centre showcases the innovative idea of establishing a nature and marine knowledge center, which can serve as a hub for education, research, and conservation efforts. It highlights the importance of promoting environmental awareness and understanding through a dedicated facility.

The proposal emphasizes the use of local resources and materials for the site's landscape and buildings. This approach promotes sustainability, reduces environmental impacts associated with transportation, and fosters a sense of local identity and culture.

The recommendation for nature-based solutions for cleaning and monitoring the river upstream underscores the significance of implementing nature-based solutions for river management, such as using natural processes and ecosystems for water quality improvement and monitoring. It advocates for proactive measures upstream, rather than relying solely on costly downstream solutions. This feature proposes the use of small monitoring devices placed upstream in the river, which can provide feedback on pollution levels to a monitoring station. This approach promotes stewardship and accountability, making pollution monitoring visually accessible to the public and holding industrial and commercial areas accountable for their pollution releases.

Patience in allowing the landscape to shape over time: This rdesign proposal emphasizes the need for a long-term approach in landscape design and management, allowing natural processes to take their course and enabling the city's population to develop a sense of ownership and care for the green spaces.

In this proposal mean tide (72cm), hight tide (107cm) and 20 year flood have been considered.

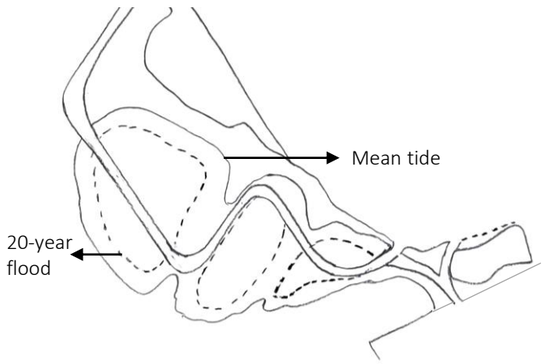


Figure 88.

In this design proposal the form is based on existing landscape with cuts and new fillings which reduces the need for mass interventions and infills at sea.

Integrated play and pedagogy throughout the park highlights the significance of play and education in the design of the park, promoting interactive and experiential learning opportunities for visitors of all ages. It recognizes the role of play and pedagogy in fostering environmental awareness and stewardship.

Minimization of potential dredging of the emergency port underscores the consideration for minimizing the need for dredging, which can have negative environmental impacts. It reflects a proactive approach in the design to minimize potential disruptions to the natural processes and functions of the river delta.

Overall, the recommendations by team Aart emphasize the importance of ecological restoration, sustainability, community engagement, and education in the design and management of the site. The integration of local resources, nature-based solutions, participatory approaches, and innovative concepts such as a nature and marine knowledge center and integrated play and pedagogy, are notable features that deserve appreciation.

Identifying overlooked aspects and factors:

The following points were not considered in this design proposal:

- There are more hard surfaces on the land with little vegetation in this proposal and there is a little untouched nature left by designing the harbor promenade on the island.

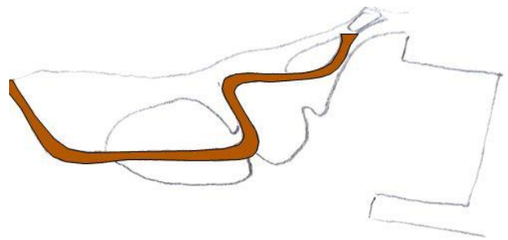


Figure 89.

- The focus is not on marine species in seawater in the area which doesn't follow the client's recommendation for re-establishment of nature with a focus on life in a saltwater environment. Freshwater/brackish water, will result in limited species diversity (because of salinity variation).

- In case of existing barriers upstream less materials will be transported by Alna river that can result in less deposition at the outlet which will not be sufficient to create a delta.

Figure 90.

06. CONCOLUSION

CONCLUSION

The primary goal of this thesis was to respond to the research question: *How can the estuary of Alna river and its surrounding area (Buffersonen) be transformed into a fjord landscape that optimizes the area's ecosystem and participates in nature restoration at Oslofjord and at the same time contributes to human wellbeing?* I encountered the complexity of this question throughout this research process, and I have tried to explore it carefully.

The background and theory chapter provided pertinent knowledge on various spatial scales, revealing the Anthropocene's intricate interconnections. The case area analysis offered information about historical and current situations. It was accordingly revealed that the transformation of the estuary of Alna River and its surrounding area (Buffersonen) into a fjord landscape that optimizes the area's ecosystem and contributes to nature restoration at Oslofjord while enhancing human well-being requires a multifaceted approach that integrates scientific principles, ecological considerations, and social aspects.

Here are some detailed points that I propose to be considered in this transformation:

Ecological restoration: The transformation should prioritize ecological restoration measures that aim to restore and enhance the natural ecosystem of the estuary and surrounding area. This can include habitat restoration, such as the restoration of wetlands, salt marshes, and eelgrass beds, which are crucial for supporting the biodiversity of the area and improving water quality . This can involve removing invasive species, planting native vegetation, and creating habitat features such as rock pools, boulder clusters, and submerged structures to promote biodiversity and improve water quality. Restoring natural hydrological processes, such as tidal flow, sediment dynamics, and freshwater inflow, should also be considered to support the functioning of the estuarine ecosystem.

Native vegetation and Biodiversity conservation: Conservation of local biodiversity should be a key focus of the transformation. Using native vegetation in the landscape design to support local biodiversity and ecosystem resilience. Incorporate a variety of habitat types such as rocky shores, mudflats, and shallow waters to provide diverse niches for different species and promote biodiversity. Measures to protect and promote endangered or threatened species should also be integrated into the transformation plan.

Increased biodiversity: providing new habitats for a variety of plant and animal species, contributing to increased biodiversity in the area.

Sustainable land use: The transformation should consider sustainable land use practices that minimize negative impacts on the environment while supporting human well-being. This can include avoiding or minimizing land reclamation, reducing pollution from urban runoff, and promoting green infrastructure, such as green roofs and permeable pavements, to manage stormwater and enhance habitat connectivity.

Public access and recreation: Provide public access to the transformed estuary landscape through pathways, boardwalks, and observation points. Design recreational areas that are compatible with the natural ecosystem, such as bird watching platforms, educational signage, and nature play areas, to encourage public engagement and appreciation of the estuarine ecosystem and educate visitors about the estuarine ecosystem, its importance, and the ongoing conservation efforts. At the same time design some parts of the landscape as areas not accessible for public where fauna and flora can live in peace.

Public engagement and education: Public engagement and education are crucial for the success of the transformation. Involving local communities, stakeholders, and decision-makers in the planning and implementation process can help ensure that their perspectives, needs, and values are considered. Educational initiatives, such as interpretive signage, citizen science programs, and nature-based recreational activities, can also promote public awareness, appreciation, and stewardship of the transformed fjord landscape . Educating and engaging people about nature and consequences of human activities is vital.

Science-based monitoring and adaptive management: Monitoring and adaptive management should be integrated into the transformation plan to assess the effectiveness of the landscape design and restoration measures, identify potential issues, and inform adaptive management strategies. Scientific monitoring can include ongoing data collection, assessments of water quality, habitat condition, biodiversity, and ecosystem services, as well as social and economic indicators to ensure success in optimizing ecosystem health and human well-being. Based on the monitoring results, adaptive management strategies can be implemented to address any emerging issues.

Consider the long-term in planning: Considering future weather extremes, sea level changes, and how nature will change over time must all be considered and through interdisciplinary cooperation, the strategy and planning for the restoration of Alna's outlet should be coordinated with those for upstream.

Creating island/ islands at the estuary of Alna river which was proposed in all three designs has the potential to provide new habitats for a variety of plant and animal species, contributing to increased biodiversity in the area. In addition, a well-designed island can enhance the visual appeal of the estuary, creating a more attractive and inviting environment for both people and wildlife. Incorporating habitat creation and restoration techniques in the island design can greatly enhance biodiversity. This can involve planting native vegetation, creating diverse topographies, and incorporating natural features to provide niches for different species. Restoring wetlands, salt marshes, and other ecologically important habitats can also contribute to increasing biodiversity in the estuarine ecosystem.

Consideration of connectivity is crucial for promoting biodiversity. Designing the island in a way that promotes connectivity with adjacent habitats and surrounding landscapes can facilitate movement of species, gene flow, and ecosystem functioning. This can involve creating channels, open water passages, and wildlife corridors that allow for movement of species, especially during tidal and seasonal changes.

The islands can also create clear difference between areas for intensive outdoor life and areas where birds, plants, insects and other wildlife can live in peace.

However, It is important to take into consideration that creating an island/islands at the estuary may result in environmental impacts such as changes in hydrology, sediment dynamics, and disturbance to existing habitats, which need to be carefully assessed and mitigated. Uncertainty is another concern in case of creating islands as long-term sustainability of the island project may be uncertain due to potential changes in environmental conditions, species interactions, and human activities, which need to be carefully monitored and managed.

Last Remark:

The topic of this thesis reveals that the challenges in the area at Alna river's outlet are really complicated and although the design proposals by highly qualified teams are quite inclusive and comprehensive, it has been difficult to cover all the aspects and address all the problems.

This case is also an example of how past decisions like putting Alna river in a culvert and making the tunnel which can't be or will be very difficult to undone can affect us today. It is evident that the past decisions have a significant impact on the present and future development of the area, underscoring the importance of making informed decisions based on accurate data and analysis.

The most recent information from Norconsult team who are selected to work further with the development of the buffer zone area confirms that design of this area is still a matter of debate as it is yet to be decided if they will have Alna river entering the fjord in this area or not. It is also still under discussion that in case of having Alna river at its present location will the river be allowed to flow into the designed area or will be blocked from entering it and should flow straight out to the fjord.

The ongoing debate regarding the presence and flow of Alna river in the buffer zone area highlights the need for an integrated and collaborative approach that involves various stakeholders. This approach can ensure that the design of the area is sustainable, resilient, and adaptable to the changing needs and demands of the ecosystem and society.

Grønlikaia's buffer zone project serves as a poignant example of the challenges and opportunities that arise when developing a complex and dynamic landscape. While there are no easy solutions, it is crucial to continue engaging in ongoing dialogue and collaboration to address the challenges and maximize the opportunities for creating a sustainable and vibrant ecosystem that benefits all.

LIST OF FIGURES:

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