Recreational spaces as a result of flood protecting barriers

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A case study of Höllviken, Scania, Sweden, 2013-09-05
Abstract
It is estimated that climate change will affect sea levels by rising them up to a meter higher than today's levels within the next century. Due to the sedentary human life style and popularity to live close to water fronts, these changes will force people to eventually either move or protect the built environment against the rising sea. When introducing remedies to a site at risk, venues for recreational activities can be implemented as a result of the barriers used to prevent floods of coastal areas. By studying comprehensive plans and various sites of flood protective remedies from around the world, ideas on how to cope with the future risks of Höllviken, Scania, Sweden was obtained. Literature about remedies, engineering and policymaking, was studied along with multifunctional spaces in order to create venues for recreational activities as a result of implementing flood protective barriers.

Findings show that the viewpoints on what interests to protect varies. By using a geographical approach in the inquires and implementations of a protective flood barrier, interests, both economical, social and environmental are attained. The implementation itself of protective features is not all that there is to it, the policymaking is a major part of the whole strategy to protect a specific site.

Strategies varies depending on different historical cultures in different areas, by learning from each other (i.e. America and Europe) a more complete policy on how to tackle various situations may be achieved. Compared to surrounding municipalities, it turns out that Höllviken and Vellinge municipality is in the front for the region when it comes to planning for future fluctuations of the sea level.

The proposed design for Höllviken in this thesis includes two sites. At the northern shore land is reclaimed from the sea in order to make room for features to protect and handle excess water, together with a site that can be used for recreational activities. At the southern shore, Kämpinge bay, the discussion is more about how to use the current sand dunes as a measure to protect against the sea level rise. Since sand dunes are easily eroded, features implemented in order to protect the dunes against destruction by human activities and wind/waves. The pathways also eases the accessibility to the beach.

Keywords: Höllviken, Rising sea levels, Flood protection, Recreational spaces, Recreational activities, Spatial planning, Urban design
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Introduction

Human beings have always urged to live close to water, historically for food/water supply and transportation. Today the reason is more for recreational purposes, and the price of water front homes gives a hint on how popular it is to live next to the water. Of the metropolitan cities with more than 5 million citizens, 65% located at the coast (Hunt & Watkiss, 2011), and the urge to develop new housing opportunities along waterfronts are strong, i.e. London (Lavery & Donovan, 2005). A majority of the global population lives at coastlines and along rivers. These areas are under stress from daily, seasonal and yearly dynamic changes as well as long-term changes in form of precipitation, rain- and dry seasons and rising water levels connected to climate change (Bogren, et al., 2008, Ruddiman, 2008).

Since the natural environment along waterfronts is dynamic in nature, human settlements create a conflict between how nature behaves and our will to control the environment. The latest published report from IPCC (2007) indicates a rise of up to 5,4°C in average temperature until 2100. This can result in a >1m rise of the sea level within the next 100 years (Bergström, 2012). The modeling to anticipate these changes improves all the time. Today it is estimated that 200 million people live on the coastal line less then 5 m above sea level, this number is estimated to increase up to 500 million by the end of this century.

In order to prevent damages along the coastlines and riverbanks various enforcements constructed (Yu, 2010, Munaretto, et al., 2012). These can vary from levees like the system in New Orleans (van Heerden, 2007) that is built to protect the city from hurricanes (Bijker, 2007), to barriers like the enormous constructions outside Netherlands (Coljin & Binnendijk, 1998), as well as pumps, excess water basins etc.

While building the protective barriers, new outdoor public spaces can be created as a result of reclaimed land. Depending on what kind of protection, (Johansson & Andersson, 2008) and the scale of the construction different uses can be obtained. In this paper it will be investigated how recreational spaces and the infrastructure of these places, can be outlined in a case located in southern Sweden, Scania, the municipality of Vellinge and the specific site of Höllviken. Also, an interdisciplinary approach to planning with geographical thinking will be implemented in order to consider both environmental and human interests in the planning process.

Aim of the thesis

This thesis aims to investigate how the construction of barriers that aims to protect habited areas from flooding, can bring multifunctional areas to a site after implementation.

To aid that, cases have been studied in municipalities nearby and internationally.
Research questions
- How can the construction of barriers with the purpose of preventing floods create new grounds for recreation and social interaction in the chosen site?

- How can the infrastructure and functions be outlined in a site like this in order to make as much use of it as possible, during flooded periods as well as during normal sea levels?

Method and materials

Literature
In order to give a background of the main issue for the thesis, a literature review was conducted upon the anticipated effects that climate change is going to influence coastlines and rising sea levels. The Intergovernmental Panel of Climate Change (IPCC) and the report from 2007 were used as a reference of the anticipated changes of the temperature and sea level, since this document is the most common and referred inquire used for the issue today. Further, literature was reviewed and discussed that varies from scientific books (i.e. Earth’s Climate; Past and Future, Ruddiman, 2008) together with various peer-viewed articles that integrates planning issues of flood protection with the changing climate and water levels.

By studying methods and models from various places around the world, a wide-ranging evaluation was obtained in order to present a concept design that will contribute to a suggestion on redevelopment for the specific site that is investigated in this paper.

In order to design a system/implement a concept of a system that will prevent an area for flooding and create new recreational spaces, knowledge about barrier and dam construction was needed. Articles about the engineering of these dams and barriers worked as a foundation in order to find a suitable barrier/dam for the specific site, together with articles about strategies, both policy making and physical implementations.

Finally, literature regarding recreational and public spaces was considered in order to design a space for recreational activities, regarding outlines of the infrastructure and layout for in the new design concept.

Case study
The case study consists of one case, where a concept design is applied. In order to investigate, compare and get background data of implementations for this case several other sites, both Swedish and international where considered. An analysis of threatened values was conducted and of existing and anticipated problems that afflict the site in the future, regarding climate and sea level changes, and opportunities to develop the site further.
To study the case of Höllviken, a site visit was done in the beginning of April 2013. The site visit included overall survey of connections to the specific sites considered in the design proposal as well as a meeting with officials at Vellinge municipality. Further the plan of action for the municipality was investigated thoroughly in order to do the design. This design was made in consideration with the guidelines that the municipality together with a consultancy has come up with in order to cope with changes in climate and sea level for the next 100 years.

The other two Swedish sites investigated, regarding comprehensive plans, are Malmö, the main city of Scania, and Lomma, a small municipality at the Öresund, slightly north of Malmö. The reason for using these two cities in comparison is due to their geographical position. All three cities are located on the west coast of Scania, within 40 km from each other, yet they have different experiences regarding flooding due to the variation on protection and prerequisites at the different sites.

**Selection**

The world wide cases studied via literature was chosen for their similarity in climate to that of the main case, Höllviken. Further, these cases were studied due to the fact that implementations regarding protection against sea level rise are already implemented and evaluated. Also, further implementations for these sites are planned regarding the findings of evaluations and inquiries. When planning for new developments, in this case flood protection, it is helpful to regard what has been done earlier and evaluate why certain implementations are functional and others aren’t. The remedies studied serve different purposes besides the main purpose of protecting from floods. In the design proposal different aspects of each case are considered.

Corton, a small town on England’s east coast, was chosen due to the fact that remedies have been implemented for a couple of decades. Municipality officials are now debating whether to continue upgrading the defense or to let it fade away due to economic aspects. A problem Höllviken may face in the future due to its similarity in size as Corton.

London and the Thames estuary system was chosen due to the possibilities the defense system provides for further developments along the flood plains. By reclaiming land it is possible for Höllviken to further develop the town, contributing to the economical aspect of the project.

The Boston case of the protective system was discussed with an economical aspect. By re-enforcing already built and natural features, costs are kept to a minimum and investigating alternatives there is to an area under threat from the raising sea knowledge was attained and implemented in the Höllviken case.

Zeeland was studied due to the long-term ongoing implementations of flood barriers and the land-use of the area. Originally the area was a delta, and agriculture was the main land-use. It has changed and today mainly aims towards tourism and recreational coastal activities. Also, the infrastructure and
transportation system in Holland as a whole is dependent on the barrier systems. These are all important aspects for the case in Höllviken.

The Swedish cases were chosen to get a broader picture on how municipalities are planning to cope with the future changing prerequisites in the surroundings of the main case, Höllviken. Therefore coastal cities in the same region were chosen, though they have some differences compared to Höllviken. I.e. Höllviken has coastline both in south and north directions to different seas, which makes the site unique in Sweden.

**Study area**
The study area is set to Höllviken in Vellinge municipality, Scania, Sweden. The site is located in the far southwest corner of Sweden, with the peninsula of Skanör/Falsterbo to the west and to the east the neighboring towns are Trelleborg (12 km) and Ystad (50 km). Malmö, with direct connections to Denmark by train and a car bridge (the Öresund bridge), and major roads running north into Sweden is located 20 km to the north.

![Figure 1. The maps show Vellinge municipality's location to the right in a Sweden scale perspective and to the left in the south of Sweden with the municipality boarders. Map created by the author.](image)

Geographically Höllviken is located west of the Scanian lowland plains and technically some part of the township is located on the peninsula of Falsterbo, which separates the Baltic Sea and Öresund. Due to this feature, the town has cost lines both in south and north. The year is divided into four distinct seasons with and average yearly temperature of 8,4°C and an annual precipitation of 660 mm.

The total surface measurements of Höllviken (see figure 2) are 7 km\(^2\) with an elevation difference of 0-4 meters above sea level. 4,1 km\(^2\) of the developed land
in Höllviken is located at +3 meters above sea level, 5,9 km² of the developed land is located +2 meters above sea level and 6,2 km² is located +1 meter above current sea level. The lowest lying 0,8 km², 1 meter and below, is not developed in the township of Höllviken as it is today. These low-lying areas are mainly located along the coasts, which are surrounding the town both to the north and south with a total extent of 4,6 km of which 3,7 km is sandy beaches.

Both the northern and southern beaches are used for recreational purposes, together with the nature reserve just east of the channel (see figure 2). Along the northern beach, that is separated from the built areas by the major road 100, a pathway for cyclists and pedestrians runs parallel with a horseback riding path. The northern beach is not used for bathing as frequent as the southern beach. Within the pine forest nature reserve several pathways are laid out that are used by runners and walkers. The population of Höllviken is around 10 000 people. The built environment in Höllviken is mainly scattered in a pine forest. The main type of buildings within the area consists of single-family houses, though in the northern parts of the town, multistory houses have recently been erected (up to 5 floors).

![Figure 2. The map (Alström & Åberg, 2011) shows the elevation of Falsterbonäset and Höllviken (located within the dotted line area of the map) in half meters above current sea level.](image)

The entire area including Falsterbonäset and Skanör have an assess value of 31 billion sek, and estimated actual value of 42 billion sek. For Höllviken the assess value is in total of 13,6 billion sek (4,159 individual properties) of which 11 billion worth of properties (3,175) is located on +3 meters above sea level, 2,5 billion worth of properties (1,063) between 2-3 meters above sea level and 0,1 billion worth of properties (175) between 1-2 meters above sea level (Alström & Åberg, 2011).

**Background**

In order to understand the climate, why it appears as it does and what is expected to happen in the future, a short review of historic climate is necessary. All knowledge in the scientific field of natural science is based upon earlier
recorded and measured events. To anticipate and hopefully understand what is expected in the future, models created from these earlier events are used. Depending on the purpose of the model it may consist of different components. Brown, who made a model of future floodplain development in England, used data from anticipated sea level scenarios, elevation of the ground, land cover, tidal flood patterns, policy making and built environment (Brown, 2006).

**Climate change history**

The changing climate has always been a necessity for the dynamics of the earth and the evolution of life along with the physical form of the planet. The changes we are facing today, however, are not what they naturally used to be. Natural changes tend to happen, and fluctuations have been enormous throughout time, but the changes have occurred at larger time spans than what is presently happening. Since the industrial revolution started, there has been a rapid release of green house gases that tend to warm up the surface of the earth and along with this, some other changes in the natural environment (Ruddiman, 2008).

For the last couple of centuries, when scientific observations have been available, some small but notable changes have occurred. These changes include observations such as the retracement of mountainous glaciers, that in some places they have retreated several kilometers in just two centuries, according to Ruddiman (Ibid.). Though in other places on earth it seems like glaciers have been advancing over the same period of time. The ice caps that cover landmasses are of importance since they have a significant role when it comes to sea level rise/decrease.

During the last 2,5 million years (quaternary), the earth has technically been in a glaciated era. This is not the first time this happened in the earth’s history. A hypothesis claims that the earth was entirely or close to entirely frozen about 650 million years ago. Since then there has been various glaciation periods, along with warm periods in the earth’s geological history (Bell & Walker, 2005,).

During the quaternary, glacial cycles span over approximately 100 000 years, interrupted by warmer interglacial cycles that lasts roughly 10 000 years. At the moment the earth is in one of these interglacial cycles, but it has bypassed the normal pattern by a couple of thousand years from the previous ones, according to Bell & Walker (Ibid.). The effect glaciers (the cryosphere) have on sea level is that they are holding water masses, resulting in a lower sea level than would otherwise occur. About 8000 years ago the English Channel had a water level 25 meter lower than it is today (Ibid.). The water level rose rapidly along with the melting of ice caps of northern Europe and within just 1000 years the sea level reached a level of 10 meters lower then it is today. Since then the rise has been fairly constant at 2 meters per millennia until recently.

Since the last glacial maximum (19 000 years ago) the sea level globally has risen 110-125 meters. During the same period of time the average temperature has increased just over 4°C to todays level (Bogren, et al., 2008).
Consequences of climate change
Both the natural environment and the anthropogenic society will experience changes with fluctuations in the climate. If the temperature will rise by 4°C within the next 100 years, it will become the highest temperature that the earth experienced since the last interglacial period more than 100 000 years ago. But this is no extreme for the planet itself. Various times before the earth experienced temperatures of extremes to both ends, what is different this time are the rapidness of the changes (Bogren, et al. 2008). With a slower change the society and natural environment will be able to adapt to the new circumstances, less so with a rapid change. The sedentary life style we adapt today and the urge to live close to water will enhance the problems that the rapid changes brings, especially changes connected to the rising sea level (Ibid.).

As stated earlier sea level will rise due to the deglaciation of landmasses, adding water volume to the sea, though it is stated that an increase of the air temperature will accumulate more moisture and increase the accumulation of the ice sheet on Antarctica. This helps reducing the global sea level rise, which is estimated to add 6 meters globally if the entire ice cap of Antarctica would melt. Apart from the addition of water level due to glacier melting, water expands while heated and is also affected short term by winds and atmospheric pressure (Bogren, et al. 2008). Overall for the anticipated rise of 1 meter the next 100 years it is calculated that half of this volume is added from the crysphere and the second half is water expansion due to rising sea/water temperature (Ruddiman, 2008). In a more long-term perspective, until 2300, it is estimated that the sea level will increase globally by 1,4-4 meters, if the global goals of an temperature rise of 1,5-2°C within the next century is fulfilled. These figures are difficult to estimate due to the uncertainty of deglacation, they are mainly calculated from thermic expansion of the water body (Schaeffer, et al. 2012).

Possible effects of rising sea levels
A rise of one meter in sea level may not seem that much, but the effects are severe. I.e. in Egypt about 15% of the cultivating land will be located below the sea level, in Bangladesh, about 13 million people will be affected when 17,5% of the land areal will vanish under water. The number of people affected in China by the same level of rise is estimated to be 72 million. The rise would directly affect 5% of the population world wide, along with recreation areas and other important spots of cultural and natural environments (Bogren, et al, 2008). With planning and economic capital it is possible to prevent some of the worst effects that is associated with the sea level rise. It is important to do the planning for the absolute worst-case scenario as an example from Holland shows. Holland suffered from a flood in 1953 when tidal water along with strong winds broke the barriers, resulting that the water reached 60 kilometers inland and 2000 people lives where lost.

Prevention from increasing sea levels
There are several views of how to cope with the complexity of coastal areas, where human interests act in conflict with the natural environment. This includes the relationship between biophysical, economical and social components that exists in the flood risk system, and what should be prioritized...
when planning for protection of floods (Mens, et al., 2011). McFadden is arguing to apply a geographical thinking when it comes to protect these sensitive areas from flooding (McFadden, 2008). Since geography is an interdisciplinary field of research, both a social dimension and a physical dimension are included within the approach of protecting the sensitive coastlines.

One of the fundamentals in the geographical approach is to understand the links between what is happening with the land/area over time and the solid structures/built environment created by humans and nature. By thinking geographically useful viewpoints are outlined in the planning for protecting a specific coastal area when it comes to analyzing the compartment of the site and managing the thresholds (McFadden, 2008). However flood protection systems have a history that stretches back in time for millennia’s.

The Chinese started attempts to control the Yellow River as far back as 2300 years ago. This was mainly done by construction of levees and reforestation of the riverbanks. Smaller channels from the river were dug out in order to spread the flow of water and minimizing the floods at exposed areas (Yu, 2010). In Europe flood control started at an upscale level during the Middle Ages. Levees where constructed along the riverbanks and reinforced by reforestation. America has the longest system of levees constructed in the world along the Mississippi river today, where construction started in 1927, after a big flooding event. The entire system includes 29 locks in order to control the flow of water today.

Large-scale sea flood protections originated a bit later then the river adaptations. In America extensive sea protection set off in the year 1900 when the island of Galveston, outside of Houston, Texas, was flooded after a big storm in September (Bijker, 2007). In the Netherlands it has been ongoing for several hundreds of years with small local implementations in order to cope with the sea. Originally the Netherlands was a large delta, which lately has been reclaimed from the sea due to investments including construction of dykes, islands and dams with locks to allow ships to passage to the costal docks. Though this adaptation in the Netherlands has been ongoing for centuries, the main adaptations have been constructed after the big flood event in Europe in 1953, where thousands of people where killed in the Netherlands and other parts of Europe (Yu, 2010).

**Literature review**

**Global assessment of risk of rising sea levels**

**Sustainable urban ecosystems**

Lundy & Wade (2011) are discussing ecosystems, blue-green interactions, within urban environments. The findings from the study, along a restored river system in social, ecological and physical geographical approach are evaluated through validity. Since water bodies in urban areas affect several disciplines of science and interests, it is concluded that this field of research needs an updated forum to be discussed in. Difficulties in the interdisciplinary approaches are that
spokesmen from the different fields have a different view on what to be prioritized in the planning process. One suggestion that comes out from the study is that a peer reviewed publication forum could help to show the benefits of future projects on how to involve ecosystems, both blue and green, in the urban environments in order to evaluate effects of restoration.

**Different engineering cultures**

After big failures in the protective systems, such as the ones in Europe during the 50's or in New Orleans in 2005, planners and engineers start to look into reasons that could have caused the failure. After the hurricanes Katrina and Rita in 2005, teams from the US went to the Netherlands in order to learn from their engineering and systems in use for preventing floods. Bijker investigates the differences between American and Dutch coastal engineering. It is stated in the report that risk management differs between the two countries, but that is not all to the story. In order to sort out an answer he claims that the entire technological culture between the two countries is contradicted (Bijker, 2007).

The main difference between the two cultures is how to cope with hazardous occasions, where the Americans are better prepared, while the Dutch are lacking evacuation plans plus the design of their protection system is rather about an everyday situation defense, not for extreme occasions according to Bijker. The Americans are developing strategies to mitigate flood hazards while the Dutch are focusing on “keeping the water out” (Bijker, p. 147, 2007), which was one of the reasons for the big hazardous effects from the 1953 flood, when the water broke through the barriers of Holland.

The research that is behind the protective systems in the two countries differs as well. While studies are done in the US on how sand moves, wave patterns and other natural phenomena, Dutch research is more of a practical implementation, with a focus of not to fight against the sea, but to adapt to the natural forces and how to cope with that (Bijker, 2007). This approach basically suggests that humans do not stand above the natural laws, we have to adapt to them.

**Implementation of different kinds of flood protective barriers**

When implementing a levee type of barrier, it can be combined with a pathway on top in order to get full use of the view to the sea. The levees on the other hand require a lot of spaces, which make them unsuitable for densely built areas but on the other hand makes them suitable as a recreation area in their own (Johansson & Andersson, 2008).

Another way to protect against rising sea levels is the use of walls. These can be constructed in different ways, which will not require as much spaces for the protection and can also be combined with a boardwalk on top. The walls may include openings that are dynamic with constructions that able them to close when needed. For this reason walls may be more suitable for densely built areas, areas that lack space and in ports (i.e. for leisure boats). Johansson & Andersson uses the pictures below to illustrate the different kinds of protections (2008).
Failure of flood protection

In order to evaluate and measure the flood protection capacity it is adaptable to use the term of robustness. The term robustness is used in system robustness that is the technical solution in order to prevent from floods and policy robustness that is the strategy worked out to cope with the threats. The policy robustness is measured over a period of time, i.e. 50-100 years, while system robustness is measured at a specific point or situation (Mens, et al., 2011).

When the system is put under stress that exceeds the normal situation, i.e. high tides, resistance threshold is occurring (see figure 4). During times with increased stress systems are facing two stages that are able to be analyzed, the response – how well it copes with the new stress situation, and the recovery phase that includes rehabilitation after a flood/tenure (Mens, et al., 2011). During the recovery phase water is redistributed, the area is cleansed and built environment, together with infrastructure is restored.

After stress is put on a system, it is evaluated how the system can be improved in order to cope better with plausible future scenarios, both for private household owners to municipal/regional officials for the entire system (Mens, et al., 2011). In New Orleans this was the case after the storm Betsy in 1965. Unluckily, upon Katrina’s arrival in 2005, the lessons from earlier experiences failed. Even though the storm was weaker in 2005, more the 20 times as many people lost their lives than the previous storm in 1965 (van Heerden, 2007).

Why a system fails even after evaluating and reinforcing it may be due to several reasons. Natural barriers, such as wetlands, are reduced in many areas around the world due to shift of land use and controlling of rivers. The lower Mississippi River area lost 1 million acres of wetland since the beginning of 20th century. This leads to an increased stress on the built protective systems from the ocean (van Heerden, 2007).
Other reasons for failure includes the construction itself, how well the protection is anchored and adopted to the current attributes of the area that it is implemented within. The outlines of the design could be wrong for the specific site or unpredicted situations that was not occurring during the review is striking, resulting in design fail for that reason, variables that was ignored during the analyse and construction had more importance to the protective implementation than predicted and that the maintenance was not enough. For the case of New Orleans in 2005 the crowns of the levees was 30-60 cm lower then they where supposed to be in order to cope with the predicted once in 100 year storms, i.e. Katrina (van Heerden, 2007). This occurred since sea level had risen and subsidence since the protection was built and improved, from the 60’s until 2005.

When a system fails to that extent that it reaches the “point of no recovery” (see figure 4), a regime shift is occurring. A regime shift is when the land can no longer be used like it used to be before the flood (Mens, et al., 2011). Parts of the Mississippi river delta were lost after the severe storm in 2005, but there are examples where even more dramatic scenarios occurred. In the 14th/15th century in Groote Waard, Netherlands, areas were flooded to that extent that agricultural and “industrial” grounds where destroyed so severely, that there were no possibilities to rebuild and use the land for the same purpose again. The area was taken back by nature without human interference.

![Alternative barrier/dam constructions](image)

Figure 4. The figure (Mens, et al., 2011) shows a theoretic response curve on a flood protection system when exposed to disturbance from outer forces, i.e. floods.

**Alternative barrier/dam constructions**

Aside from the levee systems such as the one in New Orleans, walls, as the one used along the River Thames and the dynamic system of the delta in the Netherlands, plenty of various protecting system exists. One multi-purpose system is rubber dams that Zhang, et al., investigates closer (Zang, et al., 2002). The inflatable system is durable and can be used in temperatures down to -40°C.

Since the 1950’s the rubber dams have been developed and installed around the globe, and the function varies from power generation to flood control and
recreation. The basic structure consists of a system that lets water in and out (through the dam), an operating unit for the inflatable rubber body and the foundation, normally made from concrete. As a dynamic system compared to protection with steel gates, the rubber dams are more cost effective and require less maintenance. The problem that may occur when using the rubber dams in cold weather is the damage that ice may cause. Another downside with the rubber dams are its vulnerability to vandalism, concluded from a study made in Hong Kong according to Zhang, et al., (2002).

Technical measures analyzed in Venice due to rising sea levels

Venice, known as a city that is disappearing into the sea, is facing some complications with the rising sea level. The new technological system that is supposed to tackle several of the anticipated scenarios for the next 100 years seems to be accurate. However, in order to cope with future permanent threats, such as rising sea levels and more frequent floods (high waters) the technical aspect is not all to it. The administrative part along with the policy makers has to develop adaptations as well. In the example of Venice this is not the present case, in order to get the full use of the developing defense system (Munaretto, et al., 2012).

The interest of protecting Venice started after a flooding event in 1966, which was a pricy event both economically and for cultural values loss. Since then, the laws of protecting Venice from floods contains objectives, responsibilities, instruments, measures and economic resources in order to compile the safeguard activities (Munaretto, et al., 2012). The barrier system itself consists of a system with 4 mobile barriers and close to 80 floating gates. Since cruising ships are frequent visitors in Venice a lock, big enough for the ships has been constructed as well in order to be able to carry out the important tourist industry for the city. The total cost, in order to fulfill the special laws outlined since the 1970’s, it is estimated that approximately 16 billion euros are needed, of which 10 billion has been used until 2009.

What remedies can be found in the literature for the anticipated risks?

Cities in general

From 2006 it is estimated that more than half of the world population lives in urban areas, cities. Historically it has been of importance to live close to water and this trend continues today with 65% of all 5 million inhabitants cities (or more) are located on low lying costal zones (Hunt & Watkiss, 2011). Changes occurring in the climate, and effects of these changes, including sea level rise, will affect city regions economically in the future. The threat from sea level rise is considered to be one of the most severe threats against the environment and social communities today (Yu, 2010).

Costal cities are of importance regionally and nationally for socio economical activates according to Hunt & Watkiss (2011). In order to achieve desired development it is shown that the approach should involve city scale collaborations, between administrative boards and stakeholders. It is preferable to keep the decision-making at local level compared to national level; though collaboration between neighboring cities is assumed to increase the desired
outcomes of assessment plans (ibid.). This field of science is still in its cradle and future studies will have to show how the decision-makers should collaborate in order to make the most of implementations that are task oriented, in order to decrease negative effects from climate change.

For costal cities the direct effects of rising sea levels include coastal erosion together with land loss, damages as a result of storm floods, salinity intrusion of the ground water, blocked drainage, etc. Indirectly the ecosystems and their current functions may change together with impacts of costal bound recreational activities and allocation of sediments (Hunt & Watkiss, 2011).

The negative economical effects of costal low lying cities may be immense within the next 100 years due to increased frequency of storms and the rising sea level. The storm Katrina that devastated the city of New Orleans is calculated to have damaged properties and infrastructure to a total worth of $130 billion. Until the year 2080 it is estimated that costal regions will suffer from storms is going to increase the costs from today’s measures, in USA by 75%, Japan 65% and Europe by 5%. By introducing proper protection against storms and the rising sea level costs can be minimized, estimations from Mumbai suggest that if the city is protected the total damage costs will end up at $33 billion, compared to $71 billion without protective levees, at a sea level rise of 1 meter (Hunt & Watkiss, 2011).

One strategy in order to cope with excess precipitation and risk of flooding is the use of sustainable urban drainage systems according to Yu (2010). These systems require setting aside land in order to store excess water from storms or extreme high tidal events. The effects resulted from these kind of systems is that current ground for housing will be able to cope with future impacts, that would damage the current drainage and also make land available for further real estate developments.

The implementations that is set, needs to find a balance between social and environmental impacts in order to make living possible and safe for citizens in costal cities in the future (Yu, 2010). Implementations needed, together with the land set aside for excess water may be reforestation together with planned wetlands that mimic the natural environment, which forms artificial eco-systems that are adapted to cope with fluctuations anticipated for the area. In Rotterdam adapt housing is being built upon the water. This may be one way for future ecological implementations on how to cope with the fluctuating water levels, since minimal measures are made to change the natural behavior of the environment. These housing areas may be built as floating or flood-proof homes with materials and techniques that allows the building to be flooded without damages, economical and social, as a result of the flooding (ibid.).

**England**

**Conflict between interests, costal protection**

In the example of Corton, a seaside village in England, several conflicts are pointed out in order on how to cope with the protective assessments (see figure 44, p.50). The conflict regards erosion and landslides along with salinization of
the groundwater and sites of scientific interest. In order to protect the cliffs from further erosion a seawall was constructed in the 1960’s that includes a pathway, a supportive construction for the cliffs and an area of steel clad timber groynes in order to break the waves. Further enforcements of the protective system have been added in the 80’s and early 00’s (McFadden, 2008). Just on top of the cliffs, holiday and residential homes for low-income and elderly people are in direct threat of the erosion, and in longer term the main road, along with other real estate and public service functions are threatened. In the policy plan reaching 100 years ahead from now, it is stated that the coastline just outside the village will be maintained, while the area north of the village will have a controlled “retreat” and in the south nothing will be done in order to protect the shoreline. It is stated that it is not sustainable in the long run to protect Corton with major investments from erosive forces of the sea and future changing conditions. (McFadden, 2008)

A survey was done over visitors and residents opinions, it concluded that tourists will go elsewhere if nothing will be done to upgrade and maintain the sea front recreation areas. Tourism is one of the largest values to the site today. If the area were to be left without continuous maintenance, the beach would get inaccessible due to decaying debris left by the current defense system. As a result the attractiveness of the area would diminish. This indicates that the policy makers wants to reduce the maintenance, while the users, visitors and residents of the area that has family connections and history connected to the area, are in favor of keeping the village alive and protected from floods and erosion. It is a great challenge to meet the needs from human relations, ecological values and economical sustainability in smaller societies like this (McFadden, 2008).

Reclaiming land on flood plains

Lavery & Donovan (2005) are discussing about flood risk management in River Thames (see figure 44, p.50). After the flood of 1953 the barriers where extended and the current ones, constructed in the 70’s and 80’s, have served as some of the best standard for flood barriers in the UK the past 20 years. The paper evaluates the Thames Estuary 2100 project, which is a long-term project in order to protect against floods with the new conditions that is estimated to occur within the next 100 years. This will provide new land-use grounds on the tidal plains and more efficient use of land could be obtained.

The major threat today is the high-tidal waters in combination with winds that increase the effect of the tides and the outflow of river water. The system today includes 36 solid structures of floodgates that are operated by the Environment Agency and 400 movable constructions. There is also 337km of embankments and walls to protect settlements and constructions that currently exists on the flood plains. The need for updating the system is not only due to changing conditions, but wiring and technical equipment is getting old. The system has on average been closed 3.3 times per year and is monitored around the clock 365 days a year. Due to the new upgraded system it is estimated that 120 000 new houses will be able to be constructed within the next 15-20 years within the tidal plains along Thames (Ibid.).
United States of America
The Boston metro area located (see figure 45, p.50) in Massachusetts, Northeastern USA, covers a total of 3,683 km² and currently holds 3.2 million people spread across in 101 municipalities (figure 5). The area has four seasons throughout the year with annual precipitation reaching 1000 mm per year and average temperature at about 10°C. The coastal area that is located along the eastern boarder is 825 km long. Following the coast, the natural environment consists of sandy and rocky beaches, salt marshes and estuaries. Tropical storms that hit the area time to time are weakened a bit by Cape Cod, located just southeast of the Boston metro area. Central parts are highly developed urban areas. The further north and south from the central parts, the more rural it gets, including cultivating land. There are however suburbs interspersed within the farmlands.

Figure 5. The map (Suarez, et al., 2005) shows the Boston metro area, located in Massachusetts, USA. The area covers a total of 825 km coastline and to the southeast it is protected by Cape Cod that takes the worst hit from tropical storms.

In the metro area of Boston the sea level is rising and estimated to reach a level of 30-90 cm above todays level, within the next 100 years (Suarez, et al., 2005). At the same time there is an ongoing land subsidence in the area at a rate that together with the water level makes an overall sea level rise of 1.5 mm per year (Kirshen et al., 2008). The effects for this specific area are a loss of wetlands,
floodling of low lying built environments, increased costal erosion (as seen in figure 11 p.28), saltwater intrusion in the ground water among others. There are today remedies implemented along half the stretch of the coastline of Boston metro area. These remedies consist of seawalls, revetments and bulkheads.

More than sea level rise it is estimated that the area will experience more frequently tropical storms and hurricanes in the future (Suarez, et al., 2005, Kirshen et al., 2008). The increased frequency of these storms are already measured today and reinforcements of the strategies have to be implemented in order to minimize the effect from the storms that time to time report houses collapsing along the coast line in MA. Three different strategies are investigated from an economical perspective by Kirshen et al. (2008) in order too see which approach would be the most beneficial for the area. The strategies are:

- Protection, building new and retrofitting the existing protective flood systems in Boston metro area
- Accommodation, specific measures is set in for a small local area and rebuilding/repairing damages after a storm/flood
- Retreat, commercial and residential areas that are at risk are abandoned and the ground is restored.

It is concluded from the study that high cost protection will be the most efficient for high-developed areas and low cost protection for low developed areas. The total costs for repairs and adaptations from the year 2000 to 2100 is estimated to be between $6 billion and $94 billion depending on the measure set in and climatic scenario that will appear.

For every linear meter of reinforced/adapted built flood protection a price of $1,000 is estimated while building completely new protection is set at $7,200. Further Kirshen et al. states that implementations to protect houses at risk areas, on flood plains, will reduce the costs for rebuilding/repairs by 80% if measures are set in to the specific households at risk. (2008). In the high risk zone the cost will average on $17,000 per home and those in less risk areas $3,500. This can be compared to what demolition would cost if the floodplains where to be flooded (neglected), and as a result retreat scenario implemented, of a cost per $20,000 per household and $160,000/ha for commercial and industry owned land.

Besides from the economical factors there are other values that may be affected by the implementations of the protective systems. Since seawalls were implemented the pattern for sand transportation has shifted leading to less building up of beaches and loss of these specific areas. The most beneficial system for the natural environment would therefore be the retreat, according to Kirshen et al. Through time wetlands and beaches may recover and restore the natural balance in some areas (2008). From the economical view it is however the least efficient way to go with the retreat strategy, no matter what extent the sea will rise and the frequency of storms increase.

**Holland**

Zeeland is the most westerly province in Holland (see figure 45, p.50) and covers 2,930 km² of which 1,140 km² is water. The population of the region was in 2006 approximately 380,000 people spread along 13 municipalities. The province has
four distinct seasons throughout the year with an annual precipitation of 719 mm and average temperature at about 10.5°C. The coastline covers a distance of 650 km and the natural environment originally consisted of a muddy delta that regularly was flooded due to tidal events. Measures first set in around 1200 AD (Colijn & Binnendijk, 1998) in order to protect and reclaim land from the sea. Today the area consists of more permanently dry lands in forms of islands and other features created throughout time by the settlers and reshaped by nature, including sandy beaches. A majority of the land surface lies beneath the current sea level.

The Netherlands is a nation with a long history of flood protective concern. The ongoing process of protecting and reclaiming land from the sea has resulted in that 2/3rds of the country is protected today with a total of 3,500 km of various remedies (Reina, 2005). The historical benefits of the sea, i.e. tidal floods, include fertile soils according to Colijin & Binnendijk (1998). Today the main functions along the coast for land use is conservation of nature, recreation areas, mainly beaches and leisure boats along with other water related activities, drinking water and developments of permanent residential areas, vacation homes, restaurants and hotels. The economical benefits have switched from cultivating as the main resource to the tourist industry, where especially the beaches are popular destinations.

The Delta project, as the Dutch project is called, is the crown jewel in the defense against rising sea levels. The main components of the system include dunes, levees, dykes and dams (Coljin & Binnendijk, 1998). The dunes are semi-controlled by humans and partly self-maintaining. Grass has been planted in the outer dunes in order to fixate the easily eroded sand. The Delta project is not only a defense against the threats from the sea; it is also vital for the infrastructure in the Netherlands. For future planning, nation wide and regional level, more consideration on how to integrate the water bodies with land areas.
During the 20th century, the technological development has improved significantly. Even though humans with the construction of levees and other features have modified the area for 900 years, up until the 20th century these implementations were of a small scale, both construction wise and by the effect they had on the land (Colijn & Binnendijk, 1998). The large-scale implementation that has been possible to achieve the last century has resulted in improved accessibility, infrastructure and use of the region. Roads are constructed on top of dams and levees together with locks that allow ships and leisure boats to pass through. The investments have been massive, exceeding American implementations in New Orleans and the Gulf coast (Reina, 2005). The investments could be justified by the densely populated land it protects and the intense use of said land.

Since the flood of 1953 in Europe, $10 billion has been spent on the defense system until 1997. The system is still under development and for the next decade another $3.5 billion will be spent on the defense. These figures include the entire Netherlands and both protection from the sea and rivers (Reina, 2005). The future investments mainly include improvements of river protection, 75% of the total investments, while the rest, 25%, will be set off for the sea defense. There are eight geographical areas of focus that has been pointed out as nodes of weakness in the defense according the future estimated sea level change and affection from tidal waters.

**Functionality of spaces**

**Venues for people**

One of the possible uses of a levee, and other flood protecting measures, is recreation. In order to create an accurate area for recreation and social interaction it is of importance to know a little bit about human behavior in public spaces. Gehl concludes that people seek out the shortest pathway to cross open spaces and avoid stairs and steps, if possible (Gehl, 2010).

The sedentary lifestyle we live today, with desktop computer jobs and cars as the main source of transportation, Gehl sees a connection with the increasing obesity (2010). Since the 1960’s, when 1 out of 10 Americans were classified as obese (body mass index of >30) rose to 1 out of 3 Americans in the year 2000. Similar trends have been observed around the globe.

The fitness wave, that first started off in the 80’s and repeatedly has become popular in waves until today, has resulted in expansion of fitness centers all over. In Sweden, statistics show that 31% of both men and women prefer jogging and brisk walking, as it is the most common form of exercise followed by fitness (24%) for women and outdoor activities (9%) for men (Engström, 2006). To tackle the growing problem with increasing obesity, exercise on the leisure time is not the most efficient approach. What is needed is the everyday movement that has been replaced by cars and escalators etc. This can be achieved in the
planning by promoting bicycling for commuting in the planning process and make certain points inaccessible for vehicles.

If commuting over great distances for work everyday, it is often necessary to go by car or public transportation. Because of this, it is important to have access to venues that invites movement. These must not solely be for the purpose of high intensity exercise, such as running and lifting weights; a nice promenade or bike ride could be plenty in order to keep a healthy life style to compensate for sedentary work. According to Gehl it is of importance that the access of the venue is easy to come by and that the venue is inviting in order for people to use it (2010). Since people have to invest of their time to use the venue itself, the time getting to the venue should be minimized. One way of doing this is to use connections between the most interesting parts of the venue by planning in small-scale and at eye level in order to enhance the experience for pedestrians and bicyclists.

**Multifunctional spaces**

In 2010, Boverket published a report on multifunctional spaces (surfaces) within urban areas, in relation to expected climate changes. The explanation of the criteria for a multifunctional space is a space that has the ability to store and manage surface water, lower the summer temperature, protects against harmful UV-light by shading, create meeting places for recreation and rest along with conservation of biological/ecological diversity (Boverket, 2010).

By modeling during the planning stage, zones and areas of high risk in the urban environment may be identified and it is possible to reduce strategies on how to cope with scenarios unbenefficial for the future living conditions in the planning stage. These risks may include floods, temperature and wind conditions. By mimicking ecosystems in the planning process of a multifunctional space, profits like purifying, air and water is achieved and noise reduction.

The systems that collects rainwater today in Sweden lets the water out to the drainage too fast. A strategy to reduce the disadvantages from this is to implement surfaces that can collect the surface water and store it temporarily in order to reduce the pressure on the drainage. One way to combine this kind of system with another function is to implement parks, since the hard surfaces in parks generally occupies a small percentage of the total area (Boverket, 2010). Wetland parks are another way, since the capacity is even larger for wetland parks, to reduce the stress on the drainage. Also, as part of their natural ecosystem, wetland parks handle water more efficient then the traditional park. If wetland parks are an option, it is to be included in the comprehensive planning process for the municipality.

Impacts of the climate change on leisure and recreational activities will vary, depending on the geographical location. Estimations suggest that the effects on the climate in Sweden will be favorable, if sea level rise is disregarded, compared to the current climate. Effects that this will have on leisure and recreational activities is that outdoor sports will be more tolerable during winter months, the summer season and activities connected to this season will be prolonged into the
current spring and autumn time, which provides conditions that are more beneficial to activities connected to water or taking place near water bodies (Sasidharan et al., 2001).

Assessment planning in neighboring municipalities to Höllviken

Lomma
In the municipality of Lomma the comprehensive plan, from 2011, includes measures in a first step on how to cope with the climatic changes and consequences from these, together with plans on land-use for sites adjacent the sea. A small part of the coastline is set off for mussel cultivation in order to decrease the water pollution and eutrophication of the sea. The total coastline of Lomma towards Öresund is 14 km. The average temperature around the year is 8.2°C with an annual precipitation of 680 mm.

Ongoing inquire will tell how the climatic changes are affecting the municipality. The comprehensive plan covers the next 20 years of planning in the municipality, including cooperation with neighboring municipalities for development of recreational grounds and infrastructure for commuting, including bicycle lanes among others.

Lomma has venues and sites that are worth protecting for their cultural values and recreational purposes. These include historical settlements from the Bronze Age and the Viking era among others. Lomma may have figured as an important port during these eras in history. Today’s values connected with the sea include recreational activities such as bathing, fishing and leisure boats and other water-connected activities. Together with these human interests there are ecological concerns too that the comprehensive plan note as important to preserve. This includes the marine biological life in the shallow bay and reservoirs inland that are worth protecting.

One of the main risk factors in the coastal area of Lomma is the effect of erosion. The pattern of coastal erosion has changed since Malmö rebuilt its port. After an inquiry from 2001 the municipality made a map of areas that are prioritized to protect from erosion (see figure 7).

The consequences from rising sea level in Lomma is the obvious one of flooding since a major part of the municipality is located on low ground close to the sea level, along with a long stretch of vulnerable coast (see figure 7). The flooding may affect the built environment, infrastructure, communications, drainage and sewages together with electric provision.
Figure 7. The map shows areas that are protected and prioritized too be protected in the future from coastal erosion. Map from Lomma Comprehensive plan 2011.

In order to cope with the estimated risks some measures are set in. Building permit will not be allowed, unless there are special circumstances, for new constructions unless they are being built at a minimum of 3 meters higher than the sea level to the floor. Lomma does not only face threats from the sea but also from being a watershed area connected to other parts of Scania. Measures to cope with the problems of intense precipitation therefore include meandering drainage, set aside areas for water collection in temporary dams, etc., in order to extend the total surface areal that can be set aside for controlled flooding. Along the coast at the town of Lomma, a stretch is set aside for a barrier protection and the same goes for the area around the water purification facility in Borgeby.

Malmö

Malmö is the main city of Scania and southern Sweden. Just south of the city, the Öresund Bridge connects Sweden to continental Europe. The marine environments around the city are more frequently used now than they used to be, including the port and for other purposes. The cost line includes areas for recreational activities, housing and attractive nodes for interactions. The total coastline for Malmö towards Öresund is 72,2 km. The average temperature around the year is 8,2°C and the annual precipitation is 680 mm.

The new comprehensive plan was released in 2013 and is still under the review phase from the public, however this is the one used for the following information.

Values that are at risk stated in the comprehensive plan for Malmö, is the part of the City center is located within 3 meters above the sea level including the port
and new developing areas. This is the level of anticipated extreme high tide events in 100 years. Natural environmental values along with cultural values are at risk, i.e. part of the historical center of Malmö. The pressure of the drainage will increase since the city is expanding and fewer surfaces are left for drainage, the shortage being accelerated by the increasing density of developments. The coastline of Malmö is of importance for recreational grounds too, with Sibbarp and Ribersborg as examples.

The type of actions needed in order to protect already built areas has to be further investigated, although there are several options including landfill, islands, walls and operational dams. The remedies will be implemented successively in order to protect against the long-term changes.

Before the implementation is set to action, with presentation of an action plan and construction of the protection, extensive inquiries needs to be conducted. Cooperation between the county administrative board, neighboring municipalities and other actors needs to be set up in order to cope with the future threat from the rising sea. Within the city, if no specific implementations for protection are done, the minimum ground level for new developments is set at 3 meters above sea level.

Case study

What are the specific threats of changing sea level in the chosen location

SMHI, the Swedish metrological institute, summarized reports from the time of the last IPCC (2007) until November 2012, in order to evaluate how local conditions around Sweden’s shoreline is estimated to develop until 2100. As seen in figure 8, the number varies, in an unfavorable way for the estimated sea level change. A main reason for this is the time span used for each report presented in the chart varies from each other. With these figures in the calculation and the land rise of Sweden included the area around Höllviken is modeled to have a sea level rise of 0,9-1 m until 2100 (Bergström, 2012). What is more threatening for the situation in Öresund, is the increasing winds that will force more water in the extreme high tide events. The IPCC report shows a tendency of an increase in winter floods for the area (IPCC, 2007).

Figure 8. The figure (Landeberg et al. 2011), shows the anticipated sea level rise according to different studies and inquiries. According to the chart it is expected that the sea level rise will be between 20-160 cm until the year 2100, depending on data used when modeling scenarios.
Höllviken
In Vellinge municipality, which includes the site of Höllviken, the rising sea levels were first concerned in a comprehensive plan from the year 2000. The total coastline to the Öresund is about 2,8km and 2,4km towards the Baltic Sea. The municipality did however start cooperation with Lund’s Institute of Technology in order to handle the future expected changes earlier than this. The following text in this chapter is summarized from an investigation made by a consultancy in order to create an action plan for Vellinge, on how to cope with the future predicted sea level rise (Landberg et al. 2011).

![Images showing flood scenarios with high tide of 1.6m and 2.4m, above today's sea level.](image)

*Figure 9. The images show scenarios with high tide of 1.6m and 2.4m, above today’s sea level. Images are created in a GIS software using the height of the landscape together with data about water levels, barriers etc. in order to predict consequences of the flood events (Landberg et al. 2011).*

Problems occurring with the sea are not only the average sea level; it is above all the extreme events that are predicted to increase in frequency together with the changing climate (Bogren et al, 2008). The highest sea level measured in the Skanör seaport (closest measuring station to the site) was 137 cm above the average back in 1997 and 156 cm above average in the Falsterbo channel in 1992. There are however historical recordings of high water more then 2 meters above todays average.

A prediction from SMHI in 2008, that Landberg et al. refers to (2011), estimates that the high tides will increase steadily until 2100, the high tide will reach close to 2 meters above todays average level by then, as shown in figure 10. The high tide events that occur in the Öresund normally lasts for just a short period of time, no more then a couple of hours. They are connected to events where masses of water are passing through the strait. It is expected for extreme tidal events to reach levels of 210 cm above average in 2050 and up to 279 cm in 2100.
The estimated sea level change has been mentioned several times earlier in this thesis. These figures have mainly been for the global anticipated rise. Due to the increase in westerly winds the North Sea and the Baltic Sea is estimated to gain another 20 cm over the average global rise until 2100. These are the winds that will increase the frequency of high tide situations that were mentioned earlier as well (Landberg, et al, 2011).

In the comprehensive plan of Vellinge from 2010, the analysis claims that the effects of high water stands have more to it then just rising sea levels. The ground water level, together with winds and precipitation is also of concern. Historically ditches (drainage) and walls have been constructed in order to protect the land from trespassing seawater.

With the rising sea level and increased frequency of high waters connected to winds, precipitation and ground water levels the main threats are obviously flooding and the consequences of this. Without construction of protective barriers parts of the land will disappear, decimating space for the current built environment, future developments, problems with sewer and drainage and loss of important grounds such as recreational ground and roads along the seaside.

What types of values are at risk

Vellinge, Höllviken

According to the comprehensive plan for Vellinge municipality (2010), if nothing is done, there are four main categories of values that are at risk. The categories are natural environment, cultural values, the built environment and the infrastructure.

The natural environment is mainly the seaside shore plains, which are of value for grazing and is an important biom for biodiversity to protect. Humans have used this kind of grazing grounds for a long time and therefore they retain a great cultural value. Other cultural values at stake are coastline bound recreational grounds with loss of beaches and historical sites. The area was an important trading point during the era of the Vikings (Rosborn, 2004). If the changes would occur in a non-built environment the bioms and sites of natural and recreational (natural recreational grounds i.e. beaches) would adapt to the changing sea level. However, with the built environment blocking, the natural adaptation is not
possible due to the lack of space. As a result these values would disappear when space between the waterfront and the built environment decreases (Vellinge CP, appendix B, 2010).

Without protective barriers, part of the built environment in Falsterbonäset (west of Höllviken) and venues of Höllviken itself will be flooded frequently. Consequences that follow floods are economical setbacks in order to repair after the damages and erosion that affect the infrastructure. The drainage and sewers are at risk too, since the flooding may contribute to spread of hazardous pollutions in the area. Examples of the erosive forces from the sea and storms of coastal environments are found around the world. In March 2013, a storm with following extreme high tide event, overwhelmed a couple of houses on Plum Island, MA, USA (http://www.dn.se/nyheter/varlden/har-drar-atlanten-med-sig-amerikanska-villor DN, 2013-03-10).

![Figure 11. Photo: Brian Snyder, Reuters. The picture is taken in March 2013 at Plum Island, MA, USA, and an example of coastal erosion occurring at any given time around the globe.](image)

Further, if the protective walls are not constructed, the built environment has to be replaced into other areas. This would be costly and investments already made in the infrastructure could not be used. As a result it would require new investments for infrastructure, and land today used as cultivating ground that is of high value would have to give space for the new investments and functions (Vellinge CP, appendix B, 2010).

**How are the authorities responding to the risks**

At the end of the 1960’s and beginning of the 70’s research about the effect of melting ice caps along with other features that cause changes affecting the way human beings are living today. 1977 was a year of break through within this scientific field and today’s view of the changing climate saw the light of the day. It was stated that global warming would be the climate risk of the next century (21st century), not cooling (Weart, web, 2009).

In Sweden, municipalities themselves are responsible to identify and set in measures to cope with anticipated problems of rising sea levels. According to Boverket, provisions against the rising sea levels could include surfaces of land that can cope with excess water after heavy rains, drainage that transports water away from the built environment and barriers (Boverket, web, 2013). In 2012, five of the county administrative boards of Sweden surrounding the lake Mälaren, signed a suggestion that the government would initiate inquiries to cope with the threat of future sea level rise (Skogö, 2012). During the spring of 2013 a motion was discussed at Stockholm municipality board in order to initiate cooperation and inquiries on how to cope with the rising sea level in the...
region (Ahlberg, 2013), opening doors to discuss the question region wise instead of dealing with the issue just within the municipalities themselves. Similar suggestions can be seen in other regions of Sweden too, as Malmö suggested in their latest comprehensive plan.

Vellinge municipality did start cooperation with Lunds Institute of Technology in the 80’s in order to calculate and model future changes and how these would affect the seaside municipality. Risks with the changing climate, connected to the sea level among others, were displayed in the comprehensive plan of Vellinge in the year 2000.

In 2007, a consultancy was hired in order to investigate how to cope with the future changes. A report was published in 2011, *Höga havsnivåer – Falsterbonäset samt områdena vid Höllviken/Kämpinge, Handlingsplan för skydd mot stigande havsnivåer* (High tides – Falsterbonäset and the areas around Höllviken/Kämpinge, Action plan for protection against rising sea levels), conducted by Landberg et al. The report and the outcomes were mainly based on the previous work conducted from the municipality’s cooperation with Lund Institute of Technology. In 2009 the area of investigation was broadened to include Höllviken in the action plan (Landberg et al., 2011). The action plan ended up including three time span ranges of actions to cope with the rising sea level, immediate actions (5-10 years), intermediate term actions (20-40 years) and long-term actions (40-80 years).

The explicit action plan for Höllviken is to protect the low lying built areas with a single line of barriers. These barriers will mainly follow existing natural high curves of the landscape and existing built dykes, i.e. road banks (Landberg et al., 2011).

![Figure 12. The map (base map from Google) is a name map of sites around Höllviken used in this thesis.](image)

**Immediate actions**

For the immediate actions (see figure 13) there are some general outlines for the entire municipality and a detailed action plan for Höllviken.
A measuring of existing barriers, the road 100, high points etc., is to be conducted in order to see how the existing features will cope with extreme high tide events, up to 1,8 meters above average sea level. Dams will be implemented in the drainage in order to prevent back flows of water in extreme high tide events. Last of the general implementations is to complete the natural defense with fillings that will connect the current natural and constructed barriers.

From the models constructed for the report there are a few important points that are to be protected since they are at high risk of flooding. What should be prioritized according to the consultancy in the immediate perspective is:

1. Dams connected to the culverts going through road 100
2. A barrier to the north with a center at the Viking village stretching south to connect with the road 100 and east to connect with Lilla Hammars isthmus. Control measures to secure a height of 2.1 meters of the barrier along the entire coastline.
3. The port area of the Falsterbo channel north end needs to be reconstructed. Two alternatives, reconstruct the docking area and the jetties, from todays 1,3 meters above the sea level to 2,1 meters and rebuild the constructions on the shore or; build a lock that could enclose the port area.
4. Barriers towards the south, existing barriers consists of sand dunes. Measure and control that these are of a height of 3,9 meters above sea level. Fill the gaps between existing protection with 2,1 meter barriers.

*Figure 13. The map shows focus areas for the immediate actions. Map created by the author.*
Intermediate term actions

Barriers surrounding the built environment in Falsterbo/Skanör and around Höllviken should be secured at a height of 2,1 meters. There should also be further adaptations at the top of the barriers in order to protect from the anticipated continuous rise of sea level until the year 2050. Local adaptations in the intermediate perspective for Höllviken (see figure 14) is to:

1. Build flood barriers that enclose areas that do not exceed 2,1 meters above today's sea level. The barriers connect to natural ground at 2,6 meters.

2. A barrier along Höllviken shoreline is built and connected to high points in the ground at 2,6 meters above sea level. In the later part of this period the road 100 will have to be raised or a protective barrier needs to be constructed outside the road.

3. Along the southern shores the sand dunes barriers are extended to connect southeast of the built areas in Kämpinge. The crown of the sand dune barriers are raised to 4,5 meters above today's sea level.

4. Protection in Foteviken, that is mainly located 1,3 meter above the sea level. However today road 100 constitutes protection, since the bank of the road averaging 3 meters above sea level. This requires that the bank is solid and tall enough to withstand high waves and the pressure connected to the rise of sea level.

5. Barriers or docks along the stream Hammarbäcken must be implemented in order for a continuous sufficient drainage connected to the culverts passing through the bank of road 100.

6. Along the Falsterbo channel no actions are needed if the current docks will sustain the future sea level rise. If this isn't possible the banks of the southern part of the channel needs to be rise from 2 to 2,6 meters.

Figure 14. The map shows focus areas for intermediate term actions. Map created by the author.
**Long-term actions**

The long-term actions focus on protecting built environments and areas of special interest due to their unique values (see figure 15) for the expected sea level changes that will occur until the year 2100.

At places where wave heights are expected to be high barriers are to be built at a level of 5 meters. For places where wave height is not expected to be exceptional 3 meters is recommended for the barrier height. Final height of the barriers is to be concluded in future reports when new data is obtained of the ongoing sea level rise. Locally in Höllviken these specific goals are set:

1. The barriers built until 2050 is estimated to be enough protection for long-term conditions as well. However the barriers may be adapted to tackle future rise of the sea level, in the report from 2011 it is estimated that a rise of the walls on 0.3 meters from the medium length term actions is enough.

2. New construction developments, buildings, are not to be built below a level of 3.5 to 4 meters above today's sea level due to problems that would occur for drainage and other infrastructure issues.

![Figure 15. The map shows focus areas for long-term actions. Map created by author.](image)

**Materials and construction of the planned barriers**

Along the cost-lines, northern and southern, two different protective barriers are planned. For the southern it is planned to continue and reinforcing the natural sand dunes and on the northern secure the road bank or create a new barrier outside the road 100.
How likely a certain type of soil lets water through depends mainly on the size of each grain in the soil. For Skanör and the surrounding area grain size is of an average of 0.2 mm which equals a soil with low porosity (Irminger Street, 2012). This means that the natural soil found in the area and planned used for the barriers is suitable for the task of keeping a calm water body out. The issue with sandy soils as barriers is that they are easily eroded, by wind and waves (Alström & Åberg, 2011). In order to fix the soil, vegetation can be introduced. However the vegetation is easily affected by human activities and repeated interruptions from rain and weather. In order to compensate for this issue it is suggested that a beach walk could be introduced behind the first line of sand dunes and pathways leading over the dunes down to the beach will minimize the effect on dunes by human activity when transporting down to the beach.

To ease the effect from natural forces groynes can be implemented to reduce the sand movements on the shore and in the shallows, bushes planted to ease the effect of wind together with grass to fixate the soil and to introduce wave breakers some 100 meters from the shore (Almström & Åberg, 2011). It is not yet fully understood how the sand moves around the area due to sub-surface currents, meaning that measures like the wave breakers and groynes are not yet fully evaluated on their effect in minimizing negative effects on the beach. Mapping of the sediments has been done recently but the data is not yet presented. In order to understand the movements its not enough with this first mapping (Åberg, personal communication, 2013-04-05), follow up studies needs to be done in order to see the patterns and how they are estimated to be affected by climate change and measures like the ones mentioned above.

![Figure 16. The picture shows a schematic sketch of the barrier system that could be implemented on the southern shore in order to minimize the effects of erosion on the dunes (Almström & Åberg, 2011).](image)

**What concerns has been voiced from the public**

There are no official documents or studies that reflects the opinion of the inhabitants in Höllviken, about the situation today/future situation and planned implementations, on how to deal with the threat from the rising sea. There are, however, a few articles in local newspapers and people blogging about the topic, which is where the information in the following section comes from, together with conversations of officials in Vellinge municipality.
The articles published in newspapers about flooding in Höllviken mostly regards flooding due to failures in the drainage. Concerns about rising ground water levels have been raised as a result of decreased pumping activity that the officials filed for in 2007 (Sydsvenskan, 2007-12-21) and what responsibility the municipality has regarding damages on properties due to rising ground water levels.

Another event where the drainage and sewers collapsed due to heavy rainfalls and failure in the system that controls the pumping happened in August of 2010. Heavy rainfalls led to a couple of flooded basements. For the Blolyd/Ohm household repair works were almost done when the computer system for sewer water failed, which led to a flooded basement once again in March 2011 (Klingen, 2011-03-19). The intruding sewer water also affected four more neighboring households. Vellinge municipality did pay the deductible costs to the insurance companies for the affected households.

The estimated costs for flooding during 2012 was about 4 million sek for Vellinge municipality in deductible fees to insurance companies (Samuelsson, 2013-02-20). These fees are the responsibility of the municipality to pay since they are in charge and control the drainage. An investigation on how to improve the drainage is currently ongoing in order to reduce complications connected to the system in the future.

Korpskog, a blogger writing about psychology, climate, energy and economy is skeptical of the approach that Vellinge municipality has to tackle the threat from the rising sea level. She cites a report from KTH (Royal Institute of Technology in Stockholm), which states that some counties and municipalities is going to be abandoned if the sea level rise will exceed the anticipated levels, including some parts of Vellinge. However the main focus for the municipality is to invest in flood protection and further investments to develop some of the non-built areas. Korpskog is skeptical to the ongoing and planned development of low-lying villas, some below 3 meters of current sea level, which the county board of Scania states is too low (Korpskog, 2012-11-24).

Occasionally Åberg, GIS-coordinator at the municipality of Vellinge, receives phone calls from residents in the municipality that mainly concerns the elevation above sea level that their properties are at (Personal communication, 2013-04-05). In Åbergs experience, people are not concerned of the rising sea level since that does not affect the area noticeable today. Also the knowledge about the municipality’s action plan is well spread among the residents, when it comes to how the areas around Höllviken and Falsterbonäset will be protected from future sea level rise.
Design programming for the selected case

Technical description

Current land-use

Figure 17. The map shows generalized functions of the town of Höllviken and the closest surroundings of the township.

Agricultural land, water and the peninsula of Falsterbo surround the town of Höllviken. The recreational land will be further analyzed later on with maps covering these specific sites. The map (see figure 17) gives an overview of the main functions in the town.

The main area of Höllviken consists of low-density housing. However there are some various functions within this area, including sports facilities, green areas/parks, schools etc. In the northern parts of the built environment along the coast and on the south side of the commercial area, more high-density housing is built, up to 5 stories high. The commercial area marked on the map is the only solely commercial/retail area in Höllviken.

In the mixed-use zones the majority of the businesses are service oriented, though there are some retail stores, among others in the area. Within these mixed-use zones the most part consists of low-density housing, which occupies the main area of the entire town as shown the map with the “resident low” marks. Between the mixed-use area to the east and the low-density housing area and between the northern sections of the cultural/recreational land surrounding Höllviken and the function zones to the south, two of the main roads of the town figures as boundaries between zones (see roads on figure 21).
Within and surrounding Höllviken there are three areas that are under the risk of flooding from sea level rise (see figure 18), the northern shore, southern shore (Kämpinge bay) and in the north east connected to Hammarbäcken. The drainage overview that is displayed on the same map mainly follows the larger roads and the mixed-use areas in the eastern parts of Höllviken. When displayed together with the flood risks it is shown that the northern parts along the shore, of the drainage will be affected by a sea level rise. Today water is pumped/led to two areas by the drainage, in the south to Kämpinge bay, and in the north to the bay outside of the northern shoreline.

The area surrounding Hammarbäcken is of importance in the future plans for Höllviken. This area is marked as a sensitive area when it comes to flooding. There are plans for the area to be developed in the future according to the comprehensive plan for Höllviken and therefore it is important that thorough investigations are made before construction starts. Suggestions in the action plan today include locks along the stream to control the flow of water (Landeberg, et al., 2011). This regulation of the stream would create new wetland grounds in Foteviken, at the mouth of the stream that would transform surfaces that today are dry land.

Strategies will be presented in the design section on how to ease up the pressure of the drainage, cope with the coastal areas that are under risk of flooding.
The slogan of Höllviken is “den nya staden i skogen vid stranden”, which translates to “the new town in the forest at the beach”. This is an accurate description of Höllviken since there is less then 1000 meters from anywhere within the town to a beach and the town itself is scattered in a pine forest. This makes the map (see figure 19) a bit misleading of the green structure in Höllviken. The picture (see figure 20) is taken from one of the streets in the central part where no green spaces are marked, the houses are scattered within the forest, which can be viewed on the satellite image as well (see figure 20). The pine forest continues to the west, onto Skanör/Falsterbo, while to the east, Höllviken is neighboring agricultural land. However the pine trees and other vegetation on private lots is not protected by byelaws. They exit the win of each landowner.

The most westerly green space marked on the map is a pine forest along the Falsterbo channel. This stretch of forest is classified as a nature reserve implicating national protection by law. The rest of the green structure that is marked mainly consists of parks or larger stretches of continuous forests that are non-built. Most of the coastlines in Vellinge municipality are marked as a nature reserve, including Kämpinge beach and water to a depth of 15 meters. Green structures have several benefits, such as wind breaking attributes, binding soil, collects water, etc.
Figure 20. The image (picture taken by author) to the left shows a street in central parts of Höllviken, with no marked green structure/park on the map (figure 19). The satellite image to the right (eniro.se) over Höllviken shows how the town is scattered within the pine forest.

Strategies will be presented in the design section on how new green structures may add features that will help protect Höllviken against rising sea levels and issues connected to this, such as beach erosion.

Road structure

Figure 21. The map shows road structure for main and secondary roads in Höllviken, along with parking lots that are of interest for the sites of redesign.

The road system in Höllviken contains of three categories of roads, of which two are marked with colors in the map (see figure 21) and the tertiary roads appear as a background in the map since it would be messy and difficult to distinguish the separate roads on the map. The main road 100 works as a barrier, according to the comprehensive plan, along the northern shoreline with an elevation of average 3 meters above sea level and a low point of 1,76 meters between the traffic lights. The secondary roads mainly follow the outskirts of the town or connect with the main road and other secondary roads. A couple of kilometers to
the northeast of Höllviken, at Vellinge township, road 100 is connected to the major road E6/E22 that further connects to Landskrona in the south and Malmö to the north and then continues up north, along the coast and inlands further up in Sweden.

The rest of the road pattern of Höllviken that is visible on the map consists of tertiary roads that are mainly narrow streets (see figure 20). To the south more than half of these tertiary streets feature dead ends and the rest is streets connected to one and other, except two streets that ends up with parking lots. This indicates that the system of tertiary roads is mainly for transportation to and from homes that is the main function of the area within the secondary roads.

When it comes to parking lots that are of importance to the chosen sites for the design development in this thesis there are, besides the two southern ones mentioned above, three parking lots in the north. The large parking lot in the southeast accommodates circa 280 cars, while the others each has a capacity for between 20 and 50 cars. The small parking lot to the south is paying parking; the same with the most northerly one (connected to the Viking village and campsite), while the two along the shoreline are free. One of these northern shoreline parking lots is located on the seaside of road 100 while the other is on the town side of road 100.

In the design proposal it will be discussed how the barrier of road 100 will develop in order to fit with the proposed design and suggestions for new parking lots in the north is outlined.

**Recreational venues**

![Figure 22. The map shows recreational/sport venues and pathways within and in the surroundings of Höllviken.](image)
The sports and recreational venues of Höllviken consist of different elements, ranging from sea bound activities to sport fields. The majority of the sport fields are located and connected to schools. There is one freestanding sport field (Gyahallen, with tennis courts surrounding) at the southern central parts of Höllviken.

The water recreational grounds are good for bathing, kite-surfing, windsurfing and surfing. Surfing is not allowed all year around and is regulated at some spots certain times of the year in order to not disturb other usages of the beach. At the northern shore the entire beach is okay to surf from while on the southern it is restricted to the western and eastern parts if there are people swimming at the central parts of the beach.

Along the Falsterbo channel, in the nature reserve of pine woods there are pathways that can be used for running, walking etc. However, there are no paths in Höllviken that are outlined for the specific purpose of being jogging tracks. These kinds of features can today be found in Vellinge to the east and at Falsterbo to the west.

The bicycle lanes that are consistent follow the secondary roads that frame the majority part of Höllviken and along the northern shoreline. The rest of the bike paths are mainly to connect between tertiary roads where cars are not allowed to pass and surrounding the schools of the eastern part of Höllviken.

There is a horseback riding track around the town of Höllviken, following Kämpinge bay in the south, the nature reserve in the west and the northern shoreline and then follows the secondary road towards southeast for a bit. Along this track two crossings passing on roads at zebra crossings, one in the northwest when passing the road 100 and one on the secondary road that turns southeast when a roundabout is crossed.

In the design proposal a suggestion for a new jogging track will be displayed along with venues that may be used for spontaneous activities and water bound recreational activities such as surfing with a focus on the northern shoreline.
In the comprehensive plan for Vellinge municipality it is stated that road 100 figures as a barrier within the town of Höllviken and to the east and west for pedestrian, bicyclists and horseback riders. To some extent the road, with its present outlines disturbs the recreational life along the northern shore that has a limited space between the waterfront and the road. This may result in under-utilization of a venue that has potential to enrich the recreational values of the town.

In order to pass road 100 there are four (five) options. To the west there is a non-surveyed zebra crossing that passes over the road. It is also possible to pass underneath the car bridge that passes the Falsterbo channel, however this is not an official pathway. The two central crossings are surveyed by traffic lights and connected to bus stops. Connected to the western of these two central ones there are two parking lots, one on each side of road 100. To the east in connection to the roundabout there is an underpass for the pathway. This crossing does not interfere with the traffic of road 100, though just a short distance to the south from the main roundabout of road 100, there is a smaller roundabout where a road has to be crossed in order to get to the pathway that leads under road 100. The road 100 is difficult to cross in other spots then the marked ones on the map (see figure 23) since there are ditches along both sides of the road.

In order to get to Kämpinge bay in the south there is one main parking lot to the west and one smaller in the central part. From the parking lots there is a short walk, a couple of 100 meters at most, to the beach. If arriving by foot or bicycle there are more options on how to enter to the beach. On the map roads marked...
with rounded corners and green fill are turn-arounds where it is possible to drop off passengers. Road endings marked with blue are narrow streets that are impossible to turn around (dead ends) if violation of private driveways is to be avoided. From all of these, both dead ends and turn-arounds there are pathways connecting to the beach if you go by foot. Due to the sandy ground it is difficult to bicycle from the road endings.

In the design proposal it will be discussed whether it is possible to use some other kind of crossing to reduce the barrier features of road 100 in order to make the northern shore more desirable to use. On the southern shore a pathway system will be discussed, both how it can ease the transportation and work as a stabilizer to prevent erosive forces.

Program
The main issue of this thesis is to investigate protection against rising sea level and to use the space created for other bi-purposes, such as recreational values. The outlines for the protection are set through the action plan developed together with a consultancy (Landeberg, et al. 2011). These outlines will be modified in order to cope with the functionality of the design proposal presented in this thesis. The idea of the whole design is to use the opportunities that the sea brings to Höllviken instead of trying to force the threats from the sea away. Nature will change throughout time; why not make the best of it? A map displaying the suggested outlines of the barrier will be shown in the design proposal section in order to compare the suggested outline. The action plan is set to three steps. The design proposal will focus on the first step, short-term development. Intentions of the design however is for it to be flexible so it may adapt together with the development of the barriers when needed. Focus area for the design is shown in figure 24, below, where the main focus is at the northern shore.

Figure 24. The map shows the focal areas of the design proposal.

Main focus will be set along the northern shoreline, where the protection will create opportunities for purposes besides the main one, to act as a barrier towards rising sea level. As stated in the analysis and background of Höllviken the main issue today assesses the drainage. In order to ease the pressure of this
system a barrier outside road 100 will create a space that is possible to use for temporary storage of an overloaded drainage.

In the comprehensive plan from Vellinge (2010) it is stated that focus for the next couple of years will be to develop green paths and recreation areas. Parks will get a revival to improve the function for purpose. With the barrier located outside of road 100 there will be an opportunity to create new green space, combined with the blue storage space mentioned above. By adding pathways and islands small individual parks that are connected through the pathway system and the outer and inner barriers are created, which can serve the purpose of recreational ground, jogging tracks and to further develop the planned cultural recreation path, which includes arts and a beach stroll. The new barrier will extend for about three kilometers west to east (northeast) and will be located about 100-200 meters out from the current coast line.

The system of pathways and bicycle lanes should be of function even during extreme high tide events. This is of importance for the southern shore at Kämpinge bay too. The idea is that the connected pathway will ease the tenure of the easily eroded protection system that consists of sand dunes and at the same time make it more comfortable to move along the beach. Along the southern parts of the Falsterbo channel future enforcements is needed in order to cope with rising sea level.

With coastlines in two directions just a couple of 100’s meters apart this is a great asset that is too valuable to ignore for the design. The idea is to work with the sea instead of trying to tame the sea with the constructions and designs. Also the cultural heritage from the Viking age is considered, though no specific design suggestions of what should be done are presented. An area is set aside for developing a cultural park connected to the Viking village, including workshops for creative purposes (writing, handicrafts, etc.).

Inspiration will be collected from various sites across the globe and displayed by images together with the design proposal.

*Figure 25. The picture to the left shows the eastern bank of the south end in the Falsterbo channel. The picture to the right is taken with a view towards the Falsterbo channel from the east. Further flood protection is needed in this area since the dunes are not tall enough.*
Figure 26. The picture to the left shows one of the pathways that today lead from the big parking lot in the southwest of Höllviken, down to the beach on the southern shore, Kämpinge bay. These pathways need to be developed and connected to each other in order to figure as erosion protection of the sand dunes. Connection to roads and parking lots may be further developed together with pathways as an erosion protection. The picture to the right is taken from the central parts of the southern shore on the crown of today’s sand dunes. Impacts of human activity are shown where vegetation is missing on the dune.

Figure 27. The picture to the left is shot from the west end of northern shores towards the east. The proposed idea is to reclaim some of the sea for the design in order to create a protective barrier combined with recreational space and a magazine for excess water, when the drainage is overloaded. The picture to the right is taking from the water towards road 100 at a camera height of 2 meters above sea level. The action plan idea is to rise the road in order to cope with the future sea level rise.

Figure 28. The picture to the left shows the current pathway along the northern shore. In order to decrease noise and other interferences from the road, the pathway may be raised (increases the flood protection ability too). The picture to the right shows the current cultural park, one of four existing sculptures. The new park will provide more venues for arts, rest and activities then the current beach walk does.
Design proposal

The outlines for the planned protection wall in the action plan (Landeberg, et al., 2011) has been modified, in order to make room for the new planned functions that will be introduced to the area. The northern barrier is moved out into the bay (100-200 meters, see figure 30), which results in reclaiming of land that will be used for recreational activities and decrease the stress of the drainage system in Höllviken, by including an excess water basin. The southern shores barrier stretch, will mainly follow the planned outlines.

Figure 29. The map shows the planned wall from the action plan (Landeberg, et al., 2011).

Figure 30. The maps show the outlines of Höllvikens northern shore before (left) and after (right) the new barrier is introduced. Average depth is presented in the map to the left.
The design of the park is inspired from the Xuanwu lake park in Nanjing City, China and Changxingxiang Wetland Parks in Shanghai, China. The solid stretches of land, along the coast and the outer barrier is connected via a pathway and island system within the basin. The thought behind this design is that there will be natural transitions in the park, making it more exiting to visit and stroll around for visitors. The design requires that the jetties are elevated in order to match the barrier and a lock to be constructed to regulate the flow in and out of the port, if no further remedies is set in to protect the port buildings. Masses need to be dredged from the sea floor outside and inside of the barrier.

Figure 31. The map shows a colored plan of the new park created at the northern shore.

Figure 32. The pictures (shot by the author) show inspirational sites for the outlines and layout of the design. Xuanwu lake park (left), in Nanjing city and wetland parks on the Changxingxiang island (right) outside Shanghai, where pathways are used in order to go between points of solid ground and platforms in the marshes.

Figure 33. 50 m section over a parking lot and slope down to the excess water basin.
Introduced flood remedies

According to Boverket, wetland parks have a good capability to cope with precipitation. Since the problems occurring today are related to heavy rainfalls and the drainage of Höllviken, a site to ease the pressure for the existing system is introduced. Lankheet Wetland Park in Holland figured as an inspiration to the design, as it collects rainwater and stores excess water to ease the surrounding land. Total volume of the introduced basin is at least 500 000 m$^3$ of excess water. The reason for enforcing the inner wall, along road 100, has two reasons. In case of a break through of the outer wall it figures as a second defense, plus disturbance from the road will decrease in the park for the visitors.

Figure 34. The map shows introduced remedies that deals with anticipated water issues of the site, current and future.

Figure 35. The pictures (Wikipedia) show the inspiration for the excess water basin in the design. They are shot at Lankheet Wetland Park in Holland. The basins collect excess water and treat it through natural processes as percolation and binding phosphorus among other substances.

Figure 36. 50 m section over road 100 to show how the current pathway is rised.
The recreational values of the site have been of most importance when it comes to the design. The aim of the thesis is to create space for recreational activities when introducing flood protective barriers. Since there was a lack of jogging tracks in Höllviken this feature is introduced to the site. Also paths for strolling, access platforms to the sea from where it is possible to launch surfboards and swim along with a site for an outdoor gym. If the path underneath road 100 is developed, disturbance from the road is reduced and the connection to Kämpinge bay enhanced. Since all tracks and venues are elevated it is possible to use the site year around, even when the basin and sea level have levels above normal.

Figure 37. The map shows activity venues introduced to the northern shore at Höllviken.

Figure 38. The pictures (from Wikipedia) are inspirational pictures for seaside activities. Running, an activity that is doable year-round and kite surfing, most popular in summer time but doable on ice during winter as well.

Figure 39. 50 m section over a pathway that connects islands and the outer levee.
In order to keep the park interesting throughout the visit, there are several characteristics within the park. The pine forest united to the mainland aims to connect the park with the main characteristics of Höllviken and also to reduce disturbance from road 100, give shade, fixate soil, bind water in biomass, etc. The wetland parks and garden parks also helps dealing with the water issue and adds diversity to the venue with the changing outlines, making the park exiting to pass through. The outer barrier figures as an open seaside walk, with room for arts to be displayed and possibilities to get to the access platforms to swim or surf. It is suggested that the cultural important area around the Viking village is updated with workshops, parks etc. to contribute to the cultural heritage at the site.

**Figure 40.** The map shows the variation of the park in order to keep the visitors interest while visiting and moving through the park.

**Figure 41.** The picture to the left (Wikipedia) shows an inspiration park, Hong Kong Wetland Park, to the proposed design. Mixture of wetland plants, open park features and forest. To the right (www.asamittivarlden.blogspot.se) shows a pine forest next to the water on Gotland, which will be implemented in the new park.

**Figure 42.** 40 m section over the outer barrier.
Features implemented in the design are not only collected from the above-mentioned inspirational sites. The main ideas came from the four cases studied from Europe and the US, Corton, London Thames, Zeeland and Boston along with the geographical approach. From the Corton case it is learned that people cherish their homes and it is important to protect smaller towns and societies in order to have a more diverse living society. By reclaiming land as planned in London, areas for new developments will be made available, which contributes to the future development of the site. Future demands of an area may vary from today’s use or may need to be expanded to cope with future needs.

The Boston case study shows how to use existing features for cost efficient planning for protection while the Zeeland case contributes to showing how the new functions in the area may be formed with focus on land use change and infrastructure.
Figure 46. The map shows the current outlines at Kämpinge bay, the southern shore of Höllviken.

Figure 47. The map shows outlines after design renewal, connecting beach promenade added with enforcements of the flood protective barrier. To the east the barrier follows the coast further south then the original suggestion from Landeberg et al. (2011).

The guidelines for Kämpinge bay, the southern shore of Höllviken, has been accessibility, transportation and protection, both from the rising sea level and erosion of the protective features. The protective wall continues further south along the coast in the design proposal of this thesis then the original plan from Landeberg et al. (2011). This is due to the closeness of built areas from the original proposal. If continuing further south there will be more space for future adaptations if that is needed due to changing conditions of the sea. Also present agricultural land will be spared that is otherwise in the risk of being flooded within the next 100 years.
**Introduced venues at Kämpinge bay**

![Map showing upgraded venues and connectivity to the site of Kämpinge bay.](image)

*Figure 48. The map shows upgraded venues and connectivity to the site of Kämpinge bay.*

**Figure 49. The pictures show inspirational sites for the beach walk of Kämpinge bay, to the left (Wikipedia), Västra hamnen in Malmö, with spectator venues included, and the simplicity of the Venice beach walk (airportmarinahonda.com), to the right, that is located at the far back of the beach, preventing erosion.*

**Figure 50. 25 m section over the jetty located at the western side of Kämpinge bay.**

A beach walk is introduced along the entire stretch of the bay. The design of the path aims to be simple, inspired by the Venice beach walk. There will be plenty of parking’s for bicycles introduced along the path, connected to the access paths from the town. The southwest area is inspired by Västra hamnen in Malmö with spectator venues and access platform. Why this site was chosen for this purpose is the closeness to the large parking lot and the current rules of using surfboards on the beach. The jetty is modified in order to cope with the new function.
**Enforced flood remedies**

![Map showing flood protection areas](image)

*Figure 51. The map shows areas that will get improved flood protection and new protective barriers at Kämpinge bay.*

![Coastal sand dunes](image)

*Figure 52. Coastal sand dunes (left picture, [www.landscapeinstitute.org](http://www.landscapeinstitute.org)) are a good barrier against floods, though it needs enforcements since sand is easily eroded by wind, in form of vegetation and waves (right picture, [www.news.bcc.co.uk](http://www.news.bcc.co.uk)).*

![50 m section over the beach walk and sand dune](image)

*Figure 53. 50 m section over the beach walk and sand dune, include bicycle parking.*

The enhanced barriers are slight modifications of the current dunes. For the new barriers (east and west of the site), levees of standard type are introduced. In order to ease the tenure of the dunes and maintain them as efficient protection measures of protecting the dunes needs to be implemented. Measures for this are pathways crossing dunes to beach access, vegetation and wave breakers.
Expected outcomes prior the study
It is my intention to show the reader the importance for a planner to consider the surrounding environment. In order to do cost efficient and long lasting planning, it is of importance to not just analyze the present with the ongoing problems, but also to do a study and predict the future in order to see what is expected to happen to the area in a couple of decades or a century’s time.

Depending on the size of the municipality the prerequisites in order to invest for the future and prevent floods and rising water levels will vary between the different sites. Malmö, as the 3rd city of Sweden, with more public funding and less affected coastline than Lomma and Vellinge (Höllviken) municipalities are reckoned to have the most planning and investments set aside for the rising sea level issue before my in depth investigation and comparison starts. This expectation proved to be somehow false.

The concept design proposal for flood protection for Höllviken will include a barrier to prevent flooding and help the site for the expected rise of sea level. Though some areas might still be flooded under extreme conditions the infrastructure for the newly created recreation grounds and nodes of importance will still be usable due to design and planning that will consider the importance of movement.

The barrier will help preventing floods for the built areas that are currently in the zone of risk if the rising sea level, which is calculated to occur within the next decades, according to guidelines in the plan of action formed by the municipality of Vellinge and a consultancy.

Discussion

Climate change review
As it was stated in the background it is uncertain what will happen to the climate in both the near future as well as a couple of 100 years into the future along with what consequences are estimated with these changes. As the IPCC report of 2007 states, which is the most used source today of climate changes until 2100, the temperature may rise up to 5.4°C and the sea level may rise to levels of more then a meter above todays sea level and up to 4 meters in a 300 year perspective (Bogren, et al. 2008, Ruddiman, 2008, Scaeffter, et al. 2012).

The future climate change will not only bring that occur as bad for people or the natural environment. Depending on location an area may be more suitable, both for living and cultivating and more attractive to tourists. Sweden is one of these places and with a rise of circa 2°C the climate in southern Sweden would have a similar climate as today’s central France. This is scenario could be beneficial for foreign tourists as well as domestic since todays popular destinations may be considered too hot at some parts of the year.
Review of planning and environmental knowledge

When protecting against floods there are several views and interests that needs to be considered. A geographical approach (Mcfadden, 2008) is one way to introduce the analysis of the area that needs protection. This is an interdisciplinary field of study and considers both the physical as well as social attributes of the area. According to Lundy & Wade (2011) there is a lack of forums where planning and the physical environment is joined together. Most papers and research that are made within this field of science have a clear stand point that they are one or the other (i.e. physical geographer, landscape architect etc.). This approach creates a conflict in the planning of urban green and blue spaces since the different fields have different interests that they cherish. The suggestion that Lundy & Wade comes up with is a joined forum in form of a peer viewed publication. Apart from this it would be beneficial for planners to be educated in geography, both physical and human, and vice versa, that people hired for investigations have some knowledge about the planning in order to make the most of everyone’s interests. Many universities include the planning and geographical field within the same department, i.e. Arizona State University where a department is named “The School of Geographical Science & Urban Planning”.

When it comes to flood protection systems it is more to it then just the physical adaptations, with levees, dams, dykes etc. Strategies vary around the world where examples from Europe and America can demonstrate how it may differ. Both Europe and America has long histories of flood protection, especially in the Gulf for America and Holland for Europe. The building strategies are originally habiting from the same culture and levees where constructed when Europeans settled within the Gulf region. Since then, the development of the cultures in different courses has resulted in differences. Today the main difference is the policy of the systems and what is the focus of protecting, where the American system is more of hazardous occasions, i.e. hurricanes, and the Dutch is a more “coping with the everyday” situation based. In the future where the everyday situation is estimated to change, along with an increased frequency of hazardous occasions it is of importance to learn from both of the strategies. In order to be able to live a valuable life where the sea front can be used for recreational purposes and still protect the city from the once in a hundred years event to minimize losses of economical, natural and social values.

Assessments of flood protection

Implementations of protective features to cope with rising sea levels and floods vary due to the difference in what is needed for the specific site. If the space is limited walls can be used in order to protect against erosion and high tide events. If there is more space available at the site levees are functional protective barriers (Johansson & Andersson, 2008). There are also dynamic protections, movable walls and locks that allow passages for ships and boats from the protective barrier. What the different types of protections have in common is that they can be combined in their main function of protecting against the sea/rivers with recreational spaces, infrastructure etc. However, literature on these specific sites and evaluations on the purpose of combining protection with recreational space is sparse. What can be found in the literature are mainly
explanations of how a pathway can be implemented on top of a levee or an explanation that a beach walk was put on top of the sea wall. Due to the lack of literature in this specific topic the space created by the protective barriers are in this paper considered to be viewed as a “blank piece of space” that can be used for whatever purpose that fits with the needs and requirements of the site.

After implementing a system, it is important to update the data, both for changing conditions connected to the changing climate and the maintaining of the system itself since it is put under stress from outer forces, weather, waves etc. It is also important to update the policy making for the system frequently as the case of Venice points out (Munaretto, et al., 2012). If the data is not updated properly the system will fail its function, which can be seen when studying the effects of Katrina in New Orleans 2005 (van Heerden, 2007). Data that was not considered, such as land degradation and sea level rise, made the crowns on the levees to be 30-60 cm lower then the system was originally intended to be. In order to make updated corrections in the system when it is already built it is of importance to include room for adaptations in the design of the protective barriers. Adaptations can include walls that adds height to the levee, spaces that can be adapted for different purposes due to outer factors and widening of levees that will allow a higher crown. As it is estimated that temperature in Sweden will rise for the next hundreds of years this will affect our outdoor life around the year, with a longer season for seaside activities, which increases the tenure of a system that is used for public space.

**Assessment planning in Scania, Sweden**

Of the three cities studied in Scania for this thesis, Höllviken (the main case), Lomma and Malmö, Höllviken is the one with the longest history of planning and analyzing risks of a sea level rise. Studies started of in the mid 80’s and assessments where mentioned in comprehensive plans from the year 2000. The three cities vary in attributes; Lomma and Höllviken are similar sized compared to Malmö that is more then 10 times the size of the two others. This is shown in the total coastline too where Höllviken has two coastlines, to the north and south of total 5,2 km, Lomma with 14 km and Malmö with 72,2 km. The climate with precipitation is almost identical of the three different sites. Even though the cities are close to each other geographically, they face different threats when it comes to the sea and flooding. Findings from the comprehensive plans in all of the municipalities states that the threat from a rising sea level will be central in future planning, in order to protect already built environment, cultural values, recreational grounds and infrastructure.

As mentioned Höllviken has been working with inquiries and protective planning for a couple of decades. This may not be surprising since the Falsterbo peninsula is located in the same municipality which is under threat of flooding due to the low lying land today. In Lomma one of the main threats from the sea is beach erosion, to some extent thanks to the increased traffic from the ports of Malmö. Tenure on easily eroded soils requires measures to be set in; this could be in form of wave breakers. The other major threat is flooding from rivers that have their mouths in the municipality of Lomma. In order to cope with this threat, land needs to be set aside as basins for the excess water during spring,
when flows are higher than normal. When it comes to future planning Lomma has started inquires of effects due to the rising sea. This is not the case of Malmö, where the new comprehensive plan was released in 2013. When it comes to future planning it is said that investigations is needed to cope with the future threats and cooperation between municipalities. Since the sea has no boundaries cooperation between neighboring municipalities is a good idea. Both to learn from each other’s investigations and implementations since they are facing similar threats, though the economical values at stake differ due to size differences between the cities.

For Höllviken that has an estimated value of built properties of 42 billion sek ($6.5 billion), about 0.1 billion sek ($0.015 billion) is at risks anticipated within the next 100 years. If the water continues to rise after that or if it will rise more than anticipated 2.5 billion sek ($0.387 billion) worth of properties are located under the 3-meter limit, which is fairly possible to be reached within 2-300 years. During the high tide events it is thought that the water level will reach more then 2 meters above todays average, even if this is just for a shorter period of time, damages of properties may still be severe for a small municipality.

Possible effects of protecting against rising sea, aside from the protection
The investment of protecting a town or city is a costly business, as it has been stated in examples from various sites in Europe and America earlier. With 65% of all 5 million cities (Hunt & Watkiss, 2011) situated at the coastlines massive investments and implementations will be implemented in the future to cope with the rising sea. A positive result from this is that there will be a pool of ideas to get inspired from in order on how to use and construct new barriers. For example rivers can be diverted in order to set off silt depositions in places where they work as barriers and this would give a new environment for sea birds. Another usage is that of recreational ground and creating opportunities to work out (i.e. jogging, walking, horseback riding, etc.) at a place where this would not be possible without a sea protective wall. This is where interdisciplinary knowledge of the planners comes to use.

For Europe, due to the geographical location, effects of increased costs as a result from future floods is small, 5% more then today annually compared to the USA that will suffer costs as a result of damages of 75% more then present (Hunt & Watkiss, 2011). The construction of the protection itself is a costly business and depending on the values protected it may not always be cost effective to protect a small town (McFadden, et al., 2007) against the future threats for that solely reason. In 2013 there is one ongoing project in Värmland, Sweden, where a 1200-meter barrier is constructed along a river. The estimated costs for the project are 80 million sek. Since the project is handling river protection where space is limited, more technically advanced construction is needed compared to an ocean project where space isn’t limited in the same way.

In order to attract people from outside of the town/municipality, more spectacular and features could be added and as a result increase the income of the municipality, with a higher rate of visitors to the area. Another reason could be to reclaim land in order to ease the pressure on an overly built area. The land,
depending on the needs could be used for new settlements or work as a basin, multifunctional space etc.

If nothing would be done for an area in order to protect it from future flooding there are still costs that has to be paid for, i.e. restoring the ground (Kirshen, et al., 2008). This is the most ineffective way, economically, to cope with rising sea levels. Since implementations needed for flood protection is costly it is wise to plan as efficient as possible with features existing today, both naturally and built, in order to minimize costs. By filling in existing barriers and rebuild features up to seven times of the money spent while building completely new features, according to inquiries made in Boston metro area (Kirshen, et al., 2007) can be saved. However, if it is solely built upon natural features, there are fewer opportunities to make new functional use of the space and new space created is limited. There may be problems in a long-term perspective if the sea level continues to rise even further, which it is estimated to do for a couple of hundred years. With a system built for the purpose solely to protect it can be planned for future adaptations in another manner then a road bank for example where space and function is limited.

**Discussion about alternatives for Höllviken**

When it comes to the implementations suggested in the design proposal for Höllviken, a couple of features was considered. Voices concerned by the public in Höllviken are mainly about failures of the drainage. If its not technical failures it is due to intense rain fall, which is anticipated to increase in the future. There are also plans to build a new area in the northern parts of Höllviken. The more hard surfaces there are in an area, the grounds absorption abilities decreases. In non-built areas, woodland is a better absorber then agricultural land, since the soil is more porous thanks to worms and more diversity of plants and insects. If a basin were built it would be possible, if the excess water is pumped to the basin, to ease the pressure of the drainage and as a result minimizing risk of floods due to heavy rainfall. In total the suggested basin in the design proposal measures approximately 2300x150 meters, 345 000 m². About 70% of this areal is water that has the ability to be flooded with 2 meters above todays level which gives an capacity of holding close to 500 000 m³/metric tons of water when needed extra than the normal level. Besides from holding water the basin figures as a wetland park, which is beneficial for maintaining biodiversity in the important environmental areas that the coasts are.

In the action plan it is suggested on how to cope with the main issue, the rising sea level and as a protective measure the town of Höllviken is going to be surrounded by a barrier (Landberg, et al., 2011). In order to keep costs down it is suggested to use the natural features to a maximum extent. For the southern shore, Kämpinge bay, this will be the case for the design proposal presented in this thesis. In order to create the new features presented, such as the basin and recreational spaces, road 100 will not figure as the main protection from the sea, but a levee outside the northern bay will be constructed. Since it is built almost all the way out to the coast in the north, land will be lost and won’t able to adapt by moving inland as it would in an natural environment, resulting in the beach as a whole will be lost eventually. This would also result in loss of
recreational possibilities that are at the site of the northern shore today with horse back riding trails, the cultural beach walk etc. With the levee it is also possible to reclaim land from the sea that will make it possible to develop venues for recreational activities in the municipality, which is one of the aims according to the comprehensive plan.

In order to construct the barriers material is needed. Suggestions is that the material is taken by redistributing the seabed, which at the planned barrier is circa 0,5 m below the surface. By evening out the floor in the excess water basin, inside the barrier, to 0,5-1 meter, material may also be used to construct the barrier along with the islands and connecting pathways within the park. There are also developments in Höllviken planned for the near future and waste products from these sites are also regarded as valuable land filling material for constructing the barrier.

![Diagram of high tide water, sea level, dyke, filled excess water basin level, excess water basin, dredge/new sea floor, original sea floor and shore profile.]

Figure 54. The figure shows the new profile of the northern shore with the outer barrier and dredges were some of the material for construction is taken from.

With a protective barrier creating new land for recreational purposes, the existing land can be used for other purposes. There are already plans to expand the built environment in Höllviken in the northeast. A barrier surrounding the town also gives possibilities for continuing today’s use of the adjacent land of Höllviken as agricultural land, or it may be adapted to more urban use depending on future demands of the site. The barriers protect the land from sea floods, though if further developments are needed. If further developments are constructed, the measures for Hammarbäcken needs to be further developed in order to handle high tide events from the stream.

**Venues for people**

Today road 100 is considered to be a barrier between the town and the northern shore. One reason for this could be how close the road is to the limited space that figures as the beach today. If there would be more space and features on the northern side of the road the feeling of intrusion from the road could be decreased and make the area more attractive for people to spend time at. In the sketching phase of the proposal, the idea of creating overpasses in order to erase the barrier that the road creates was considered. This was discarded due to reasons that it is insufficient to use an overpass, according to Gehl (2010), if it is
not an absolute necessity, since people rather stay at the same level when walking. Considering that the road is a two-lane road it would be a lot of effort to climb the stairs in order to walk just 10 meters to get across. Therefore I propose the current crossings with traffic lights will stay. What have been added are two parking lots in the shore side of the road in order to make accessibility easier for people driving to Höllviken.

For the southern shore at Kämpinge bay nothing will be added in order to increase the accessibility with cars. This is due to the existing pattern today of the roads in Höllviken, which aren't built for heavy traffic. Instead the system for pedestrians and bicyclists will be improved in order to enhance the usage of bikes and walking. A result of a paved beach walk is that there will be a greater protection against erosion on the easily eroded sand that makes the ground in the south. This protection does mostly affect the ground underneath and closely located to the path. In order to prevent erosion for the natural barriers (sand dunes) vegetation is a great way of binding the soil and sand, and it does also make the site and path more luscious.

During the analytical phase of the site it was found that there are no jogging tracks within Höllviken, the closest ones are to the west at Falsterbo and to the east at Vellinge. The suggested levee gives the opportunity to add a jogging trail within Höllviken without interfering with other functions of the area. As more then 30% of Swedish people are active when it comes to jogging or walking briskly as a form of exercise it will give opportunities for people to run and walk in a car free environment. Other popular outdoor activities in Höllviken are surfing in various forms. It is a unique spot in Sweden since the coastline faces two directions and two different seas. This means that wind direction is a factor that is of less concerns here then other spots. Adaptations for surfing will be made at both sites, to the south mainly spots for relaxing and viewing is added on a spot connected to the shore. At the northern shore the walk will be longer to get from the parking to the spots where surfing, kite-surfing etc. is possible. The longer walk along with the usage of seafloor material for constructing the barriers results in that deeper water is reached at the points of entry (platforms) for the surfboards, which is profitable since the risk of injury decreases with deeper water.

Since one of the functions for the new area is as a basin for excess water the amount of exposed ground will fluctuate with the need of filling the basin up. In order to have the pathways functional throughout the year they need to be elevated. The solution to cope with this problem is to create islands and extensions, peninsulas, from both the original coastline and the levee. Elevated pathways are used to connect the islands and peninsulas within the area. To develop this system of islands and peninsulas landfill is needed. This can be taken from areas in the municipality that will be developed (i.e. the new housing area to the east) and from sediments at the sea, which is one method used frequently in Holland and Dubai for example. Besides of using the site as a wetland park, that Boverket (2010) recommends in order to cope with excess water problems, several smaller island parks are created. Also mentioned in the comprehensive plan is revival of parks and developing these further within the
municipality. Specifically the cultural beach walk is mentioned to be further developed in the plan for Höllviken, which there is more possibilities to do with the new outlines created for the entire area as a result from the outer levee. The inspiration of creating individual parks in a water body connected to each other via pathways first comes from the Xuanwu lake park in Nanjing city, Jiangsu, China (see figure 32).

Discussion about possible effects of the implementation

Functions of the land
After implementation of the new and updated venues, the functions of the town wont change noticeably from the current situation shown in figure 17. However, there will be more space for recreational activities within the town of Höllviken along with increased protection against future flood events, more green spaces surrounding the town and connecting the characteristics of the town, and accessibility to the sites at the northern and southern (Kämpinge bay) shores. There will also be possibilities to expand the built environment more freely after future demands if the barriers wont were constructed just at the line of today’s developments as suggested in this thesis. After implementations, one of the effects strived for is an increase in social, recreational and environmental values.

It is also suggested that the site connected to the Viking village (see figure 40, p.49) should be an updated cultural area with space for development of parks and workshops. The idea is to broaden the usage of the reclaimed and protected land and entice a more diverse group of users to the site and to Höllviken as a whole. Suggestions of cultural activities at the site are workshops and studios for handicrafts to emphasize the heritage from the Viking era, and also writing and arts studios. The writing and arts studios are suggested due to the beautiful surrounding environment of the area.

Risk of flooding
Today the largest flood threat of Höllviken is the drainage, especially during heavy rains. As Boverket (2010) stated, one of the main failures is that too much water, too fast, increase the stress of drainage systems, leading to failure. By introducing the excess water basin water can be led away in order to ease the direct tenure of the system and portion the managing of excess water to times with less risk of failure after heavy rains.

The future threats, and to some extent current, the sea level (Ruddiman, 2008) is considered as a feature to consider. Examples from around the world show how effects of flooding and erosion due to sea level rise and hazardous events (Kirshen, et al., 2008, van Heerden, 2007, Hunt & Watkiss, 2011, Yu, 2010), affect areas economically, socially, environmentally, etc. negatively. By the implementation of flood protections in Höllviken the aim is to reduce the negative effects from floods as much as possible. Due to the economical values that are at stake and the costs of implementing large-scale flood protection, strictly economical benefits might be difficult to argue for, as in the case of Corton (McFadden, 2008). However, by using a geographical view (Mens, et al., 2011, McFadden, 2008), a wider spectrum of benefits to protecting features is presented.
The flood protections introduced and enforced at the sites are of the levee type since space is not an issue (Johansson & Andersson, 2008). At the northern shore the outer barrier, that functions as a high tide protection and a wall for the excess water basin will have a construction height of 3 meters, which is plenty to cope with the anticipated risks until 2100. Since the levee is located outside the coast there are no space limitations if the barrier needs to be raised further, which requires more areal land. If minor changes are needed it is possible to complement with a wall at the crown. The wall should be of the T-type since this is more efficient and stable than the l-type of crown wall. The inner wall of the northern shore (road 100) functions as a second protection if the first wall fails. Enforcements to today’s outline of the stretch is to rise the part on the cost side of the road, including the pathway for pedestrians and bicyclists and the horseback riding trail. The idea with a double wall is to keep the road 100, the only way to get to Falsterbo, functional during high tide event, even if the outer protection would fail.

At the southern shore the current conditions are a bit different. The idea is to use the current dunes and enforce these in orders to cope with the anticipated sea level rise (Landeberg, et al., 2011). At the far ends to the east and west, normal soil types of levees are introduced, where the ground consists of soil instead of sand. It is important to match the material of the protection with the underlying in order to eliminate risks of mishaps (van Heerden, 2007). By extending the barrier further to the southeast then the original plan, see figure 29, some agricultural land will be spared from flooding as a result of rising sea levels the next 100 years. It will also give room for adaptations if conditions would change. The idea is similar to that of the northern side, to be able to adapt and protect the built environment and infrastructure, even if an outer barrier would fail.

Since sand is more easily eroded then smaller grained soil, it is important to protect the dunes themselves. Since it is an area that is frequently used by people it needs to be managed, both maintaining, i.e. control and plant vegetation (Coljin & Binnendijk, 1998) and planning wise. Dunes are dynamic features of the land, and formed both by wind and waves. In order to minimize the transformation, apart from vegetating, wave breakers is a remedy to implement. There are several kinds of wave breakers in use today, to know which one is most suitable for the specific site further inquires of sediment movement of the area needs to be done.

**Green structure**

What will be added to Höllviken in this design proposal is large area/park of green and blue structure at the northern shore. Other then this there will be no major change to the characteristics of the area. At the northern current shoreline a pinewood park is added. The thoughts of this element in the design are to connect the new park with the town, that is scattered within a pine forest, on the opposite side of road 100. More to it, the green structure helps collecting precipitation since green is a soft surface compared to built environment that lacks the same ability to absorb water (Boverket, 2010). The green structure in the park changes with the different usage of the specific site. The pinewood
creates a disturbance barrier from road 100, while further out to the sea in the park less high vegetation is used in order to give full view of the sea. The wetland plants and the other smaller parks contribute to a preservation of biodiversity, which is important from an environmental point of view.

At the southern site the main purpose of vegetation and green structure is to bind the sand in the dunes to prevent erosion due to wind. In order for this to work it is important that the vegetation on the dunes is undisturbed since it is sensitive to activity (see figure 26). Hedges and bushes may also be used on the inland side of the dunes in order to prevent the dunes from moving inland (Alström & Åberg 2011). In order to prevent tenure of the vegetation paths leading over the dunes down to the beach is implemented. Also the pathway that stretches from east to west inland from the dunes reduces the tenure of the beach as well as ease the transportation. Apart from all the mentioned features above, vegetation also contributes to clean the air and water, which is an important feature in cities and towns where pollutions from traffic, etc. downgrades the air and water quality.

**Recreational venues**

There have been additions and renewal of current recreational grounds at the sites. For the southern shore a spectator venue and access platform for surfing (all kinds) is implemented. More than that there are no additions to Kämpinge bay in recreational activities since the main usage is bathing and strolling on the beach, which is considered to be fully functional at present. The addition of spectator venues for surfing, both in north and south could contribute to making Höllviken a central place for competitions and associative activities of the surrounding area in this growing sport.

For the northern coast jogging tracks is added, due to two reasons. Firstly, jogging and brisk walking is the most common activity form in Sweden. By introducing a venue where this is possible without interference from traffic, at least at the site, and changing views along with characteristics, which is important in order to keep the venue interesting according to Gehl (2010), the site has potential to contribute to the outdoor life of Höllviken. Secondly there are no jogging tracks within Höllviken today. Apart from the tracks and paths the original beach walk is kept, but raised according to measures mentioned above, together with the horseback-riding trail.

Other additions are an outdoors gym, the access platforms and an updated cultural walk. Due to the outlines and functionality of the venue at the northern shore, it is supposed to be used and visited by anyone and throughout the year and possible to use, even during high tides. Recreational activities connected to the sea are of great economical value, which can be seen in tourist destinations all over the world, i.e. the Dutch coast (Coljin & Bennendijk, 1998). Therefor maintaining and advertising for unique destinations could be profitable as a result of increased tourism.

**Evaluation of the world wide cases**

The cases studied have contributed to the implementation and outlines of the design proposal when it comes to reasons to enforce protection to the site. This
was achieved with the knowledge attained from the geographical approach, with cost efficiency of the projects, and with the land-use of areas (functions) besides the protecting features. However, the scale of the studied projects differentiates with the main case of Höllviken. Corton is the only small-scale project where the main function of the system is to protect against coastal erosion, which is estimated to become a future problem for Höllviken.

The larger scale projects (London Thames, Boston and Zeeland) are difficult to directly implement due to the immense budgets and measured scale compared to Höllviken. However, all of the studied projects give ideas on how to make the design and protective features workable, even when they are down sized in scale. Most important is to focus on the future users of the site; hence it is of great value to study already implemented remedies and the current functionality and benefits from the specific implementation.

**Costs and benefits of the project**

If using figures and sums presented earlier in this thesis the estimated costs for the design would be in the range of 250-450 million sek (Kirshen et al., 2008 and the example Värmland, mentioned earlier in the discussion).

The actual values of properties situated up to 3 meters above today’s sea level is estimated to a value of 2,6 billion sek. Also, the barriers open up for future developments in areas that would otherwise be impossible to use for constructions and agricultural land, due to high tide events and the average rise of the sea. A denser built environment would make higher income possible for the municipality and thereby making investments more profitable in a long-term perspective. The design also includes development of recreational surfaces in the township, incorporating sites for exercise and cultural/social meetings.

Another benefit of the design is that it reduces damages linked to the drainage on private properties, which currently costs the municipality 4 million sek annually in deductible fees. The actual costs are therefore a lot higher but are currently covered by the insurance companies. As the risk of floods increase the costs for insurance will raise affecting the sum that both private households and the municipality has to pay in order to deal with the damages.

**Conclusion**

The aim of this thesis is to investigate how a barrier that is aimed to protect against floods can bring multifunctional areas to a site after implementation. To conduct this study several cases around the world with similar climatic conditions was studied where different remedies are already in use. By studying the sites from different perspectives (reclaiming land, recreational activities etc.) a broader approach to the development of Höllviken was achieved and ideas on how to cope with the issues for the specific site were formed. This results in the suggested design proposal. For a project like this it would be interesting to investigate the economic aspects and benefits further as a future research project, with the final goal to develop a plan on how to realize the project.
The method has resulted in enough data to develop a design proposal that fulfills the original aim of the thesis.

In order to do efficient planning for protective measures, and planning in general, it is important for the planner to consider fluctuations and anticipated changes in the natural environment. Since it is uncertain to some extent, how the sea level and climate will develop over the next century remedies for protection should be constructed to be able to cope with estimated worst-case scenarios for the specific site. This is due to avoid failures similar to the Dutch flood in 1953 and New Orleans in 2005. The protective remedies themselves are not the only focal points in order to cope with predicted floods; the policymaking is another important measure. It seems that planning should be considered to deal with the everyday scenario, to keep the water out, together with plans and possibilities to deal with extreme events (such as once in a hundred year events, i.e. Katrina), in order to function most efficient. It is also profitable to cooperate over borders to include neighboring municipalities when dealing with rising sea level issues.

The first research question handles how the construction of barriers can create new grounds for recreation and social interaction. Reclaiming land from the sea is achievable by introducing an outer barrier at the site of the northern shore in Höllviken. This measure will not only enhance the safety and usability for the built environment and infrastructure within the town, even during high tide events. It will also create new ground that can be used for recreational activities and possibilities to use the land protected by the barrier for new developments. The usage of multifunctional spaces, which is used to both cope with environmental issues, as well as social activities is a good way to develop for the new reclaimed area since space is limited in the town. It adds more soft surfaces to the town as a whole that is more efficient to deal with intense precipitation than hard surfaces are, which are planned to be extended in the near future within the town of Höllviken.

The second research question is dealing with the possibility of infrastructure and functions of the area to be used during both normal and high tide events. By strategically placing new pathways at the northern and southern shore of Höllviken, it will not only be possible to use during high tide events, as it is located on barriers and elevated connected paths. The existing infrastructure (drainage and roads) will also be protected from the high tide events and possible to use during these conditions. Erosion will be prevented to some extent as well. By elevating and reinforcing existing measures, infrastructure is protected and can be used even during high tides (road 100), which is the only land bound road to Falsterbo. A beach walk will increase the accessibility and transportation through Kämpinge bay and also prevent the easily eroded dunes of stress from human activities.

Efficient planning requires knowledge about the dynamic environment that we live in, whether it is tropical or arctic climate, changes have always occurred and continue to do so. Humans have to adapt to these changes since these are powers too great for us to fully control.
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Appendix