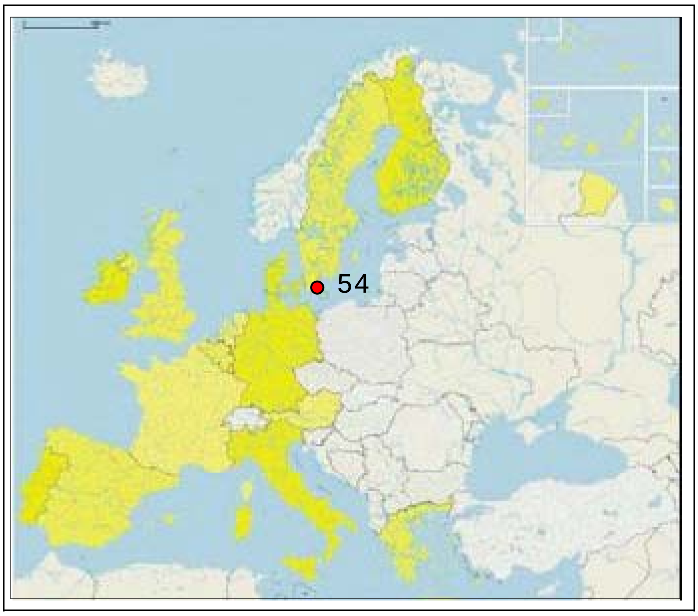
FALSTERBO PENINSULA (SWEDEN)



Contact:

Hans HANSON

Lund University
Dept. Of Water Resources Engineering

Tel: +46 46 222-8987
Fax: +46 46 222-4435

E-mail: Hans.Hanson@tvrl.lth.se

1. GENERAL DESCRIPTION OF THE AREA

1.1 Physical process level

1.1.1 Classification

Fig. 1: Location of case area.

Falsterbo Peninsula is located in the most southern province of Sweden, Scania. Sweden is subject to land uplift by isostatic rebound. Notable erosion only occurs in Scania where the land uplift is around zero. The rest of Sweden does not suffer from coastal erosion because of the land uplift. The Scania coast is micro-tidal.

The coastal type according to the scoping study is: 3b. Wave dominated sediment. Plains
Dune coasts in micro-tidal zones

Fig. 2: Overview of the case area.

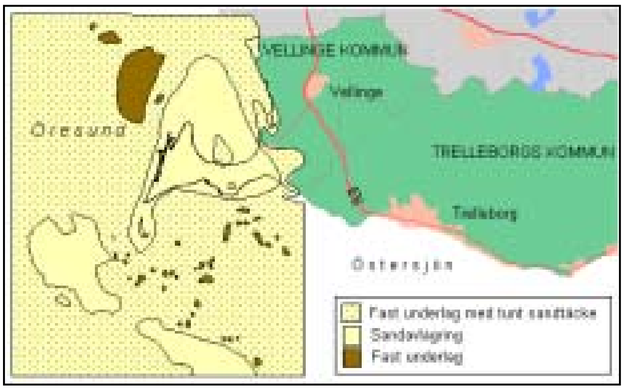
1.1.2 Geology

Sweden forms the Archean marginal basement with the Baltic-Russian sedimentary basin to the east, the Danish-German basins in the south and the Caledonian mountain range in the west. During several stages of the Quaternary, Sweden and the surrounding seas were completely glaciated, as well as during the final, Weichselian substage, which culminated only some 30,000 years ago.

When the front of the receding ice, in about 12,000 BC, reached Scania, the southernmost province of Sweden (where Falsterbo is located), a complicated history of shore development started that was dependent on rate of deglaciation, land uplift by isostatic rebound, sea-level variation and shifting outlets from the Baltic basin. The present rate of land uplift by isostatic rebound varies from 0 in southern Scania, where the case area Falsterbo Peninsula is located, to a maximum of 0,9 m / century on the coast of the Bothnian Bay.

The inland ice produced a till cover of variable texture and thickness and glaciofluvial sediments of two distinctive types: sandy, coarser sediments and suspended silt and clay.

The province of Scania, from a geological point of view, belongs to the European continent rather than to Fennoscandia because the Late Cretaceous covered it. The Archean basement was broken up, mainly in the Permian, along NW-SE fracture zones, resulting in horsts and grabens. Except for the Horst areas, glacial drift deposits are usually thick in Scania, 40-50 m is not exceptional.



Although low coasts dominate, active cliffs cut in till and glaciofluvial sediments are found along elevated tracts. The isoline of zero-land uplift runs NW-SE through central Scania, which at least partly explains why Scania is the only mainland province with notable coastal erosion.

Fast underland med tunt sandtacke= solid subsoil covered with sand.
Sandavlagring= sand cover by eolian transport
Fast underlag= solid subsoil

Fig. 3: Geological subsoil of Falsterbo Peninsula.

The peninsula started to form 6-7000 years ago, during post-glacial time, and has a rather simple geologic stratigraphy. The on average about 10-m thick unconsolidated, fine- to medium sand layer rests on clay-till, under which is bedrock of Danian limestone. Along three stretches, the clay-till rises higher and locally almost reaches the surface. It was around these elevated parts that the peninsula once started to form.

The three elevated clay-tills are more resistant against erosion than the unconsolidated sand layer. Through wind and wave action, sand therefore accumulated around these resistant deposits and built spits and tombolo's, which, in turn, created lagoons by connecting the till deposits to each other and to the mainland. These lagoons then became filled with sand through overwash and eolian transport, and the peninsula started to form.
As can be seen in Figure 4, the peninsula beaches consist of easily erodible beach sand. The southern coast and western coast of the peninsula exist of fine- to medium sized sand grains, while the northern coast exists of fine-grained and organic material.

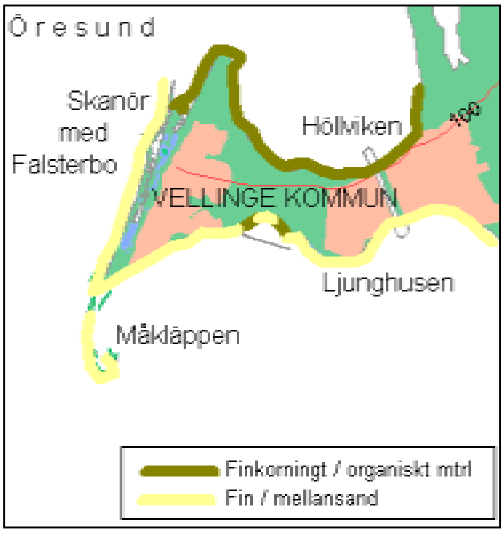


Fig. 4: Morphological features peninsula.

Finkorningt / organiskt mtrl= fine-grained and organic material
Fin / mellandsand= fine- to medium sized sandgrains

1.1.3 Morphology

Along the practically tideless coast of Falsterbo Peninsula, distinct morphological features are found. South of the Peninsula, the island of Makläppen is found together with two sand-tongues. Clear indications that the peninsula has not reached its equilibrium shape are found. The island of Makläppen will become totally integrated with the peninsula, and the two sand-tongues on the south coast will eventually join and establish a new coastline. Then, processes similar to those, which once created the peninsula, will fill the lagoon within. Both the joining of the two sand-tongues and the integration of Makläppen can be related to dumped dredging material in the 1940s. The construction of the harbour (in Skanör) led to the birth of a down drift (directed northward) spit, which is several kilometres long.

1.1.4 Physical processes

Tide

Normal tidal ranges in the adjacent Baltic Sea are less than 0,25 m. Tidal action plays practically no role in this area.

Storm events

Extreme water levels are not directly related to local strong winds, but arise from regional hydrographical and meteorological effects.

Sea level rise

Sea level measurements made in the area since 1945 are studied and it is shown that NHW level has risen by an average of some 0,5 cm/year the last 51 years and around 0,75 cm/year in the last 25 years. An extrapolation of the data showed that the NHW level in 2050 with a probability of 50% can be expected to be around 148 cm above the present mean sea level.

Waves

In Figure 5, the wave directions at the Falsterbo Peninsula are shown. The predominant wave direction is west to southwest. The longshore current is mainly wave-induced. The average wave heights vary from 0-1 m, the wave climate is moderate.

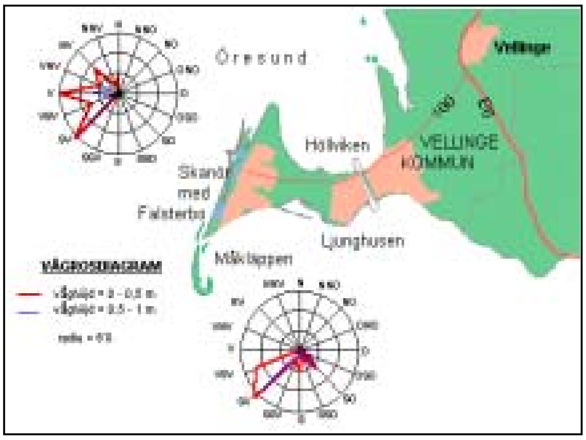


Fig. 5: Wave directions at Falsterbo Peninsula.

Land subsidence

At the southern coasts of Scania, instead of land uplift, there is a small land subsidence present of 0,5 mm/year.

1.1.5 Erosion

Structural erosion

The land subsidence, though it is really small and seems insignificant, on the long run will result in ongoing erosion at the biggest part of the southern coast of Scania. On a shorter timeframe, the net longshore transport caused mainly by wave action is of considerably greater importance for the erosion of the coasts. The unconsolidated layer is very sensitive to erosion and high water levels, especially as the topography is very flat.

The net longshore transport is shown in Figure 6 for Falsterbo. Along the western coast the transport is directed northward and along the southern coast it is directed westward. This is caused by the predominant wind directions west-southwest. The south coast is sheltered from the dominant wind/wave direction and therefore the net direction is westward. Furthermore, it can clearly be seen that the net transport is largest in the surf zone close to the coast. Sediment supplies are primarily from the east, and potentially the south-west and the incident waves are typically erosive in nature.

Fig. 6: Net sediment transport direction Falsterbo Peninsula.

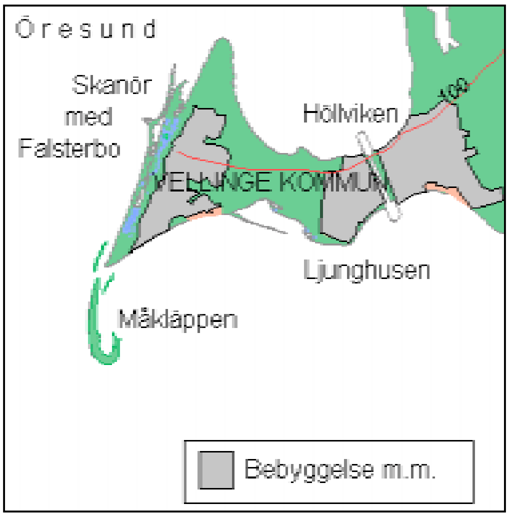
Hanson and Larson (1993) applied the numerical shoreline change model GENESIS to estimate the potential sediment transport rates along the south and west coasts. For calibration, at Skanör Harbour the sediment budget was formulated, which indicates a net longshore sediment transport along the west coast of 39,000 m^3/year to the north. The calculation with the model gave a net longshore transport of 35,000 m^3/year to the north for the west coast and 61,000 m^3/year to the west for the south coast.

1.2 Socio-economic aspects

1.2.1 Population rate

Falsterbo Peninsula has about 10,000 inhabitants. In Figure 7 the built-up area of Falsterbo peninsula is shown. Falsterbo Peninsula covers an area of approximately 50 km2 (very rough estimate!). The population rate is 10,000/50 = 200 persons /km2. Thus, the area is densely populated. The population rate of the entire commune of Vellinge is 29,641 / 142 km^2 = 209 persons/ km^2 resembles the result very well.

1.2.2 Major functions of the coastal zone



Falsterbo peninsula is famous for its unique scenery, white beaches, and golf courses, factors that make it an excellent recreational area. A great part of it has nature reserve status. Skanör is an old village from the herring period that peaked about 700 years ago. Nowadays it is a suburb to Malmo and a summer village. Falsterbo is a twin village to Skanör dating from the Middle Age when herring was fished and sold around the Baltic Sea. Between World War I and II, famous people met at 'Falsterbohus' and enjoyed the long sandy beaches and the nice summer weather.

Fig. 7: Built-up area Falsterbo Peninsula.

- **Tourism and recreation:** Falsterbo is especially known for birding tourism, it is a famous flyway for migrating birds, which make Falsterbo one of the European hotspots for ornithologists. Furthermore, horseback riding, sailing, wind-surfing are popular activities attracting tourism at Falsterbo Peninsula.
- **Urbanisation** (protection of human lives and investments)
- **Nature conservation:** The area Foteviken is present in Falsterbo, this has been a Ramsar site since 1974. The area, that covers 7530 ha, includes several nature reserves.
- **Fishery and aquaculture:** The major industry at Falsterbo exists of a large fishing dock in the harbour in Skanör.

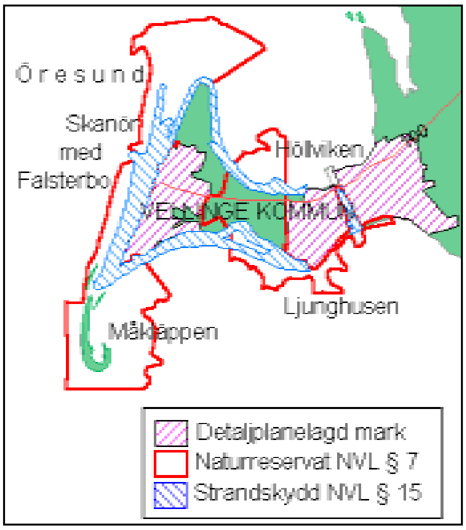


Fig. 8: Planning for Falsterbo Peninsula.

In Figure 8, the spatial planning for Falsterbo Peninsula is shown. The built-up area remains within the existing borders. Outside the built-up areas the greatest part of Falsterbo Peninsula is pointed out as nature reserve. Furthermore, a protected coastal strip is appointed along the entire coastal line of Falsterbo Peninsula. This coastal strip is fixed by law.

1.2.3 Land use

The land use at Falsterbo Peninsula can be seen in Figure 8. Most of the coastal strip is reserved for coastal protection purposes, as is required by the building restrictions in Denmark. No agricultural use of this coastal strip occurs, the land use functions are recreation and nature. Built up urban areas are located outside the defined coastal strip (at least 300 m from waterline).

1.2.4 Assessment of capital at risk

According to Bryant et al (1995), the coast at Falsterbo Peninsula is at high risk.

- High: city or major port or > 150 persons/km2 or >150 m road/km2 or > 10 m pipeline/km2
- Moderate: 150 < persons/km2 > 75 and 150 < m road/km2 > 100 and 10 < m pipeline/km2 > 0
- Low: persons/km2 < 75 and m road/km2 < 100 and no pipelines

The population rate of 200 persons/km2 also implies a high risk according to this classification.

2. PROBLEM DESCRIPTION

2.1 Eroding sites

2.1.1 Current Scenario

The case study will focus on the coastal dynamics along the valuable south and west coasts, characterized by rather wide sandy beaches suitable for recreation but prone to erosion. The north shoreline is subject to much lower incoming wave energy and generally quite stable. No geomorphologic features of particular interest exist here and it is not as valuable as the south and west coasts.

In Figure 9, the eroding sites on Falsterbo Peninsula are shown:

➢ North of the Skanör Harbour

Since the construction of the harbour a long time ago, a substantial withdrawal of the beach north of the harbour has taken place (leeside erosion). South of the harbour large quantities of sand have accumulated.

➢ Makläppen

The erosion-affected area is the coastal stretch west respectively east of the Falsterbo lighthouse.

Concluding, in the current situation the erosion problems are very local and are not present on a large scale.

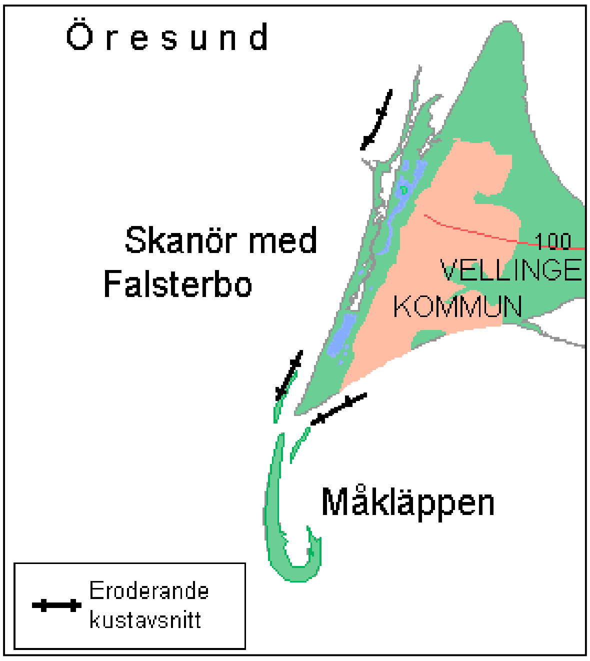


Fig. 9 : Eroding sites at Falsterbo Peninsula.

2.1.2 Future scenario

Falsterbo peninsula is very low-lying and built up of unconsolidated sand. Thus, it is very sensitive to increasing sea levels. Sea level measurements made in the area since 1945 are studied and it is shown that NHW level has risen by an average of some 0,5 cm/year the last 51 years and around 0,75 cm/year in the last 25 years.

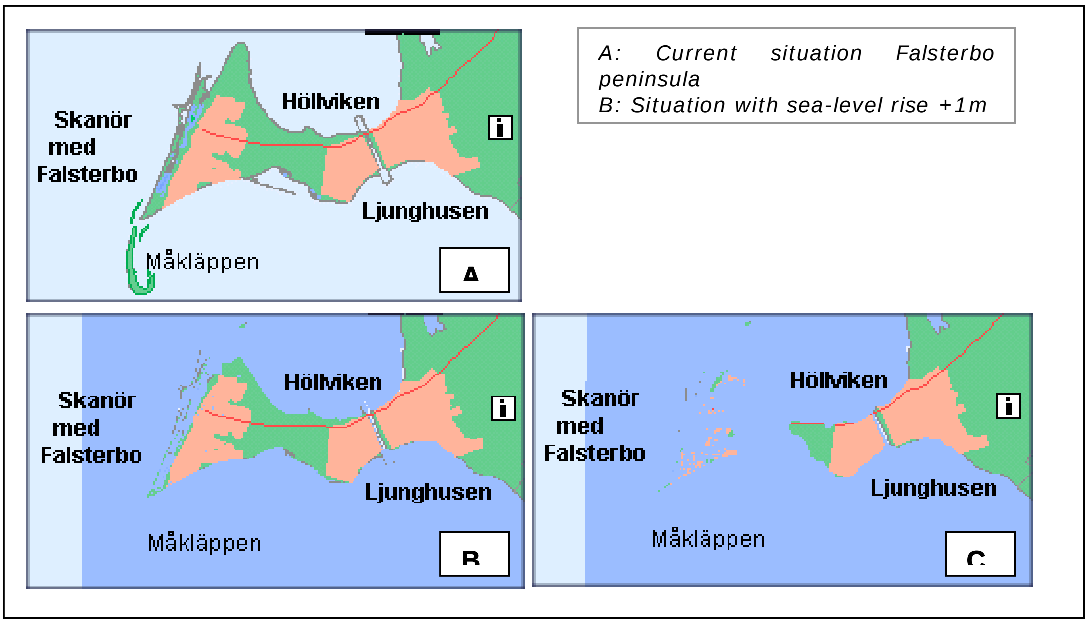


Fig. 10: Effect of sea-level rise on the Falsterbo Peninsula.

It is found that the annual-high water level around the peninsula increases by 5 mm per year and statistically will exceed +1.5 m in relation to present mean sea level every 2 years by 2050. According to a digital elevation model (DEM), such exceedence will result in inundation for some 20% of the westerly urban areas. Extreme water levels are not directly related to local strong winds, but arise from regional hydrographical and meteorological effects. Hence, extreme waves and water levels are unlikely to occur concurrently. The exceptional sensitivity of the local coastal environment is confirmed by the fact that human activity has contributed to the rapid growth of the three most distinct features along the peninsula coast.

To illustrate the effect and importance of sea-level rise for Falsterbo, the situation with a sea-level rise of 1 m and 2 m without further measures taken is shown in Figure 10. The most sensitive part of Falsterbo is the western coast with spits, barriers and lagoons and the island of Makläppen. With a sea-level rise of 1 m this area will be flooded, the villages Skanör and Falsterbo is expected to be flooded when the sea-level rise is 2 m. This indicates the importance of sea-level rise (and land subsidence) for the peninsula Falsterbo.

2.2 Impacts

The impacts of the local erosion, taking place in the current situation, are not drastic. The eroded areas are not inhabited thus human lives or investments are not at stake. The erosion does have an impact on recreational beaches, however the island offers a lot more fine beaches in the current situation.

Looking at the future scenario for Falsterbo, including the sea level rise and land subsidence, much more serious impacts are foreseen. For a relative sea-level rise of 1 m all the recreational beaches and important nature reserves are flooded according to prediction. For a relative sea-level rise of 2 m human lives and investments are threatened; the villages Falsterbo and Skanör are predicted to be flooded in this situation.

3. SOLUTIONS/MEASURES

3.1 Policy options

Fig. 11: View towards southwest point of Falsterbo.

Up until now, the policy option for Falsterbo Peninsula has been "do nothing". The locally threatened areas are not very valuable and therefore no action has been undertaken recently. Historically, some measures were taken to slow down or stop the erosion locally ("hold the line" or "limited intervention").

3.2 Strategy

3.2.1 Current situation

For the current erosion problems, no measures have been taken recently. The measures, which have been taken, are very old and only remain effective in a few parts. These historic measures are located in the coastal area east of the lighthouse and consist of hard coastal measures. No measures were taken north of the harbour where leeside erosion occurs. Apparently this leeside erosion does not cause any problems.

3.2.2 Future scenario

Vulnerability to high water levels and wave action is of concern for the 10,000 residents of the peninsula, especially in consideration of global warming as enhanced inundation and coastal erosion problems may ensue. Rational counteractions of such problems are possible only through sufficient knowledge of local coastal processes. Equally important are planning and ability to identify threatened areas. Therefore, extensive studies are now being carried out about the possible sea level rise at Falsterbo Peninsula and the possible consequences this can have for the peninsula. Furthermore, studies are being carried out as to what solutions can be applied to counteract the sea level rise.

Fig. 12: Historic measures at Falsterbo.

In general, in Sweden beach nourishments are very unusual for coastal protection. In the unusual cases the volume of supplied material is of the order of a few thousands up to 15,000 m^3. In almost all coastal erosion cases, revetments or groins have been used.

3.3 Technical measures

3.3.1 Type

East of the southern tip of Falsterbo some measures have been taken a long time ago. A seawall and a groin were built to prevent further erosion of the beach. The seawall and groins were made of wooden poles. These poles were fixed in the foreshore zone of the beach (in the water).

3.3.2 Future scenario

Of the anticipated mean sea-level rise and potential shift in precipitation/ evapotranspiration rates until 2050, the former is believed to have greater impact on the unconfined groundwater-table position. An important finding is that a limited sand-layer thickness largely governs the groundwater-flooding liability of a given region.

Vegetated earth dams and beach nourishment are the most viable solutions for potential flooding and erosion problems. They can be integrated into the unique landscape and precious coastal areas with minor aesthetic impacts. In addition, the moderate wave climate means that long time intervals can elapse between re-nourishments.

4. EFFECTS AND LESSONS LEARNED

4.1 Effects related to erosion

Up until now, the general policy option at Falsterbo is do nothing because the locally occurring erosion so far does not cause any problems. The local measures that have been taken a long time ago only remain effective in a few parts, most of the erosion east and west of the lighthouse is continuing.

Falsterbo peninsula is very low-lying and built up of unconsolidated sand. Furthermore, the south of Sweden is the only region in Sweden where instead of land uplift a situation of small land subsidence (0.5 mm/yr) is present. Thus, it is very sensitive to increasing sea levels. Therefore, relative sea level rise in the future can be of great importance for Falsterbo, the flooding risks will increase significantly for the entire peninsula. Therefore, extensive studies are now being carried out about the possible sea level rise at Falsterbo Peninsula and the possible consequences this can have for the peninsula. Furthermore, studies are being carried out as to what solutions can be applied to counteract the sea level rise.

4.2 Effects related to socio-economic aspects

Because the historic measures were applied so locally, the impact on socio-economic aspects in the current situation is not of real importance. However, possible future measures will have a great impact on socio-economic aspects because the functions tourism, nature and urbanisation are under great threat of the rising sea level and have to be protected by applying coastal protections. If nothing is done, the present coastal strips will be flooded. These coastal strips represent the most important functions of Falsterbo Peninsula: recreation and nature. In other predictions even the urban areas of the peninsula will be flooded.

4.3 Effects in neighbouring regions

Because of the small scale of the coastal protection measures in the current situation, no effects were noticed in neighbouring regions.
Future measures to protect the peninsula from flooding will possibly fix the peninsula's coastline. Clear indications that the peninsula has not reached its equilibrium shape have been found; therefore fixing the coastline will disturb the natural processes towards equilibrium of the peninsula and can have far-reaching influences on neighbouring coastal regions. Furthermore, if the peninsula's coastline is fixed in a situation that is not the equilibrium state, a lot of maintenance will be needed to maintain that coastline.

4.4 Relation with ICZM

In Sweden, coastal planning is mainly the responsibility of the municipalities, for some special sector planning the region or even national level can become responsible. The coordination of the different state sector interests in the physical plans of the municipalities however, is the responsibility of the County Administrative Board. The County Administrative Boards develop regional guidelines, and have to assure that national and regional policies will be considered in local planning. An Environmental Code was drawn up with the purpose to create a stronger environmental legislation. Furthermore, following the HELCOM recommendation 15/1 (protection of the coastal strip), a protected shoreline zone ranging 100 m inland and offshore is reserved for out-door recreation and nature protection and may be extended to 300 m if necessary. The planning control system is mainly restrictive; the state of implementation depends very much on the way these planning instruments are used.

In Sweden, on a national level fifteen national environmental quality objectives were adopted in 1999, these comprise “a balanced marine environment, sustainable coastal areas and archipelagos”. It says that sea and coast must have a high degree of biological diversity, opportunities for aesthetic experiences and natural and cultural values. Industrial activities and recreations shall be carried out in a way that promotes sustainable development.

Integrated coastal zone planning is in a very early stage in Sweden, increased environmental problems and conflicts between different interests in coastal areas led to experimental works with integrated physical planning of sea and coast by the Swedish Marine Resources Commission and the Swedish Board of Housing, Building and Planning.

In the plans to protect Falsterbo against the future sea level rise, the unique landscape and precious coastal areas play an important role in the choice for a coastal protection scheme. An integrated approach of the coastal protection plan is therefore necessary.

4.5 Conclusions

Effectiveness

The locally taken measures are very old and in general not effective anymore. However, the erosion has not caused great problems in the past at Falsterbo Peninsula. Because Falsterbo Peninsula is low-lying and built up out of unconsolidated sediment and because of the small but present land subsidence, the peninsula is very sensitive to future sea level rise and will need extra coastal protection to prevent flooding. Before taking any measures to combat the predicted sea level rise, extensive studies of the effects of sea level rise on the peninsula are needed to determine the best solution.

Possible undesirable effects

No undesirable effects have taken place in the current situation, however for future large scale protection schemes it has to be taken into account that the Peninsula is very sensitive for human interference and taking these measures could have some undesirable effects.

Gaps in information

For future possible measures, the influence of large coastal protection schemes at Falsterbo Peninsula is difficult to predict because the peninsula is not in its equilibrium shape yet and has shown to be very sensitive for human interference. Therefore, extensive studies are needed before measures are taken.

5. REFERENCES

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Figures:

Figure 1: http://www.icm.noaa.gov/country/sweden.html
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