VATTEN – Journal of Water Management and Research 68: 21–30. Lund 2012

MODELLING COASTAL EROSION IN BJÄRRED, LOMMA MUNICIPALITY – LONG-TERM EVOLUTION AND PROTECTIVE MEASURES

Modellering av stranderosion i Bjärred, Lomma kommun – Långsiktig utveckling och skyddsåtgärder

by CAROLINA DE MAS and JOHAN SÖDERGREN
Alumni from Lund University, Water Resources Master's Programme
E-mail: carolina.de.mas@maerskoil.com, Johan.o.sodergren@gmail.com

Abstract

The aim of the present work was to investigate the erosion phenomena taking place at the coast in Bjärred and the possibility of introducing additional protective measures. An aerial photograph analysis showed that the beach has eroded an average of 4.3 m during the time period 1963–2002. Among the measures applied by the municipality in the past, only concrete slabs had a good performance by completely halting the erosion at the site. Calculations of cross-shore transport rates showed that the erosion will increase greatly with a future sea water level rise. One main part of the study was to run simulations of the study area using the shoreline evolution model GENESIS. The simulated protective measures were placement of breakwaters, revetments (concrete slabs or sheet piles) groins and beach nourishment projects. The analysis of the shore evolution, also including financial and environmental aspects, lead to the conclusion that placing revetments in combination with beach nourishment (with vegetation added to the sand) was a good option and should be further investigated.

Key words – coastal erosion, runup, sediment transport, climate change, GENESIS, protective measures

Sammanfattning

Syftet med det här arbetet är att undersöka hur stranderosionen verkar i en påverkad strandremsa i Bjärred och möjligheten att implementera ytterligare åtgärder för att förbättra situationen. En flygbildsanalys visade att stranden eroderat i genomsnitt 4.3 meter för tidsperioden 1963–2002. Bland skyddsåtgärderna som hittills använts är det enbart flexplattorna i området som haft en god verkan, då erosionsförloppet avstannar helt. Beräkningar av den vinkelräta sedimenttransporten visar att erosionen troligen kommer att öka dramatiskt med en förväntad havsnivåhöjning. En stor del av studien innefattar simulering av området genom användandet av datormodellen GENESIS. De simulerade skyddsåtgärderna var vågbrytare, strandskoningar, hövder samt sandutfyllnad. Analysen, vilken även innefattade ekonomiska och miljömässiga aspekter, ledde fram till slutsatsen att strandskoningar i kombination med sandutfyllnad (med planterad vegetation i sanden) var ett bra alternativ och bör undersökas vidare.

Introduction

Many coastal areas around the world experience the effects of erosion and shoreline retreat. This phenomenon leads to great economical, environmental and social losses for the affected communities. The risk of a near future climate change, including both sea water level rise and increased wind speeds, might increase the erosion related problems to a great extent. This has forced many municipalities to start implement some integrated action plans in order to protect their shores and properties from the wave action.

In a coastal area there is a continuous supply and loss of sediments and, as long as they are balanced over a period of time, the beach profile is in equilibrium. This means that the profile can experience some retreat or accretion (often seasonal variations) but is always tending to recover its original shape.

If the rate at which sediments leave an area is higher than their incoming rate this equilibrium is lost, and erosion will occur. If so, the shoreline will change in shape and size while sediment is transported away. The sediment might either be transported following a longshore direction or a cross-shore direction.

Longshore drift is mainly caused by the impact of oblique wind generated waves and due to near shore currents. Cross-shore drift, instead, is mainly due to storm impact and high water levels meaning that large amounts of sand can be transported away in a short period of time. Human activity around a coastal area can accelerate these processes and increase the erosion rate. (CEM, Longshore Sediment Transport, 2002a); (CEM, Cross-shore Sediment Transport Processes, 2002b)

Cross-shore transport of sediments can be directed landward or seaward. As mentioned above, a large amount of sediment can be carried away from the shore during a short period of time during a storm event. When calm weather conditions take place onshore transport typically occurs, lasting for a longer time period and carrying smaller amount of sediment but during a longer period of time. Sometimes fine material might be transported away from the shore and settled far out in the sea, thus not returning to the shore. (CEM, Cross-shore Sediment Transport Processes, 2002b) A simplified method to calculate the cross-shore transport rate uses the variables dune foot height, dune height and slope of beach berm, together with the vertical runup height of the incoming waves.

When dealing with coastal erosion in a specific area there are different ways of classifying the actions that can be made to overcome it. One way of dividing them into categories is shown in table 1 (Pope, 1997).

This article is based on a Master Thesis developed during the autumn and winter of 2010 through the collaboration between the Department of Water Resources Engineering at LTH, Lund University and the consultant company Ramböll Sverige AB in Malmö. The aim is to use a computer model to simulate the effect of suggested protective measures for the coast stretch in Bjärred, Skåne.

Table 1. *Categories and actions.*

Category	Action
Abstention	No action taken
Adaption	Learn to live with it (includes retreat)
Moderation	Slow down the erosion rate
Restoration	Fill up the beach
Armoring	Separate water from land

Materials and Methods

Study area – Bjärred

Historically, Lomma municipality in southern Sweden has faced problems with erosion at different places along its shoreline. One of the most affected areas in the municipality is Bjärred, located some distance north of Lomma village. During the winter storms of 2006/2007 erosion caused a waste water pipe to be almost revealed, thus in danger of breaking and polluting Lomma bay. In addition some property walls, located right above the dunes, were damaged by the wave impact.

The study area covers a coast stretch of approximately 400 m ranging from Västra Kennelvägen (in the north) and Öresundsvägen (in the south). This particular area is of interest since a major retreat of the shoreline has been observed during the last years. Lomma bay is a very shallow water body where the depth 800 m offshore is only about 2 m (Brännlund and Svensson, 2005). At a distance of 900 m the depth is around 4 m, which is assumed to be the depth of closure.

A previous study showed that the soil in the study area is of varying grain size, with a significant content of clay and silt, but with no particularly dominating grain size. From the edge of the water, the foreshore slopes lightly upwards until reaching the dune foot, which has an average height of 1.4 m. The top elevation of the dune is around 3 m referred to the mean water level (Brännlund and Svensson, 2005).

Shoreline evolution and protective measures in Bjärred

The evolution of the shoreline in Bjärred during the past decades can be observed when comparing aerial pictures from different years. An accurate analysis of them can provide information about the rate of shore retreat, which areas are the most affected and thus define where to put more efforts in protecting the shore. Aerial pictures of Bjärred were obtained from Lantmäteriet covering the years 1939, 1955, 1963, 1973, 1978, 1985, 1998, 2002 and 2010 (Lantmäteriet, 2010).

The retreat of the vegetation line is assumed to be representative for the shoreline retreat and easier to extract from aerial photographs. The photographs were digitalized and analyzed using the ArcGIS based tool Digital Shoreline Analysis System (DSAS), which quantified the total erosion and the erosion rate between certain years.

The analysis was split into two time periods and the

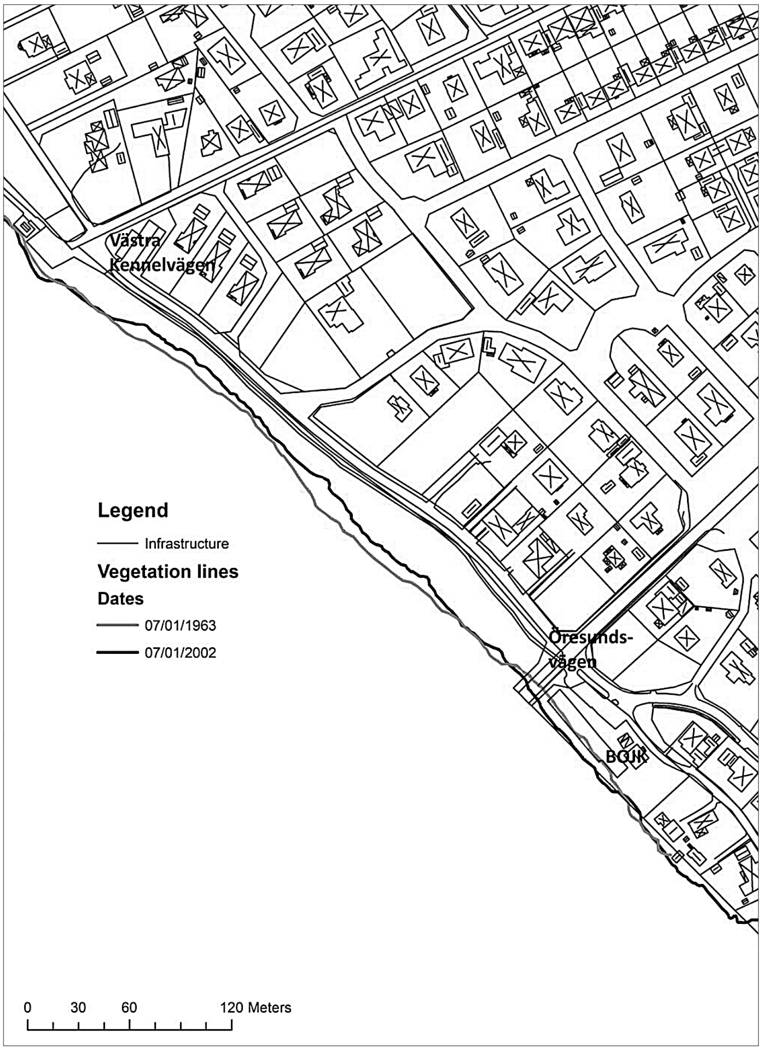

Figure 1. *Vegetation line change 1963–2002.*

results from the first period, ranging from 1963–2002, is presented in Figure 1. The division into two time periods was done mainly because there is a major change in the shoreline in the northern part of the study area, representing revetments that were built during 2006. Erosion appears to take place in the whole study area except for a small stretch where there is accretion (green area). During 1993, revetments were built in that part and therefore the accumulation in that area is most likely not natural but originating from restoration of the shoreline. The average retreat for the time period is 4.6 m, at some places reaching even 13 m and the yearly average retreat for the whole study area is 0.11 m/year.

In 2006 a 100 m test section with different types of revetments and gabions was built in the northern part of the study area. Among these actions taken by the municipality, the only coastal protective measure efficiently working was the placement of concrete slabs on the beach. Other tested structures, such as gabions have not provided satisfying results mainly due to the fact that the underlying soils eroded.

Wave hindcasting

The in-data for the computer model used to simulate the shoreline evolution are wave heights and wave periods. These values were needed to be hindcasted using wind data from SMHI. When having the hindcasted waves some manual calculations of wave runup and the number of occasions when cross-shore erosion occurs, meaning when the runup is higher than the height of the dune foot, are also performed.

Waves can be created in different ways of which wind is the most common generating mechanism. The factors affecting the size and shape of the waves are wind speed, storm duration and fetch length. A wave is generally generated at the open sea and then propagated towards land. This travel changes the properties of the waves, where there is a decrease in wave celerity the closer to the shore they travel.

A method to hindcast waves has been used for the water conditions of Lomma bay. Historical wind and water level records from the weather stations Falsterbo and Viken were assumed to be representative for the study area. To estimate the wave growth it was necessary to understand under which conditions the waves are generated. If winds blow for a certain time with certain intensity there are two factors limiting wave generation. These are fetch length or the duration of the wind.

Lomma bay is considered to be a shallow water body (Larson, 2010). For a given wind speed and fetch condition, the generated wave height and period in shallow and transitional waters will be smaller compared to the waves in deep water. This is due to the loss of energy caused by bottom friction and percolation (Komar, 1998).

When approaching the shore, the forecasted waves will experience several transformation phenomena such as refraction, shoaling, diffraction and breaking. For analysis purposes, these changes will not be taken into account but when simulating the shoreline response using the computer model GENESIS the model will perform all these transformations through internal models. The frequency of occurrence of each hindcasted wave height between 1976 and 2008 is shown in Figure 2.

There is also an interest in estimating the runup in the study area because it is the main phenomenon responsible for cross-shore erosion when water hits the dune foot. If the runup is high enough, overtopping might occur and the waves could endanger structures or other infrastructure behind the dune. The combination of high water level together with high wave generated run-up levels causes some extreme values of the total runup. Results of the water level and runup at a certain time between 1976 and 2010 are shown in Figure 3.

As mentioned above cross-shore erosion occurs when the runup hits the dune foot. For the conditions in Bjärred this happens when the runup exceeds 1.4 m, which happens in average 13.6 times per year.

Climate change

The Intergovernmental Panel on Climate Change (IPCC) states that most likely climate change induced by human activity is a fact, and this will induce a change in sea water level and winds. The IPCC gathers the latest discoveries in science regarding climate change, including changes in sea level and winds. The latest report released, when the thesis was done, was in 2007 (Assessment Report 4, AR4) and it presents four different scenarios of the global climate change and discusses figures of sea level rise in the years 2070–2100. Considering the scenarios introduced by the IPCC, four different scenarios, regarding change in sea water level and winds, are considered for the further analysis and computer modelling and they are summarized in Table 2. As can be seen in table 2 Scenario H1 represents *no increased climate change*, while I2 represents the *worst case scenario.*

By changing the wind and sea water level data to fit the different scenarios the following results of wave run-up are summarized and compared in Table 3. The more

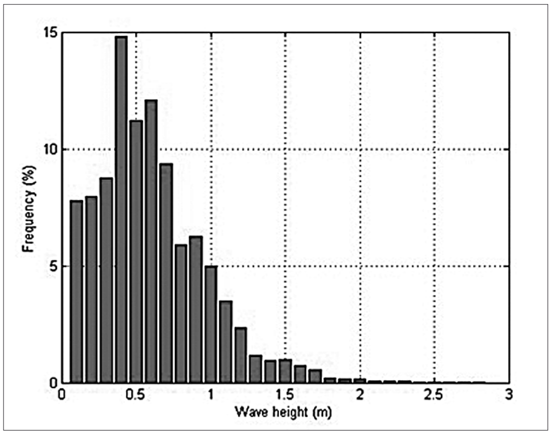

Figure 2. *Frequency diagram of wave height, 1976–2008. (Processed data from SMHI, 2010.)*

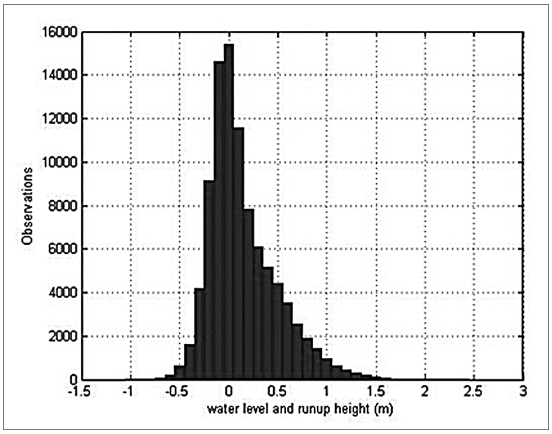

Figure 3. *Distribution of water level and wave runup, Viken 1976–2010. (Processed data from SMHI, 2010.)*

Table 2. *Summary of scenarios used for further analysis.*

	Sea Water level	Winds
Scenario H1	Following historical trend	No increase
Scenario H2	Following historical trend	13 % increase of winter winds
Scenario I1	Increased 79 cm linearly up to 2070 (1.3 cm/year)	No increase
Scenario I2	Increased 79 cm linearly up to 2070 (1.3 cm/year)	13 % increase of winter winds

Table 3. *Values of runup for different scenarios.*

Scenario	Mean runup level (m)	Maximum runup level (m)
Historically	0.14	2.45
H1	0.19	2.49
H2	0.20	2.49
I1	0.38	2.55
I2	0.38	2.63

important site specific parameter is to know how often the water level will reach the dune foot and erode the dune. For the different scenarios the results are shown in Table 3.

As can be seen in Table 4, the number of occasions when erosion will take place increases significantly. These numbers assume that the cliff foot will not migrate but stay in the same position. In reality the height of the cliff foot will most likely change and the number of times when erosion occurs be more constant. This migration is due to the erosion, though, meaning that the numbers still give an indication of the magnitude of the increased erosion rate.

Shoreline evolution model

GENESIS (Hanson and Kraus, 1989; Gravens et al., 1991) is a modelling system based on the one-line shoreline change concept. The name stands for **GENE**ralized model for **SI**mulating **S**horeline Change. It computes the shoreline change at grid cells along a given coastline during a certain period of time as a function of the breaking wave height and angle.

One-line models can be used to estimate rates of longshore sand transport as well as long-term shoreline changes. The main assumption is that the beach profile has a constant shape, the shoreline, and the equations are applied to only one contour line. The model consists of two sub-models, one that transforms the incoming deep water waves and one that calculates the transport of sediments.

Lomma bay analysis

By simulating the transport of material from a series of incoming waves it is possible to get an idea of the sediment transport behavior of the whole bay – direction of the main drift of sediments and the net transport rates. After digitizing the bay area and setting up the model according to the geography of the bay in GENESIS and assuming a shoreline in equilibrium, the mean values of both net and gross transport rate for each cell during the whole simulated period (48 years) are analysed. For the general pattern of sediment movement, the most interesting parameter to study is the mean net transport. Its evolution shows that sediments move southward in the north part of the bay. In the area of Bjärred, rates of gross and net sediment transport have, approximately, the same values and with opposite signs. Therefore it is concluded that all the longshore sand drift is directed southward. This behaviour obtained by GENESIS is supported by some field evidences of local disturbances around structures.

Table 4. *Number of occasions when erosion occurs in the area.*

Scenario	Number of times runup exceeds cliff foot elevation (1.4 m)	% of total observations	Times per year
Historically	434	0.47	13.6
H1	522	0.56	16.3
H2	613	0.66	19.2
I1	1277	1.37	39.9
I2	1469	1.57	45.9

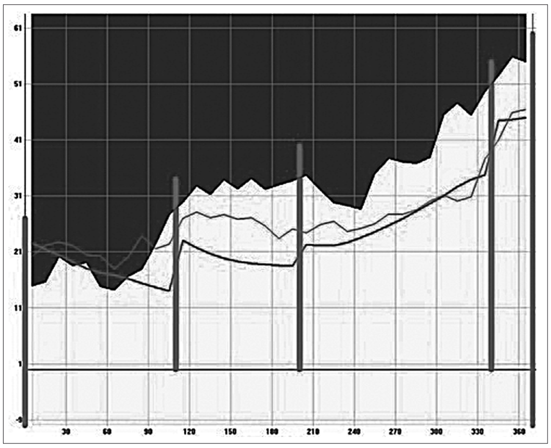

Figure 4. *GENESIS results for model calibration.*

Study area – calibration and validation of a model

The next step of the study was to find the model parameters to represent the evolution of the shoreline in the study area of Bjärred. The calibration of the model was performed by analyzing the shoreline during a period of 20 years, between 1978 and 1998, which reproduced the variation of these two measured shoreline position.

The original shoreline of 1978 is visualized by the solid part. The thick line is the calculated shoreline in 1998, performed by the calibrated model, whereas the thin line is the measured shoreline in 1998, using the aerial photos. The piers that are scattered along the area are represented by the thick red lines perpendicular to the baseline. The calibration can be seen in Figure 4. With this being the best result, it was only possible to explain up to 50 % of the shoreline development. Regardless, the aim of the simulation is not to quantify the exact amount of change but to obtain a good pattern of the profile evolution. In this way, when simulating future shoreline changes depending on the actions that could be applied in the area, it will be possible to explain whether they improve or do not improve the nowadays conditions.

The calibrated model was then simulated for an independent period of time of 8 years, between 2002 and 2010. Since results showed that the calculated shoreline tended to follow approximately the same trend as the measured in 2010 the validation process was over.

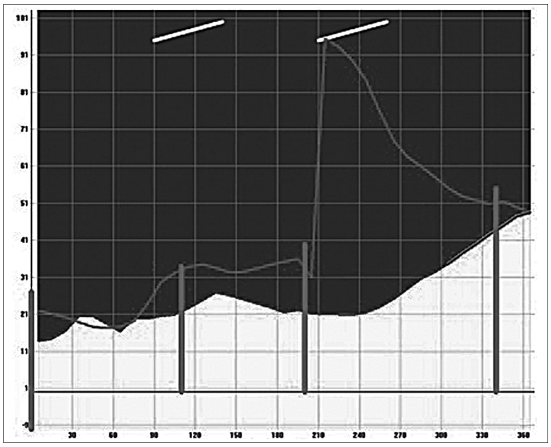

Figure 5. *Detached breakwater performance, scenario H1 in 2030.*

Results

Analysis

This work focuses on the engineering part of the coastal protection by showing the simulated results of the shoreline evolution after application of different measures. Other factors, such as economical and environmental factors are briefly discussed at the end. The calibrated model obtained in GENESIS is used to simulate the physical evolution trend of the shoreline when different protective measures are applied. It is necessary to remind, once again, that the model does not provide how the shoreline will look in the future but gives an estimation of the pattern of shore movement in a qualitative way, not a quantitative. Consequently, it will be used as a tool to assess which of the proposed actions/structures that improve the nowadays conditions to the best extend in the area and which ones are detrimental.

For assessment purposes, the different behaviours of the protective measures are simulated for scenario H1 during a short-term period (lasting 20 years, up to the year 2030) as well as for a long term period (60 years, until 2070). The scenario H1 means no change in the wave trend, and wave data ranging from 2000–2008 is assumed to be representative for the whole time period.

No protective measure applied

As a reference, the shoreline evolution when no protective measure is applied, is simulated initially but is not discussed further in this work.

Detached breakwaters

Detached breakwaters decrease wave energy reaching the shore, thus reducing both the longshore sediment transport as well as the height of the waves, which induces dune erosion. The dimension and quantities are not numerically developed, but a trial-and-error approach is applied and the configuration providing the best performance is presented in Figure 5.

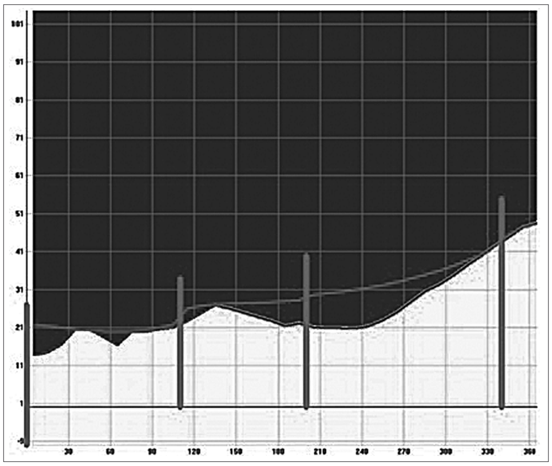

Figure 6. *Extended revetment performance, scenario H1 in 2030.*

The shoreline in 2010 is represented by the solid part and a quick creation of a tombolo is observed (thin line). It originates from the shallow water depths of the bay, meaning that only a limited amount of sediment needs to be settled to create the tombolo. Since a tombolo in most cases is not a desired feature the simulation in GENESIS stops when it is created. The physical effect of a tombolo is that it will totally stop the transport of sediment along the shore, meaning that erosion downdrift (left) will increase.

Extension of revetments

Since the erosion mainly takes place as dune erosion when the runup is high, armouring the beach is the most efficient option to stop the erosion at a specific area. This is what has been done in Bjärred so far and is considered an option also for the study area. Two options could be considered: concrete slabs or sheet piles. The biggest difference between the two is that sheet piles would be placed behind the dune allowing the erosion to take place until it reaches the piles and then the beach will be renourished. The simulation of revetments does not differ between slabs and sheet piles though, and the result is shown in Figure 6.

The concrete slabs are represented by the thick line along the shoreline. The simulation shows a satisfying result – note simulated shoreline – as erosion seems to stop where slabs have been placed. One can argue that erosion will lead to downdrift of the structure. In this case it can be seen that the southern part of the area, that is not protected, shows a very low rate of erosion, wherefore the downdrift erosion is relatively small.

Beach nourishment

As a soft protective measure, the goal of beach nourishment is to maintain the beach's environmental and recreation values. By adding sediments regularly the erosion will not stop but the added sediments will be eroded instead of the original beach material. The simulation is run under the conditions that 4 m (horizontally) of sand is added to the shoreline every 3 years and the simulation result can be seen in figure 7. Results are better explained by plotting the shorelines after nourishment together with the shoreline if no action is taken, as well as the original shoreline in 2010. It can be seen that there is a positive difference, but quite marginal and this means that almost all the added sand has disappeared by 2030. (Hanson, 2010) It can be claimed, thus, that a nourishment project would actually slow down the erosion rate but only to a small extent.

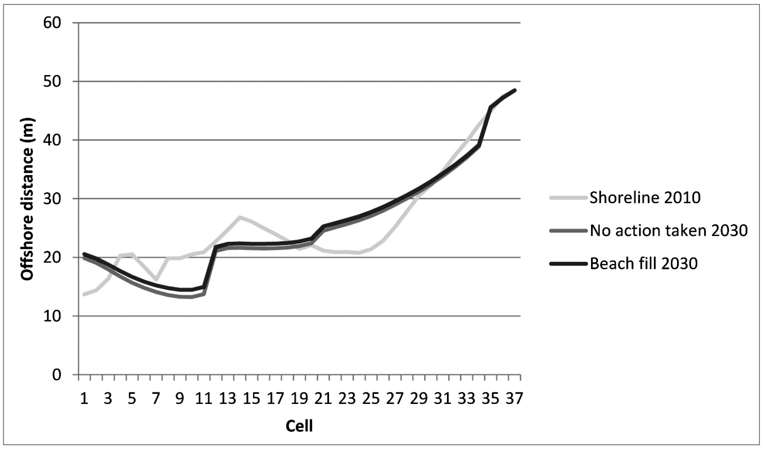

Figure 7. *Beach nourishment performance.*

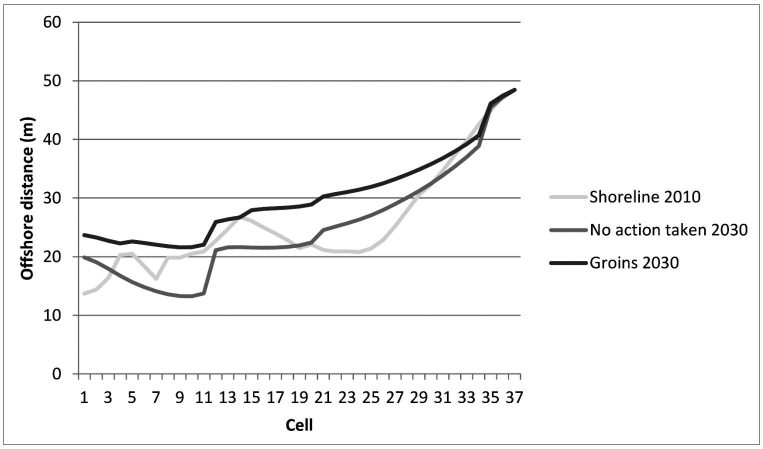

Figure 8. *Groin performance, scenario H1 in 2030.*

Extension of revetments with nourishment

A combination of the two previous discussed actions show a positive progression of the shore by 2030, being really close when just opting for concrete slabs but with the added marginal difference of the beach fill. In addition to the engineering parameters, by adding the beach fills on top of revetments a better aesthetic effect is provided by the nourishment and the more desired natural appearance is achieved.

Diffracting groin

Groins are an effective hard protective measure to trap sediments transported along the shoreline. As one of the major sources of the shoreline retreat in the study area is the dune erosion, the hypothesis is that groins will not give a satisfying protection for the shore in Bjärred (Brännlund and Svensson, 2005).

Figure 8 shows that the groins show some improvement (thin line) compared to the nowadays condition (solid part). Nevertheless, this accumulation can cause erosion in downdrift areas as the sediments will be trapped between the groins. Another point to take into account is that groins are only able to trap longshore transport. This means that they cannot provide protection against cross shore sediment transport. As storm events lead to significant erosion in the study area groins will not be taken into account for further analysis even though the simulations show good results.

Summary of results

The summary of results regarding each of the protective measures is presented in Table 5. As already mentioned, the previous analysis is only to determine whether the shoreline presents a favourable evolution compared to nowadays situation or not.

Accordingly, the measures that provided improved results are revetments, beach nourishment projects and a combination of them. These options are further analysed together with the detached breakwaters. As assumed, groins did not work since the major source of erosion is the dune erosion. Even though the detached breakwaters did not have a satisfying performance in GENESIS it will be discussed further in order to supply background information to decision makers.

Assessment

The evaluation of the proposed protective measures is done not only from an engineering point of view but also taking into account environmental and economical aspects. A summary of all the evaluated measures is presented in Table 6. The details of the financial evaluation are not presented in this article but only the final results. To be able to compare the different protective measures it is assumed that the hard structures will be designed for a life time of 50 years. Accordingly, the measures that provided improved results of the shoreline response are the placement of revetments, beach nourishment projects and a combination of them. The detached breakwaters did not provide a satisfying simulation result, but as can be seen in the table above they are a cheap option and it might be worth investigating this solution further.

Table 5. *Summary of simulation results.*

Protective measure	Improved evolution
None	no
Breakwater	no
Revetments	yes
Beach nourishment	yes
Revetments with nourishment	Yes
Diffracting groins	Yes, but not cross-shore

Table 6. *Evaluation of protective measures.*

Protective measure	None	Detached break-waters	Groins	Concrete slabs	Sheet pile	Beach nourishment	Concrete slabs with nourishment	Sheet piles with norusihment
Improved evolution	no	no	yes, but not cross-shore	yes	yes	yes	yes	yes
Cost (SEK/year)	0	19 000	–	41 400	60 000	134 400	175 800	194 400
Environ-mental impact	–	–	–	Erosion downdrift Recreational values Vegetation and animals	Change in ground-water flow High water pressure Berm unprotected	Compactation works Vegetation damage	(combination)	(combination)

Conclusions

The coast in Bjärred has undergone severe erosion in the past century as proved by analysed aerial pictures of the area. Between 1963 and 2002 the shoreline has retreated with an average of 4.3 m and in some spots even reaching 13 m of drawback. Since the retreat is not homogenous along the whole stretch of the shore some parts might not be in need of protection.

Most certain there will be a future sea water level rise, which will induce increasing cross-shore transport. Historically there has been no overtopping of the beach bank but with increased sea water level this will most probably be a fact. It will lead to flooding of the adjacent road and most likely of the storm/waste water system as well, which might lead to inundation of basements in nearby properties. Direct effects of the overtopping might also be increased erosion in the area since water on the road flows towards the sea.

The results from the shoreline evolution model should be considered with great caution. First of all, it assumes that sand is always available when calculating longshore transport rates, likely leading to higher quantities than in reality. Its reliability could also be discussed as it can only explain around 50 % of the shoreline behaviour due to wave impact. In addition, the predicted future scenarios for waves due to climate change have been used for assessment purposes. It is clear, then, that their application induce a high uncertainty as well. The reader should be reminded that the results obtained from the simulations are **qualitative** and not quantitative and should be used for comparison between different measures and not as evaluation of a single structure. If more accurate results are desired, further investigation of the area is needed.

Nevertheless, the model indicates that if no protective measure is adopted the shore would keep eroding in the future. The tested structures that seem to improve the nowadays situation are the extension of concrete slabs, the placement of a sheet pile in front of the waste water pipe, beach nourishment, as well as a combination of revetments and nourishment.

When considering beach fill projects, they result in the need of a much higher budget compared to the revetments (concrete slabs and sheet piles), mainly due to the maintenance costs associated. This could be taken as an important drawback but, however, periodical nourishment has the main advantage of preserving the beach environmental and recreation values. Besides, the addition of sand supposes a continuous sediment buffer to compensate for both cross- and longshore transport.

The placement of concrete slabs involves a lower budget alternative and they should be able to completely stop both long and cross-shore erosion, as they do not allow any movement of sand. Nevertheless, their placement entails significant negative visual and environmental impacts on the beach, as the profile would be modified and they are also likely to enhance downdrift erosion. The natural and visual harmful effect could be reduced by placing vegetation growth through the slabs' gaps or add beach fill material above the revetments.

The construction of a sheet pile would also efficiently protect the dune and thus the water pipe and structures behind the beach. Its construction has the lowest costs, but it would not stop the longshore drift of sediments as the beach berm would remain unprotected.

Recommendations

It is highly recommended that Lomma municipality should take some fast actions concerning the still unprotected beach stretch in Bjärred. The proposal is to opt for a hard structure to efficiently stop the erosion (concrete slabs or sheet pile) and protect the waste water pipe adjacent to the shore. Depending on the financial situation a combination with beach fills will give a more pleasant aesthetic appearance of the beach. The best possible results will be obtained if the beach is scheduled for nourishment every 3 years but a more economical solution is to plan for nourishment every 5 years instead.

The cost of nourishment in front of the structures should be weighed against the positive effects it might lead to. More people would seek to spend their weekends and holidays in the area, either sailing or just having some peaceful walks along the coast. Some benefits derived from the existence of a sandy beach could compensate for the high costs of sand filling.

Despite the measure that will be taken in the area the municipality should definitely consider increasing the capacity of the waste/storm water system in the area to prevent future flooding due to overtopping. By working proactive with this and increasing the capacity before it is too late, some problems might be prevented. An alternative to increase the capacity of the existing system is to construct a new system for draining the water on the road.

Acknowledgements

The authors wish to thank Professors Magnus Larson and Hans Hanson, as well as Elisabet Hammarlund, Ramböll Sverige, for the technical support provided during the development of this project.

References

Brännlund, I., and Svensson, L. (2005) Stranderosion i Bjärred, Lomma kommun. En undersökning av påverkan från vågor och vattenstånd. Lunds Tekniska Högskola, Institutionen för Teknisk Vattenresurslära. Lund: Lunds Universitet.

CEM. (2002a) Longshore Sediment Transport. Coastal and Hydraulics Laboratory, Department of the Army. Washington: US Army Corps of Engineers.

CEM. (2002b) Cross-shore Sediment Transport Processes. Coastal and Hydraulics Laboratory, Department of the Army. Washington: US Army Corps of Engineers.

Gravens, M., Kraus, N., and Hanson, H. (1991) GENESIS: Generalized model for simulating shoreline change, Report 2: Woorkbook and System User's Manual. 345.

Hanson, H. (2010) Lunds Tekniska Högskola, personal meeting, 2010-12-08.

Hanson, H., and Kraus, N. (1989) GENESIS: Generalized model for simulating shoreline change. Report 1: Technical Reference. Waterways Experiment Station. Vicksburg, MS, USA: US Army Corps of Engineers.

Lantmäteriet (2010) Aerial pictures of Bjärred, 1939–2010.

Larson, M. (2010) Lunds Tekniska Högskola, personal meeting, October, 2010.

Komar, P. (1998) Beach processes and Sedimentation. New Jersey, Oregon State University: College of Oceanic and Atmospheric Sciences.

Pope, J. (1997) Responding to Coastal Erosion and Flooding Damages (Vol. 13:3). Journal of Coastal Research.