Happisburgh Rock Sill Recovery and Re-Location

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Revision 1

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Revision 0	19 October 2014	P.A.J. Lawton	Draft
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Happisburgh Rock Sill Recovery and Re-Location

1. Introduction

In 2002/03 and 2007, a total of 8,886 tonnes of rock was used to form an approximately 400 metre long rock sill on the beach in front of the cliff at Happisburgh. In 2007, the supply of the rock was funded, in part, by the community through the Coastal Concern Action Group. The line of the original sill extended from the now demolished lifeboat ramp to the cliff immediately south east of the point where Beach Road met the cliff. Additional small quantities of rock have been added to the sill since 2007 to reinforce it and to extend it to protect the earth ramp beach access from the new Beach Road car park. Small amounts of rock have also been used to bolster the now derelict revetment immediately north of the site of the lifeboat ramp. The rock sill was not designed to prevent erosion. Rather, it was designed to attenuate erosion in the short term, buying time for assets at risk. A virtue of using rock in a defence structure is that it can be recovered for re-use. This is a factor that was considered at the time of planning the sill. The remains of the derelict groynes and revetment along the frontage protected by the sill have since been largely removed and a substantial amount of debris, such as concrete and brickwork, has been taken off the beach.

Whilst the rock sill, in its present position, continues to function as a defence, ongoing beach and cliff erosion will reduce significantly its effectiveness as a defence. Also, as the relative distance between the rock sill and the cliff line increases and the beach erodes/steepens, it will become increasingly more difficult and expensive to recover the rock for re-use as a coastal defence structure.

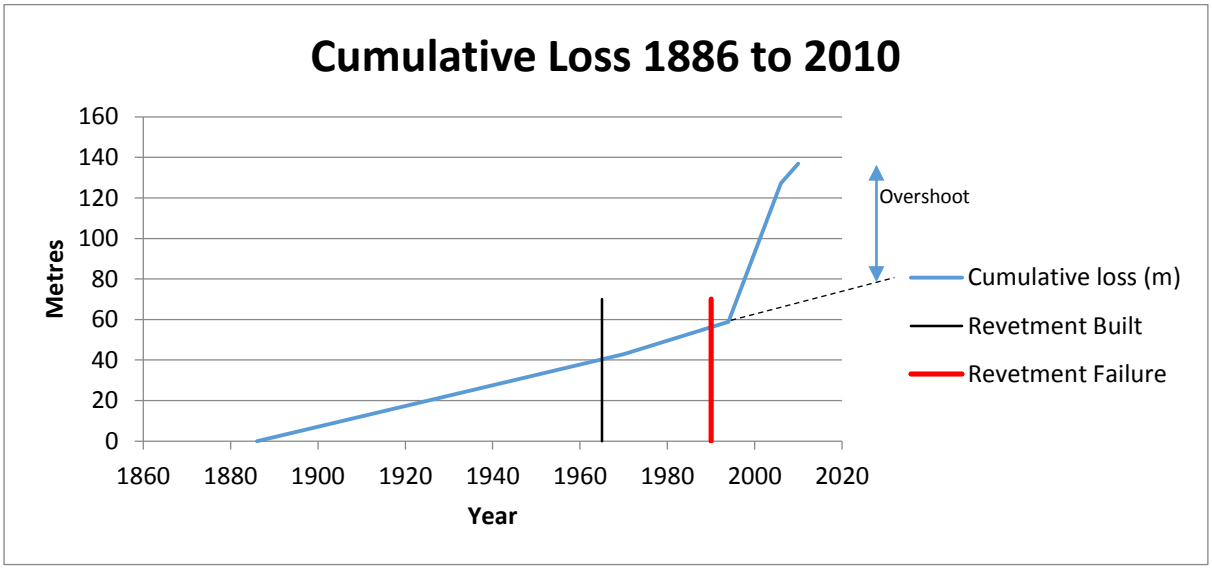
A detailed assessment of cliff recession rates associated with any options discussed in this report does not form part of the brief.

This report examines the feasibility of recovering the rock and re-using it in a defence structure. The report includes the following topics:

- Feasibility of recovering the rock
- Potential erosion risk whilst recovering the rock
- Options for its reuse as a defence at Happisburgh
- Beach debris and derelict defences
- Budget costs
    - Works
    - Fees
- Consents including:
    - Planning
    - Marine Licence (MMO)

2. Erosion

The failure of the traditional defences along the study frontage has resulted in very substantial increases in the rate of cliff recession and beach erosion. The recent failure of the timber revetment north of the old lifeboat ramp is a very good example of this. In the paper "Cliff and Shore Erosion under Accelerated Sea Level Rise, 2014"[i] it was postulated that the failure of the defences at this location has led to a phenomenon described as "overshoot". i.e. the coastline migrating further landward than the position it would (apparently) have reached if the structure had never been built. The embayment down to the start of the Cart Gap sea wall evidences this and the cliff recession north of the old lifeboat ramp is, almost certainly, responding in the same way. It is considered that overshoot at Happisburgh is a function of the step in beach level across the timber revetment. At times, it could be seen that the beach seaward of the revetment was up to 1.50 metres lower than the landward side. The following chart, showing losses in the embayment and taken from unpublished work by Lawton, illustrates the extent of overshoot for the embayment. Any option considered for the recovery of the rock used in the existing sill needs to consider consequential erosion and the possibility of overshoot occurring.



3. Options for the re-use of the rock

The table below outlines the options considered for the rock sill at Happisburgh, this is followed by more detailed consideration of each option.

Option	Description	Outline
1	Do Nothing	• Reduced chance of coastal erosion overshoot • Loss of rock and defensive value • Submerged hazard • Does not protect the community assets of the car park and beach access.
2	Remove Rock Sill	• Coastal catch up and possible erosion overshoot • Removal of future submerged debris • Ability to reuse rock elsewhere • Does not protect the community assets of the car park and

		beach access.
3	Rollback Rock Sill	• Prevention of erosion overshoot • Potentially a further 10 years of a level of protection from erosion • Protects the community assets of the car park and beach access.
4	Rock Revetment	• Insufficient rock leading to only 100m of protection • Higher level of protection for the area protected, but risk of outflanking. • Limited protection of community assets of the car park and beach access.
5	Rock Groyne	• Down drift impacts • Limits to beach access • Insufficient rock available • May not protect the community assets of the car park and beach access.
6	Relocate Rock Sill to caravan site frontage	• Frontage is a Site of Special Scientific Interest and would require careful consideration and consents • Where sill is removed coastal erosion and potential erosion overshoot are likely. • Loss of protection to homes at Beach Road and community assets
7	Split Rock Sill	• High risk of outflanking of the sills • Reduced level of protection of the cliffs • Reduced ability to maintain beach levels • Creation of unstable coastline • Risk of very unstable beach and beach levels • Protects community assets

Table 1 Options Summary

Seven options have been considered including the do nothing option. The existing sill protects approximately 400 metres of cliff. In discussing the options below, the suggestion for the sites of the relocated defence is tempered by the practicalities of recovering the rock, transporting the rock, and cost. Environmental issues are discussed later in the report. It can be seen in figure 1 that a reasonably good beach will facilitate access to the complete length of the sill. Hence, with the appropriate equipment, most of the rock can be recovered. However there can be no guarantee that all of the rock will be recovered.

An important factor in the discussion of each option is the protection of the community assets of the Beach Road car park, the public toilets at the car park, the community space, play area and beach access.

Figure 1. Rock Sill

Any scheme for the recovery of the rock will also require the removal of the remains of older and derelict defences currently forming part of the rock sill close to the remains of the old lifeboat ramp. The cost of this work is approximately an additional £15,000 which is not included in the estimated

Figure 2. Older derelict defences behind the sill

cost of the options.

Option 1 – Do Nothing

In the context of this appraisal, to “do nothing” is to leave the rock sill in place and allow nature to take its course. The rock sill was not designed to prevent erosion but was designed to attenuate erosion in the short term. Erosion of the soft cliff by the sea will continue at an increasing rate as the sill becomes less effective. At the same time, the level of the beach platform in front of the sill will be progressively eroded. As a result, the sill will be attacked increasingly and more aggressively by the sea. Despite the size of the rock armour used in the sill, rock will be displaced increasingly damaging the original profile of the sill rendering it even more ineffective as a defence. The sill will eventually become “detached” from the line of the cliffs exposing them even more to the action of the sea. As the cliffs and beach retreat, it will become increasingly difficult to recover the rock for use elsewhere and impossible to maintain the rock sill as a defence.

It is likely that the impact of the phenomenon of overshoot will be very much reduced at the site of the existing sill. This is because most of the old revetment has already been removed allowing the beach to respond to the more hydrodynamically efficient rock sill. There will, nevertheless, be increased erosion of the cliff.

Regarding public safety and, in particular, beach users, the submerged rocks will eventually become a hazard to people in or on the sea.

There are costs associated with this option some of which are intangible. The cost of doing nothing is the ultimate loss of the rock as a material, its defensive value and damage to amenity stemming from the hazard to beach users. The value of the rock alone is estimated to be £500,000. (Q3, 2014)

Option 2 – Remove the Rock Sill

This option is self-explanatory. The rock is taken off the beach and used beneficially in a sea defence elsewhere. By doing this the safety hazard of leaving the rock in-situ is eliminated. However, it is certain that there will be a very substantial increase in the rate of erosion (catch up) and quite possibly overshoot. The extent of cliff recession cannot be predicted accurately but it could be similar to the embayment to the south.

The cost of removing the rock off the beach and stockpiling locally is estimated to be £59,000 (Q3 2014)

Option 3 – Rollback the Rock Sill

The existing sill achieved its design objective of buying time for the assets then at risk by attenuating erosion. The original sill was built in two stages, 2002/3 and 2007 and there is now approximately 8900 tonnes of rock in place. This option involves the recovery of the rock and the construction of a new sill as close as is practicable to the base of the cliff and parallel to the cliff line. In practice, the rock sill will have to be four to five metres in front of the cliffs for both construction plant access and, importantly, use by the public in traversing the beach.

The advantage of using a sill is that it will alter the normal patterns of cross-shore sediment transport, improving the beach level behind it. The sill will attenuate wave energy hence a freeboard above MHWS of 1.00 metres approximately, will, it has been estimated, attenuate up to 90% of wave energy. In the extreme condition of a 100-year water level, the sill will be submerged to a depth of 1.2 metres approximately and will attenuate an estimated 35% to 60% of the wave energy. An example of the effectiveness of the sill was the December 2013 storm event where cliff losses behind the sill were relatively small compared with nearby locations.

It is suggested that the length and cross section of the sill be similar to that of the existing sill with the limits being the remaining concrete structure of the old lifeboat ramp and the earth ramp that provides access to the beach at the site of the new Beach Road car park. It is also proposed that the remaining concrete structure of the old lifeboat ramp be retained as part of the new sill forming the point where the sill closes with the cliff.

The rock sill will not prevent erosion of the cliff. However, it will almost certainly prevent overshoot reducing significantly cliff damage and recession. Hence, there is the possibility that in a further ten years is may be necessary to "roll back" the sill to maintain its effectiveness.

The estimated cost of this option is £54,000 (Q3 2104)

Option 4 – Rock Revetment

A very effective form of defence, using rock armour, is to construct a sloping revetment at the toe of the cliff. To be effective, wave run up and overtopping has to be limited in order to avoid erosion of that section of the cliff above the revetment. In "normal" conditions, this type of revetment will prevent overtopping. However, in extreme conditions, this revetment will be overtopped and there will be wave damage of the cliff. It is estimated that to protect the frontage currently protected by the rock armour sill will require the placing of 28,000 to 30,000 tonnes of rocks up to 8 tonnes in mass.

The hydrodynamically efficient revetment structure will also, at least, reduce local beach scouring along the protected frontage. The defence will, however, be damaged over time by outflanking. However, once outflanked, the damaged rock revetment will continue to perform a reduced defence function acting as a small breakwater or sill.

The diagram below shows a cross section through a rock revetment originally designed as part of a previous study of defence options at Cart Gap but considered to be appropriate for this site.

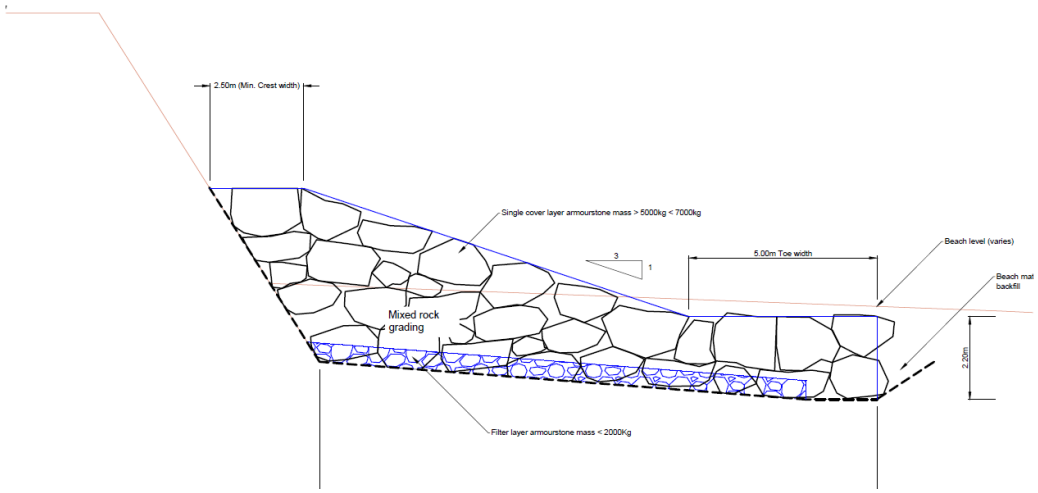


Figure 3. Cross section through rock revetment

A rock revetment requires a core of smaller rock with the larger rocks used as armour to the sill. The smaller rock helps improve the hydrodynamic performance of the sill and acts as a filter layer.

Roughly one third to a half of the rock tonnage needed to construct the revetment would be the smaller sized rock. Only 8,900 tonnes of rock is available: All of which is of a size that would normally be used as armouring rather than core material in a revetment.

The 8,900 tonnes could be used in a revetment but the length protected would be not more than 100 metres. i.e. less than a quarter of the length protected by the existing sill. If the large rock available was used alone it would provide a reasonable degree of protection but it would not be as effective as a designed rock revetment using smaller rock as core material. Experience has shown that in severe events a rock revetment without a designed core will not prevent extensive damage to the cliff. The photograph below shows cliff damage behind such a privately funded revetment at

Figure 4. Cliff erosion behind rock revetment at Bacton

Bacton following the December 2013 storm surge event.

In respect of beach amenity and the protection of community assets, it is suggested that the most appropriate location for a rock revetment is now as protection for the beach access and cliff at the site of the new Beach Road car park.

The estimated cost of constructing a rock revetment of up to 100 metres in length is £58,000. (Q3 2014)

Option 5 – Rock Groyne

This option provides a rock armourstone groyne built out from the cliff in the location of the car park beach access ramp. The purpose of the groyne is to at least prevent the loss of beach material in the alongshore direction and encourage the build-up and retention of a beach. The groyne will also act as a breakwater, reducing wave transmission and hence protect the cliff.

A negative aspect of this option it that it will cause downdrift beach erosion. This will impact not only on the beach immediately downdrift towards Cart Gap but also on the beaches managed by the Environment Agency beyond Cart Gap. A direct consequence of this beach erosion will be a corresponding increase in cliff erosion.

A peripheral but important consequence of this type of defence is that as it is cross-shore it will make it difficult for people to traverse the beach. Hence, there are substantial safety and amenity implications to be addressed as well as very careful consideration of the hydrodynamic loading and sediment transport implications.

No outline design work on the size of a groyne has been done. However, earlier work by HR Wallingford (Ostend to Cart Gap Coastal Strategy Study 2001) suggests that a groyne 100 metres long might be an appropriate size. Only half of the rock needed to construct such a groyne is available.

This option can be discarded immediately given that there is not sufficient rock available and its devastating impact on adjacent beaches and cliffs.

Option 6 - Relocate Rock Sill to caravan site frontage.

This option would involve relocating the existing rock sill to protect the caravan site frontage, providing greater protection to the caravan site. All of the site frontage would be protected by the relocated rock.

The whole of the caravan frontage is a Site of Special Scientific Interest (SSSI), designated for its geological interest. This militates against securing the mandatory consents needed for the implementation of this option. Whilst the caravan site would have the benefit of protection, if consents can be secured, there would be very substantial erosion from catch up and potential overshoot at the site of the existing sill, possibly on the scale experienced at the embayment between the village and the Cart Gap sea wall. The community assets and the remaining homes at Beach Road would be at substantial risk as a consequence.

The estimated cost of this option is £62,000 (Q3, 2014)

Option 7 - Split Rock Sill

This option would spread the rock over a wider frontage, essentially providing short sections of sill with gaps between. As an example, the 8860 tonnes of rock could be used to build say three separate sills each up to 120 metres in length with an allowance at each sill for returns to the cliff. The length potentially protected would be longer than the existing sill affording some protection to the caravan site. This, however, introduces the problem of obtaining a consent because of the SSSI.

The cliff at the gaps between the sills would continue to be attacked by the sea creating minor embayments of uncertain size possibly leading to the outflanking of each sill. Whilst providing a reduced level of protection to the land behind the sills, a consequence is a reduced ability to maintain beach levels which, in turn could impact on the performance of the individual sills.

This option affords a reduced level of protection to community assets and the homes at Beach Road and protects only part of the caravan site.

The estimated cost of this option is £58,000 (Q3, 2014)

4. Environmental Value

A review of environmental interests in the study area includes an assessment of any environmental designations, the geology, flora and fauna and the historic environment.

a. Environmental Designations

There is a Site of Special Scientific Interest (SSSI) running north-west from the beach access ramp at Happisburgh to just north-west of the Happisburgh Caravan Park. This designation (Happisburgh Cliffs) is based upon interest in the glacial deposits exposed within the eroding cliff face. Key concerns here are to ensure that the cliffs are allowed to continue eroding naturally wherever possible. [ii]

b. Geology

The geology of this area comprises largely of glacial drift deposits comprising heterogeneous clays, silts, sands and gravels. This mixture of deposits reacts differently to the effects of waves, tides, rainfall and weather. The clay deposits are generally more resistant to erosion by the sea, and often remain as an outcrop, jutting seaward from the cliffs while sandy deposits on either side retreat more rapidly. The net result is a typically ragged cliffline, with numerous small bays and headlands. While the erosion of the clay provides no useful beach material, the sandy deposits in the Happisburgh cliffs do provide beach material, adding to the "sediment budget" for the coastline both locally and further along the coast to the east and south.

c. Flora & Fauna

Since the cliffs are experiencing nearly continuous erosion, and thus restricting the vegetation and animal communities on the cliff faces, the variety and interest in flora and fauna for this area is not as great as in other regions of Norfolk. Sand Martins do nest just below the top of the cliff face in sandy areas and where vegetation does gain a temporary foothold, it is most prolific in area where the water seeps through the cliff face.

d. Historic Environment

The historic environment may be defined as comprising all traces of past human activity and including archaeological remains (on land and the seabed), historic buildings, parks and gardens and historic landscapes. There are no buildings of historic interest within a reasonable distance of the beach affecting the delivery of this scheme. There are, however, numerous buildings in and about Happisburgh which are of significant interest.

The recent discoveries of the internationally important sites of early hominin activity to the immediate west of the site under discussion highlights the archaeological and palaeoenvironmental sensitivity of this area, where the exposure of buried land surfaces has revealed spectacular evidence of prehistoric human activity (for example the Happisburgh Footprints, c. 130m to the west of the rock armour).

5. Consents

a. Planning

The coast protection works outlined in this report are of sufficient scale to be above that of permitted development, they are considered as “engineering works” and, as such, require a planning permission under the terms of the Town and Country Planning Act 1990.

North Norfolk District Council (NNDC), the local planning authority might need the following to be satisfied before a planning application can be validated:

1) Bio-diversity survey and report
2) Environmental Statement
3) Noise Assessment

Bio-Diversity Survey and Report

This survey and report is sometimes required if there are any of the following at or adjacent to the application site:

1) Protected species (all species protected under the Wildlife and Countryside Act 1981, Conservation (Natural Habitats, &c.) Regulations 1994 and the Protection of Badgers Act 1992).
2) Designated sites, important habitats or other biodiversity features (Sites of Special Scientific Interest, Special Areas of Conservation, Special Protection Areas, Ramsar Sites, County Wildlife Sites, habitats, and species listed in the UK Biodiversity Action Plan).
3) Features of geological importance (quarries and pits, coastal cliffs and foreshore, river and stream sections and road and rail cuttings).

It can be seen that the Happisburgh site's cliffs come under items 2 and 3 above.

Environmental Statement

The Town and Country Planning (Environmental Impact Assessment) Regulations (1999) set out the circumstances in which an Environmental Impact Assessment (EIA) is required. Where an EIA is required, an Environmental Statement in the form set out in Schedule 4 to the regulations must be provided. Where an EIA is not required the Council may still require environmental information to be provided. An applicant may request a 'screening opinion' to determine whether an EIA is required before submitting an application.

The Regulations apply to two separate lists of projects:
`Schedule 1 projects', for which an EIA is required in every case; A rock recovery scheme is not a Schedule 1 project.
`Schedule 2 projects', for which an EIA is required, only if the particular project in question is judged likely to give rise to significant environmental effects. Schedule 2 includes the following activity description:
"Coastal work to combat erosion and maritime works capable of altering the coast through the construction, for example, of dykes, moles, jetties and other sea defence works excluding the maintenance and reconstruction of such works."

The indicative threshold given for schedule 2 is:
"The impact of such works will depend largely on the nature of the particular site and the likely wider impacts on natural coastal processes outside the site. EIA will be more likely where the area of the works would exceed one hectare."

Special considerations apply to Sites of Special Scientific Interest (SSSIs). Given the position of the Happisburgh Cliffs SSSI, an EIA may be required to support the application for planning permission.

Noise Assessment

A noise assessment may be required for the recovery of the rock. There are no sensitive buildings in the area hence, a noise assessment is unlikely to be required

b. Natural England

Natural England (NE) is the statutory "guardian" of the SSSI and will be consulted by NNDC during the planning permission application process. NE will have a substantial say in the progress of the application even if the proposal does not include a defence in front of the SSSI.

NE does not issue consents but is required to issue a formal consultation response under the terms of S28 of the Wildlife and Countryside Act. It would be prudent to discuss any defence proposal with it at the outset.

c. Coast Protection Act 1949

Notification to carry out the works under the terms of the Coast Protection Act 1949 will need to be completed for options 4, 5, 6, and 7. Notification may not be required for Option 3, rollback of rock sill, as it is considered to be maintenance as such activity was always planned and required for this structure.

d. Marine and Coastal Access Act (MCAA) Part 4

The Marine Management Organisation (MMO) carries out licensing and enforcement functions under the Marine and Coastal Access Act (MCAA) Part 4, on behalf of the Secretary of State in the English inshore region and all English, Welsh and Northern Ireland offshore regions.

Any activity seaward of mean high water springs (MHWS) will require a licence issued by the MMO. The proposed defence will, almost certainly, require a licence. In support of the application, the MMO may require an Environmental Assessment but this can be covered by the EIA discussed above. The MMO also require a full method statement clearly outlining how the works will be undertaken, including details of any vehicle access routes which may cross the intertidal area as well as an heritage statement which thoroughly assesses the impact of the proposed works upon the historic environment particularly the internationally important sites of early hominin activity.

e) Habitat Regulations

The Norfolk coast is host to Special Areas of Conservation, Special protection Areas and RAMSAR sites. As such any proposal should be considered against the Habitat Regulations. The proposal is within the policy detailed in the Shoreline Management Plan on which a Habitat Regulation Assessment was completed.

f) Water Framework Directive

Proposed works which may impact on water bodies should be considered in relation to the Water Framework Directive. The proposal is within the policy detailed in the Shoreline Management Plan on which a full WFD assessment was completed.

6. Short Term Impact of Rock Recovery Works

In normal conditions, the existing rock sill tends to hold a good beach on both the seaward and landward sides. However, the beach here is quite sensitive to actions changing the local beach sediment system. During the works, a change in beach levels can be expected possibly exposing the clay beach platform. Despite the large investment in clearing beach debris by NNDC in 2011/2012, it is almost certain that more debris will be exposed following the loss of beach sand. An opportunity

to remove more debris may be available during the currency of the rock recovery and reuse works. The cost of this is not included in the estimated costs of the options discussed earlier. The estimated budget needed for debris removal is £20,000.

The relocation of the rock will, at times, expose the cliffs to increased attack by the sea. For example, it is quite possible that a "gap" in the line of the defence will be left open for a short time. This risk can be mitigated through good site management but it cannot be eliminated.

7. Remaining Derelict Defences

Figure 5 Derelict defences

Figure 5 illustrates an example of the remains of groynes and revetment seaward of the existing rock armour sill. A good beach, such as that shown, would allow access to much of the remaining derelict defences allowing heavy plant to be used to remove them. If the rock sill is removed or relocated, it is quite possible that beach will be lower at this position militating against the safe removal of the dereliction. As a result, these derelict defences and, in particular, the steel piles will be a submerged hazard to people in or on the water. It is recommended that the derelict defences be removed, as far as is practicable in the circumstances, in conjunction with any scheme to relocate the existing rock armour sill.

Given the nature of the work, it is not possible to provide an accurate estimate of the costs of this work. If the work was to be done as part of a rock relocation scheme, an additional budget of £17,000 might be appropriate: Much higher if done separately.

Addendum

North Norfolk District Council has requested that one further option be considered, that of placing the rock armourstone recovered from the existing sill at the base of the cliff. This additional option is described and discussed below.

Option 8

Linear Rock Bund Located at the Base of the Cliff

In this option, the 8,886 tonnes of rock used in the sill is moved inshore and placed at the base of the base of the cliff: In essence, the existing sill is rolled back to the toe of the cliff. The length protected by this defence is similar to that of the existing sill with the limits being the site of the old lifeboat ramp and the earth ramp that provides access to the beach at the site of the new Beach Road car park. This structure is up to three metres in height and has a base width of three to four metres. Given the large size of the rock available, the structure is very porous having the same void to rock ratio as the existing sill.

This rock bund will provide some protection to the base of the cliff in that wave energy will be dissipated partially. However, the large voids in the structure will allow waves, albeit with reduced energy, to attack the base of the cliff. Waves will also break on the structure with the spray always landing on the face of the cliff. Hence, the defence does not counter the damage caused by overtopping. As described in Option 4, this type of defence will not prevent substantial damage during a storm event. The damage is likely to be even more severe than that shown in figure 4 given that the rock bund has a relatively smaller cross section.

A defence built at the base of the cliff normally enables the beach to act as an integral part of the defence by attenuating wave energy before it reaches the cliff. This is unlikely to be the case here as the beach has already been severely eroded following the construction of the original timber revetment with a highly (wave) reflective steel pile toe. The now relatively steep beach is too narrow to provide any significant attenuation. As the defence is located at the top of the beach, it is moderately efficient in hydrodynamic terms and with the cliffs continuing to erode here and updrift, the health of the beach might be maintained or even improved but there is very little certainty here given the known volatility of beach levels.

This option affords a moderate level of protection to community assets and the homes at Beach Road. As the cliff erodes it will be necessary to consider rolling back the structure again in time for it to continue to be effective as a defence and to counter the effects on outflanking.

The estimated cost of this defence is £60,000 (Q3 2014) not including an increased weather risk.

Option	Description	Outline
8	Rock Bund located at the toe of the cliff	• Prevention of erosion overshoot • Potentially a further 10 years of a level of protection from erosion • Moderate protection of the community assets of the car park and beach access. • Does not obstruct the movement of people on the beach

Table 2 Addendum to Table 1

Recommendation

The advantages and disadvantages of all of the options considered for the reuse of the existing armourstone are summarized in table 1.

Key factors in making a recommendation as to which option is the most appropriate include:

1. Effectiveness as a defence
2. The best use of the existing rock
3. The protection of community assets
4. The condition of the beach.
5. Cost

Only options 3 and 8, rollback the sill and a rock bund at the base of the cliff respectively tend to satisfy factors 1 to 3 above. An important feature of the rock sill is that it attenuates wave energy before the wave reaches the head of the beach. This has the added benefit that the beach landward of the sill will normally be held in place by it thereby improving beach amenity and improving the beach's capacity to further attenuate wave energy. The rock sill has been very effective as a defence at this location and there is no reason to assume that the realigned sill will not behave in a similar way. The rock bund will also attenuate wave energy but, by virtue of its position, will not prevent the sea and waves acting on the cliff possibly also at most states of the tide. Spray from waves breaking on the rock bund will continue to act on the cliff face causing erosion. The rock bund will not improve the narrowness and steepness of the beach limiting the beach's effectiveness as part of the defence. Hence, option 8, the rock bund, is likely to be less effective as a defence relative to the rock sill.

The cost difference between option 3 and 8 is small but at an estimated cost of £58,000 (Q3, 2014), the rock sill is the least expensive of the two options.

It is recommended that Option 3 – Rollback the Rock Sill is implemented.

It is also recommended that any works contract for the reuse of the rock includes provision for the further removal of beach debris and the removal of the remaining derelict defences if weather, sea state and beach condition are suitable.

8. References

[i] Cliff and Shore Erosion under Accelerated Sea Level Rise. Environment Agency Report – SC120017/R, 2014

[ii] COUNTY: NORFOLK SITE NAME: HAPPISBURGH CLIFFS
DISTRICT: NORTH NORFOLK
Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981 as amended.
Local Planning Authority: North Norfolk District Council
National Grid Reference: TG 379314 Area: 5.9 (ha.) 14.5 (ac.)
TG 383311
Ordnance Survey Sheet 1:50,000: 133 1:10,000: TG 33 SE
Date Notified (Under 1949 Act): – Date of Last Revision: –
Date Notified (Under 1981 Act): 1985 Date of Last Revision: –
Other Information:
A new site.
Description:
This locality is important both for the cliff exposures which uniquely show three glacial deposits, the Cromer Tills (of Anglian age) with intercalated waterlain sediments, and for the underlying Cromer Forest-bed Formation, exposed in the foreshore, with excellent development of pre-Pastonion and Pastonian sediments. An important site for dating the Pleistocene succession of East Anglia with a range of sediments from marine to freshwater and glacial, spanning five stages, from the pre-Pastonian to the Anglian.