Hunstanton Sea Cliff – Ground Engineering feedback following site visit on 11th October 2017

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1) Introduction

Hunstanton Cliff extends north around the shoreline from the northern extent of the current Sailing Club car park for circa 1.3km (0.8 miles), before petering out into sand dunes. Available information suggests the cliff is up to 18m high.

AECOM are assisting the Borough Council of King's Lynn and West Norfolk in preparing a Coastal Management Strategy for the area, which includes Hunstanton Cliff.

There are ongoing Health and Safety issues associated with ongoing erosion (coastal erosion) of the cliff and associated significant blockfalls, including risk to the public on the beach and continued encroachment of the crest of the cliff on the public space and property adjacent to Cliff Parade. Of particular concern at the crest of the cliff is the presence of three notable structures, the cliff top lighthouse, coastguard cottages and the remains of St. Edmund's Chapel.

Although warning signs are displayed at beach access points at each end of the cliff, the public still encroach right up to the base of the cliff, oblivious of the risk.

Ongoing erosion of recent years has claimed a significant amount of public space previously present adjacent to Cliff Parade, including a cliff top footpath and a significant area of land previously associated with the lighthouse, which previously included a larger plan area and further buildings on the seaward side of the existing building.

Although engagement with the local community has demonstrated that continued erosion of the cliff is undesirable, there are restrictions and preferences in place which affect methodologies available to reduce the rate of erosion of the cliff face;

- Hunstanton Cliff is designated as a SSSI,
- There is a recognised benefit that continued erosion sustains a 'fresh' cliff face with respect to local geological features,
- Consideration that funding for major works is unlikely to be available.

An AECOM team visited the area on 11th October 2017 to assess the current condition of Hunstanton Cliff from a Geotechnical and Coastal Engineering perspective, walking south to north along the beach and north to south along the cliff top.

The aim of the visit was to;

- Assess the current condition of the cliff,
- Identify the failure and erosion mechanisms;
- Consider the suitability of options to slow down / reduce the rate of erosion.

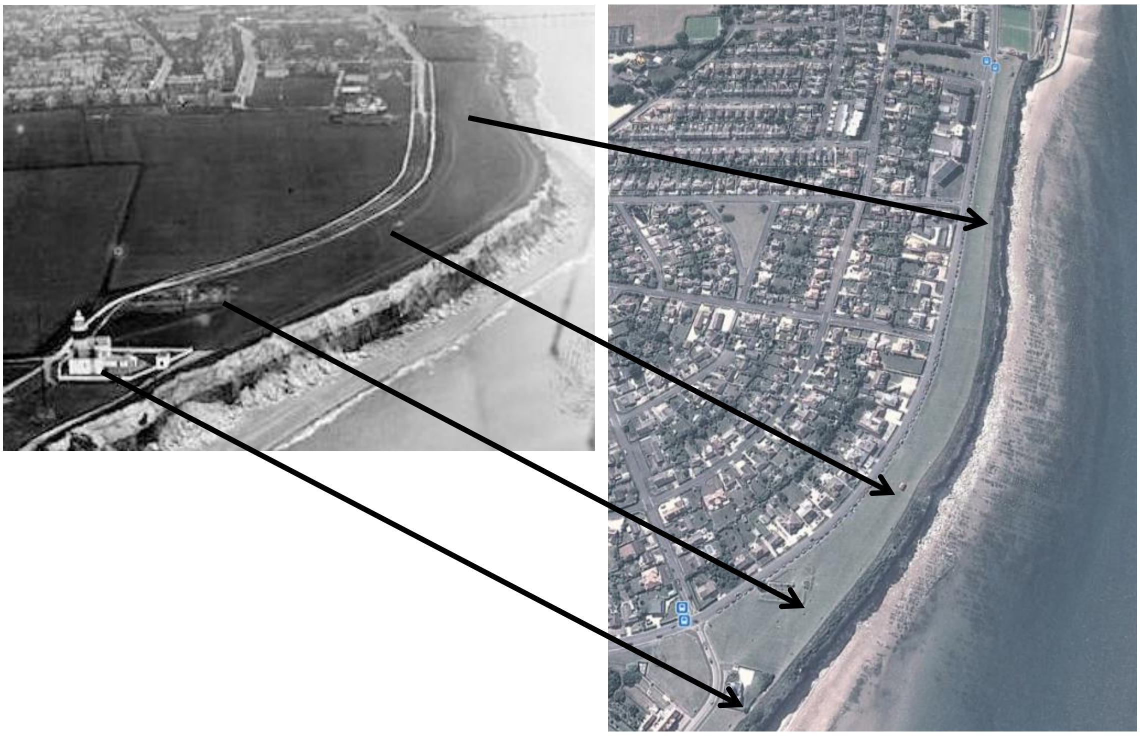
The photo below was taken at high tide at 10:39hrs on Wednesday 11th October 2017. This tide had a predicted level of 6.7m, compared to a higher predicted level of 7.4m in subsequent months. Note that the sea was fairly calm at this time, with little evidence of waves breaking onto the cliffs. A higher tide with rough conditions would look very different.

There is historic evidence available through the internet which starts to demonstrate the extent of collapse and erosion along Hunstanton Cliff;

- Historic maps viewed on the National Library of Scotland website, dated 1886, 1904, 1927 and 1955, appear to show the progression of the cliff top to the east, with deviation of the top of the cliff, a boundary line and a footpath.

- Several photographs show a public footpath directly along the crest, which has since fallen away, including the extract below taken from an image obtained from ‘Kings Lynn Forum’. Although a photograph date and direct comparison of the base of the cliff is not available from this aerial position, the photograph below was taken on 11th October 2017 from the foreshore. The striking feature from the aerial shot is the amount grey / white material mounded at the base of the cliff. This material is chalk, which has collapsed from the upper cliff.
  In direct comparison, it is important to note the lack of failed material on the beach in the recent photograph, which highlights the power of the sea to wash failed material away. As such, it can be concluded that relying on the failed material alone to protect the toe of the cliff is not a long term solution.

- Several photographs show a significant reduction in the area of land previously associated with the lighthouse, which previously included a larger plan area and further buildings on the seaward side of the existing building. A wider view of the image obtained from the ‘Kings Lynn Forum’ shown abobe can be directly compared with the image for the area available on Google Earth Pro. Noting the position of the shelters in the distance, the remains of St. Edmunds Chapel and the extent of the grounds and outbuildings associated with the lighthouse, this comparison clearly demonstrates the amount of regression of the cliff top towards these features.



Currently, there are four visible fence lines or lines of fence posts along the cliff top, which are considered to have been erected as the cliff top progressively failed in order to keep the public a safe distance from the crumbling crest. Some concrete fence posts and wire are also present along the beach, which is also evidence of the progressive failure.

2) Existing Condition

The risk posed to the public by the instability of Hunstanton Cliff was immediately noticeable. Numerous significant blockfalls were present along the whole length (approximately 16 No.), as well as scattered and groups of large blocks of chalk along the majority of the beach. This shows that, without any intervention, rockfalls should be expected to continue to occur in the future at any point along the length of the cliff.

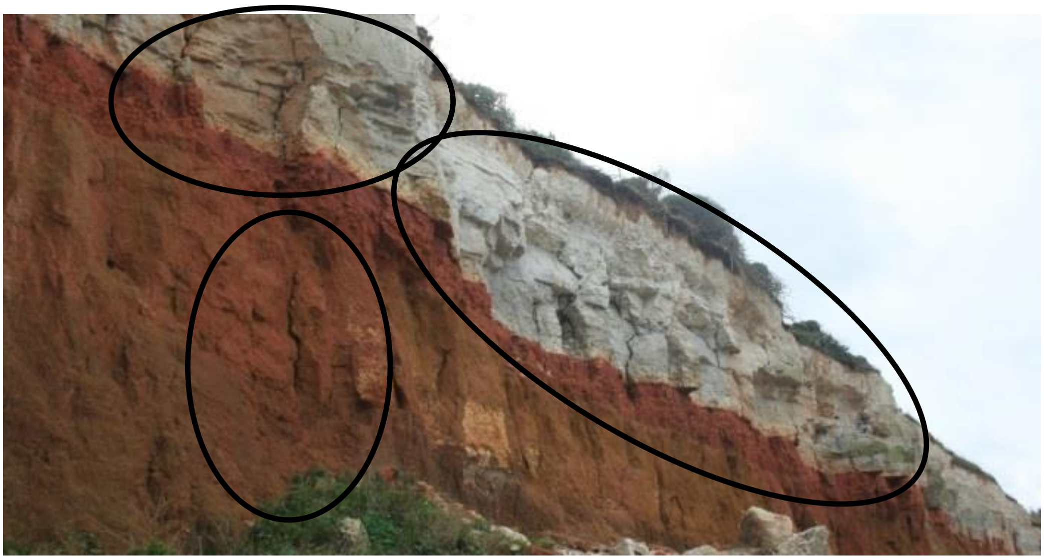
It should be noted that there are numerous significant detached blocks high on the cliff face which may fall to the beach during the next significant rainfall / weather event.

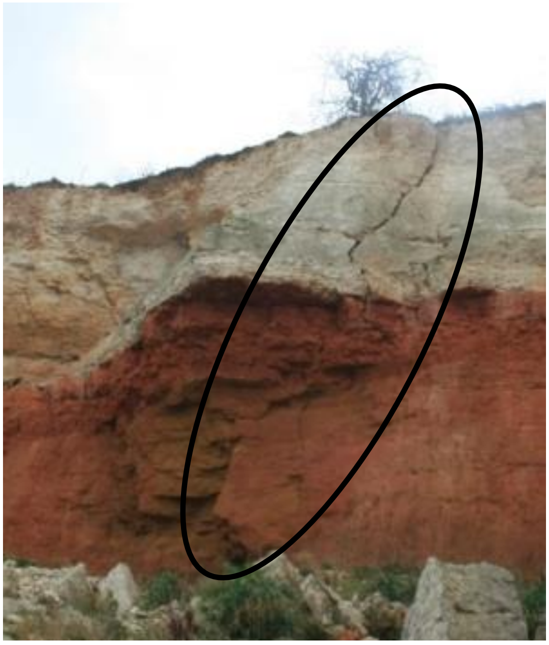
Photos of some of the larger blockfalls are provided below.

Photos of some of the scattered and groups of large blocks are provided below.

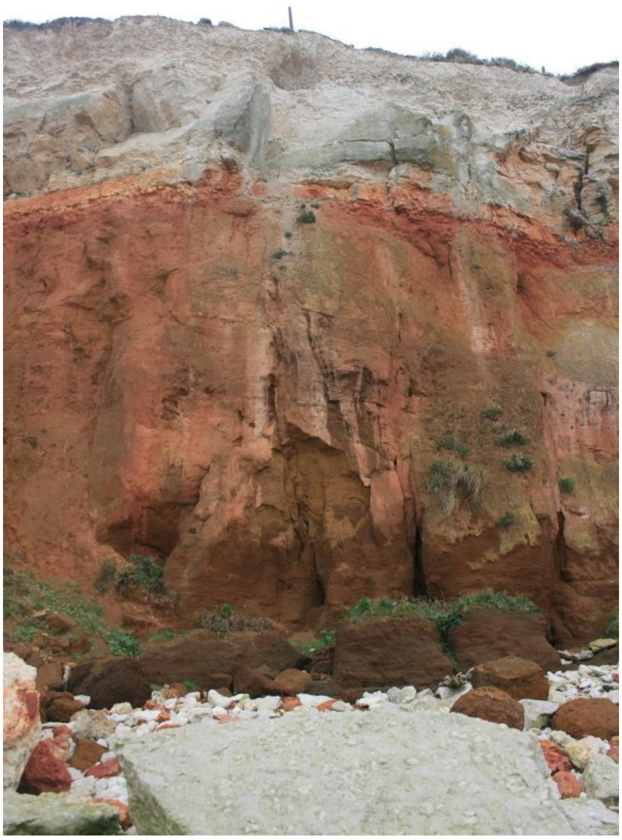
While the above primarily show chalk as the failed material, significant blockfalls have occurred from the Carstone, which have resulted in a number of overhangs, both in the chalk and the Carstone. In contrast to the accumulations of chalk debris, the failed carstone material is often no longer present because it is a much softer, weaker material than the chalk and has been totally eroded away by wave action. The main recent collapse feature in the Carstone is shown below; note the lack of failed material from what will have been a significant failure.

Evidence of the progressive nature of failures was identified by the dilation (gradual widening) of joints (cracks / fissures) within the rockmass. This was particularly evident in the upper areas of the cliff where wave action and undercutting had resulted in removal of the support provided by the rockmass below.

Erosion due to wave action along the base of the Carstone is evident along the base of the length of the cliff where it is not masked by debris from blockfalls. This erosion results in a smooth surface on the Carstone, as opposed to the broken appearance further up the cliff. Wave action also targets the joints, working away through scour, abrasion and hydraulic action to result in open joints, which are then prone to progressively worsening as the waves hit, resulting in significant loss of support to the material above.



This continued scour results in loss of support to the Carstone. Although the majority of failed material from the Carstone has been totally eroded away by wave action, some examples of the mechanism are still visible, as below.

Other features present on the face which may be having an adverse effect on stability of the cliff are associated with drainage. There are numerous pipes daylighting at the crest of the cliff. The age of these pipes is not known, but it is considered likely that they are historic and that sections have broken off as the cliffs have failed around them, possibly as a result of poor joints / leakage.

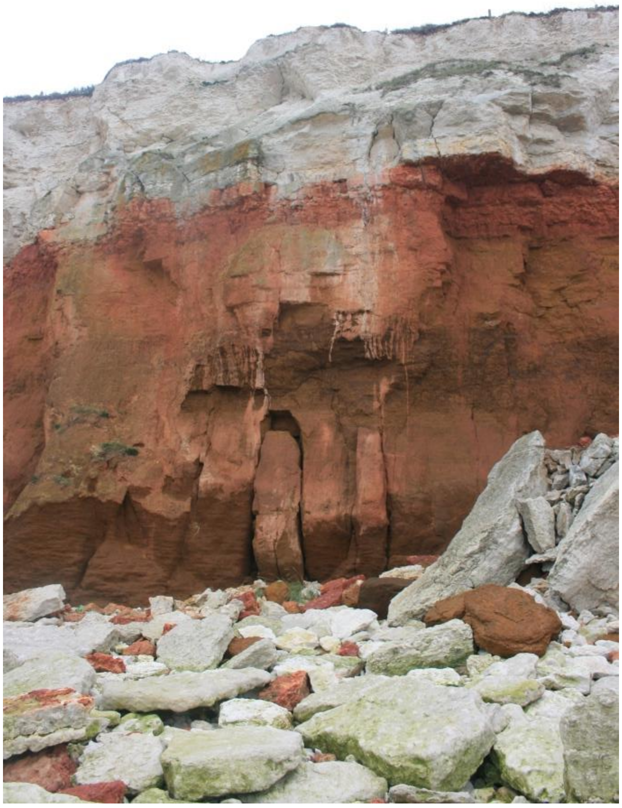
None of the pipes were flowing at the time of this visit, so it is not known if they are still connected to a drainage system, or taking groundwater, but the scour and discolouration of the rock below them highlight the effect they can have on stability. 3 No. pipes are visible at the southern extent of Hunstanton Cliff, above the northern end of the sailing club carpark, the largest one of which is supporting a large concrete block.

Below the shelter opposite the end of Clarence Road, there is a gulley within discoloured rock, which may be indicative of a pipe being present, although nothing was visible from beach level. The bottom two photos below show a small pipe daylighting above a significant blockfall, although it is not known if the presence is coincidental.

Possible pipe masked by vegetation

Surface staining is present along several sections of the face of the Carstone, which suggests that water does percolate out of the rock face, although being dry at the time, it is not known if this water originates as surface water flowing directly across the ground surface above and down the face, through joints in the chalk or along the interface between the chalk and the Carstone.



3) Failure Mechanisms

It is considered that the ongoing instability experienced along Hunstanton Cliff is a result of several different mechanisms;

- Erosion of the base of the cliff by wave action causing undercutting and subsequent blockfall above,
- Erosion of the cliff face by groundwater percolating through joints in the rock,
- Erosion of the cliff face by surface run-off water,
- Erosion of the cliff face by water flowing from drainage pipes which daylight directly onto the cliff face.

Of these mechanisms, the majority of the cliff erosion of Hunstanton Cliff is due to wave action / erosion at the base of the cliff. As shown on the photographs above, wave action forms a smooth surface on the base of the Carstone as it erodes, which also targets the joints, working away through scour and abrasion to result in open joints, which are then prone to progressively worsen as the waves continue to hit. This continued erosion results in loss of support to the Carstone above which ultimately results in blockfall as the upper unsupported material fails along the naturally occurring joints. How far this failure continues through the Carstone and the chalk depends on the competence of the rock and the condition of the joints. In addition, where the face above does not fail immediately, creep may start to occur due to loss of support, resulting in the opening up of the joints and later failure.

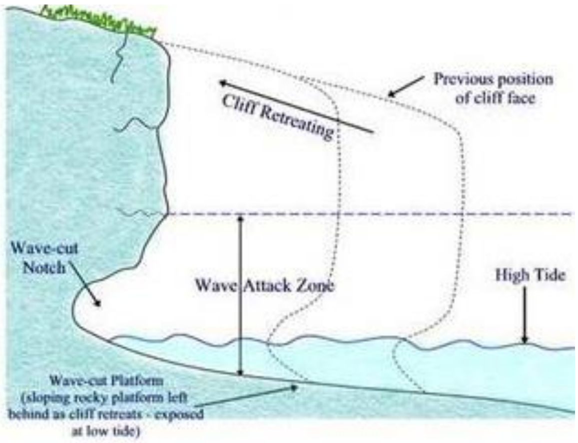
Each of the three mechanisms associated with erosion of the cliff face by water emerging on the upper face is a direct result of rainfall, differing whether or not the rainfall has percolated through the joints in the rock, has run directly off the surface and over the face or has been collected in an inadequate drainage system.

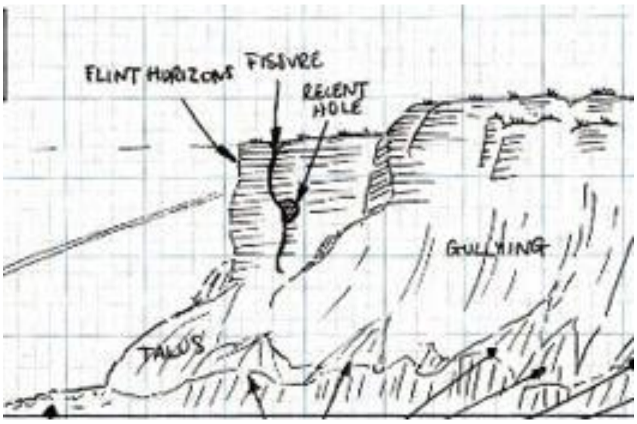
Water percolating through the joints will act to erode within the rock mass and add weight to the unstable material through saturation.

Surface run-off water and water emerging from the pipes will flow down the face, accelerating failure as it gathers in the joints, again by acting to erode within the rock mass and add weight to the unstable material through saturation, but while also filling the joints and pushing the unstable material further towards the point of failure.

Instability due to each of these mechanisms is accelerated due to the fact that both the chalk and the Carstone are heavily jointed, which acts to allow progressive failure much quicker than in a less jointed rock mass.

The images below depict the action of coastal erosion which results in retreating cliffs, as is present at Hunstanton, where there is a ‘wave attack zone’ extending well above the level of high tide, a ‘wave-cut notch’ undercut into the base of the cliff as the wave action erodes the Carstone, ‘fissures’ in both the chalk and the Carstone, which start to open up as the support below reduces, and ‘gullying’ as a result of the various actions of water running down the cliff face. Talus is a term given to failed material which gathers at the base of a cliff or face as a result of failure.





4) Options

As Hunstanton Cliff is a geological SSSI and there is a recognised benefit that continued erosion sustains a ‘fresh’ cliff face with respect to local geological features, it has been set out in previous studies that the selected option should look to ‘slow down (not stop) cliff erosion’.

Previously discarded options include;

- **Do Nothing –** discarded as this ‘would result in continued erosion of the cliff’.
- **Sprayed concrete –** discarded ‘on both environmental and social grounds as its image would not fit in with the landscape character’,
- **Rock Bolts –** discarded as ‘unlikely to provide enough interior strength to the cliffs to reduce erosion. They would not directly reduce wave attack and therefore they are unlikely to reduce erosion. Bolts are also unlikely to improve cliff drainage’,
- **Beach Nourishment and Recycling –** although not discarded in the Pilot Study, this option has not been carried through as an initial proposal. This option comprises initially nourishing the beaches in front of the cliffs with a large amount of sand or shingle which will be moved by coastal processes along the beach, following which, a recycling process will be implemented to move lost material back up to the required location.
  It is noted that, although this option would require heavy plant to place and recycle the sand / shingle, this has not been added as a ‘negative’, unlike the maintenance of a rock sill has been logged as requiring ‘significant intervention with vehicles on the beach which could potentially disturb nesting birds’.

Also discussed in the Pilot Study, but neither discarded nor included in the recommendations, is the improvement of cliff drainage. While this option would not reduce erosion due to the action of waves, both improving the current drainage network and intersecting groundwater or run-off before it percolates down through the joints in the chalk or flows over the cliff edge would reduce the possibility of failures associated with saturation of the rock and the joints in the upper parts of the cliff, as is evident at several locations along Hunstanton Cliff and referred to above.

Other options set out in a Pilot Study for a 200m long section around the lighthouse are as follows, with Positives and Negatives as provided in the Study, along with an AECOM comment on Suitability in italics.

- **Base Netting** Install netting at the base of the cliff to collect fallen material to prevent it being dispersed and washed away.

Positives	Will reduce the impact of waves during regular, every day tides by allowing accumulation of material to protect against wave action on the cliff toe. Allowing continued erosion will maintain the geological features of the SSSI.
Negatives	Recognised in the Pilot Study that regular maintenance / replacement will result in a high whole life cost. Would result in a reduction of beach size. Associated safety issues with having a large volume of rocks on the beach.
Suitability?	*It is unclear from the Pilot Study whether this netting would be attached to the face or installed as a fence a distance away from the cliff toe.* *If attached to the face, it is considered that base netting will only catch material falling from the base of the cliff, so generally the Carstone. With little fallen Carstone present along the beach, it is apparent that this material readily breaks down / erodes away under action of the waves. As such, this option may collect fallen material, but will not retain it.* *If installed as a fence, it is considered that blockfall from the chalk may either flatten the fence or fall beyond it.* *However netting is installed, it is considered unsuitable.*

- **Sand Bags** Locally sourced sand sealed into bags and placed at the base of the cliff to reduce wave energy and capture cliff material to build up erosion protection.

Positives	A cheap short term option to protect the base of the cliff.
Negatives	Recognised in the Pilot Study that regular maintenance / replacement will result in a high whole life cost.
Suitability?	Discounted in the Pilot Study as unsuitable due to high whole life cost.

- **Gabions** The most expensive option considered due to the regular maintenance and replacement required as the wires that hold the rocks in place weaken and break. Set out as a possible option for the future, should other options be deemed unsuccessful.

Positives	Allowing the nesting birds to continue to use the cliff. Erosion from the top continues to maintain geological interest of the site.
Negatives	Reduction of beach available to visitors and locals. Potentially creating a safety hazard.
Suitability?	*Considered unsuitable due to the likelihood that the structure will be broken down, thus allowing fill material to be washed away.* *The suggested positive above regarding continued erosion of the upper chalk does not address the H&S issues of blockfall.* *The suggested negatives above could be debated, in that there is already extensive rock cover along the base of the cliff from failure of the chalk, which already reduces the width of the beach and provides a safety hazard.*

- **Rock Sill** An expensive measure in the short term to reduce erosion but over time could cumulatively be a cheaper option.

  Positives Allowing the nesting birds to continue to use the cliff.
  Erosion from the top continues to maintain geological interest of the site.

  Negatives Reduction of beach available to visitors and locals.
  Potentially creating a safety hazard.

  Suitability? *The suggested positive above regarding continued erosion of the upper chalk does not address the H&S issues of blockfall.*
  The suggested negatives above could be debated, in that there is already extensive rock cover along the base of the cliff from failure of the chalk, which already reduces the width of the beach and provides a safety hazard.

5) Likely Most Suitable Option

Of the options above provided in the Pilot Study, it is considered that the creation of a **Rock Sill** would be the most suitable, as it is a more resilient option than either Base Netting, Sand Bags or Gabions and would have a long lifespan with minimal maintenance. While the Pilot Study has suggested this option has the negatives of reducing the area of beach available to tourists and potentially creating a safety hazard, it must be noted that the width of the beach is already reduced in its existing condition due to the presence of rockfall debris, which makes this the closest option to what the natural effects of erosion are providing. The risk of injury to the public by rockfall would therefore remain unchanged.

It must also be realised that, although signs are erected to warn the public of the dangers, the extensive blockfalls currently present do create an attraction to the public to climb and use the large blocks as seating or picnic areas. Also, the blockfalls are a natural occurrence, and any option that effectively replicates a natural occurrence could be seen as a preferred option, particularly if an option which may provide a long life with minimal maintenance, but a Rock Sill placed as a remediation solution will still attract the public as above, so will always provide a replication of the risk.

As set out above, the mechanism considered likely to be the cause of the majority of the instability of Hunstanton Cliff is wave action / erosion at the base of the cliff, which results in lack of support at the cliff base and subsequent collapse of the Carstone, leaving overhangs in the chalk to collapse at a later date. As such, it is this feature which needs attending to if any.

The creation of a **Rock Sill** fits this requirement, but construction works undertaken at the base of the cliff would have to consider the risk of injury to construction personnel at the base of the cliff resulting from vibration of construction plant. Such vibrations may result in the existing chalk overhangs failing while construction teams are on the beach. As such, it may be prudent to consider a scaling exercise to remove loose blocks or masses or chalk ahead of the placement of the rock.

Rock selected for use as erosion control must be suitably resilient to erosion and the action of waves. Although adding further cost to construction, it may also be possible to face the unseen already eroded Carstone behind the rock sill with resin or sprayed concrete to further protect the existing material, although this should be considered alongside the restrictions set in place by the SSSI.

References – 'National Library of Scotland'; 'Kings Lynn Forum'; 'Google Earth Pro'.