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## HOLDERNESS COAST (UNITED KINGDOM)



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## 1. GENERAL DESCRIPTION OF THE AREA

### 1.1 Physical process level

#### 1.1.1 Classification

One of the youngest natural coastlines of England is the Holderness Coast, a 61 km long stretch of low glacial drift cliffs 3m to 35m in height. The Holderness coast stretches from Flamborough Head in the north to Spurn Head in the south. The Holderness coast mainly exists of soft glacial drift cliffs, which have been cut back up to 200 m in the last century. On the softer sediment, the crumbling cliffs are fronted by beach-mantled abrasion ramps that decline gradually to a smoothed sea floor.

The Holderness coast is a macro-tidal coast, according to the scoping study the classification of the coast is:

2. Soft rock coasts
- High and low glacial sea cliffs

#### 1.1.2 Geology

About a million years ago the Yorkshire coastline was a line of chalk cliffs almost 32 km west of where it now is. During the Pleistocene Ice Age (18,000 years ago) deposits of glacial till (soft boulder clay) were built up against these cliffs to form the new coastline. The boulder clay consists of about 72% mud, 27% sand and 1% boulders and large pebbles.

#### 1.1.3 Morphology

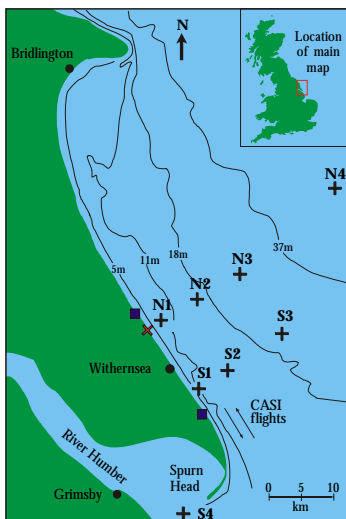


Fig. 2: Holderness coast.

The coastline sweeps in a smooth 'S-shape' from just south of Bridlington in the north to Spurn Point in the south at the mouth of the Humber Estuary. This smooth shape is only broken where sea defences have reduced erosion at the protected point and increased it southwards.

The seabed erodes by the action of waves, causing a deepening of the area fronting the cliff. The submarine contours drop off rapidly offshore, at Dimlington Highland in the south the 10 metre submarine contour is only 600 metres from the beach. The coast is thus subject to the full force of the waves from the North Sea with little attenuation before they reach the cliff line. The sea is continually able to reach the base of the cliff. Part of this area is designated an off shore Marine Sensitive Area.

Generally the natural beaches of Holderness are almost always narrow and unable to stop wave erosion. During the winter they



Fig. 1: Location of case area.

have only a thin layer of sand covering the underlying clay, and in high summer the beaches build up enough for recreational purposes. The seabed consists of the glacial mud, sands and boulders, as do the cliffs.

There are dynamic sandbanks that are thought to move along the coast and mark the most rapid areas of erosion at the base of the cliff. This could be the main method of longshore drift on the Holderness Coast. A morphological description of different characterizing parts of Holderness coast is given below.

➤ **Northern extremity: Flamborough Head**

In the north, Flamborough Head is characterised by high steep chalk cliffs containing numerous caves, arches, stacks and slumps. The sea attacks the coast around the headland in two ways. Waves beat against the vertical cliffs and, at the high water line, weak points in the chalk are worn away into caves. The weakest points are where vertical cracks or fault lines have appeared in the horizontal beds of chalk. At places on the cliffs where the chalk juts out, these caves are worn away into rock arches. If the top of an arch collapses, the result is a pillar of chalk cut off from the rest of the headland - this is called a stack. Flamborough Head has many caves and arches, as well as a few stacks. The process of erosion that has created them can take hundreds of years to do its work.



Fig. 3: Features at Flamborough Head.

➤ **Middle area**

Further south, the coastline is composed of a variety of unconsolidated glacial deposits, dominated by boulder clay but also containing sands and gravels. This loosely consolidated soft sand and clay is easily eroded by the action of waves, falling into the sea in huge landslips. In some areas the overlying till grows thicker and is inter-bedded with sands and gravels, also of glacial origin. Local beaches are sustained by sediment from the erosion process, sand and shingle.

➤ **Southern extremity: Spurn Peninsula**

Clear evidence of the southward-directed long shore transport is found in the development of the spit at the southern end of the Holderness coast, Spurn Head.

The area known as Spurn forms the southern extremity of the Holderness coast and includes the unique feature of Spurn Head formed around the end of the 16th century. This 5.5.km long spit rises only a few meters above sea-level and reaches across the mouth of the Humber, extending into the Humber estuary at the rate of approximately 10cm per year. It is built up of sand and single, the debris of the soft coast of Holderness to the north, and has a breadth seldom exceeding 270 m. There are two principle hypotheses - destruction and regrowth, and development by wash-over.



Fig. 4: Spurn Peninsula.

Neither of these hypotheses has been confirmed, however it is apparent that the integrity of the peninsula is a balance between the erosion of the eastern shoreline and deposition on the western side. Deep water is found close off the seaward side of Spurn Head.

### 1.1.4 Physical processes

#### Wind and waves

At Holderness the environment is primarily one of fetch-limited wind wave development, the dominant wave direction is north-easterly, creating a north-south orientated net long shore current. Waves during normally occurring storm events can reach up to 4 m.

#### Tide

Tidal range at the Holderness coast is very high and can reach up to 7 m.

#### Sea level rise and land subsidence

Hulme and Jenkins (1998) report that predicted changes in mean sea level around the UK coast will be similar to the global mean rise (within 2-3 cm). There will be local differences due to regional changes in ocean currents and atmospheric pressure, but an important factor that must be taken into account is vertical land movements. Thus, for example, by 2050 East Anglia (Holderness) is predicted to sink by 9 cm, whilst Western Scotland is predicted to rise by 11 cm. Table 1 lists the predicted *net* sea level rise (including land motion) by 2050 for five regions around the UK coast.

**Table 1: Relative sea level rise around UK areas (in cm) by 2050; including land subsidence/rise.**

	Low	Medium-low	Medium-high	High
West Scotland	2	9	17	63
East Scotland	8	15	23	69
Wales	18	25	33	79
English Channel	19	26	34	80
East Anglia	22	29	37	83

The medium prediction for Holderness coast is about 30 cm in the next fifty years (6 mm/year). This rate is significantly higher than 1-2 mm/years that has occurred in the previous 100 years.

#### Storm events

Storm events are of great importance at the Holderness coast. The erosion occurs mainly during storms and tidal surges. Wave heights for extreme events are shown in Table 2.

**Table 2: Extreme events at Holderness.**

Extremes every 1/.. years	Hs	Tm
1	5 m	7 s
100	7 m	10 s
1000	8 m	12 s

## Current

The Gulf Stream is directed southward at the eastern coast of England. However the long shore current is mainly wave and tidal driven.

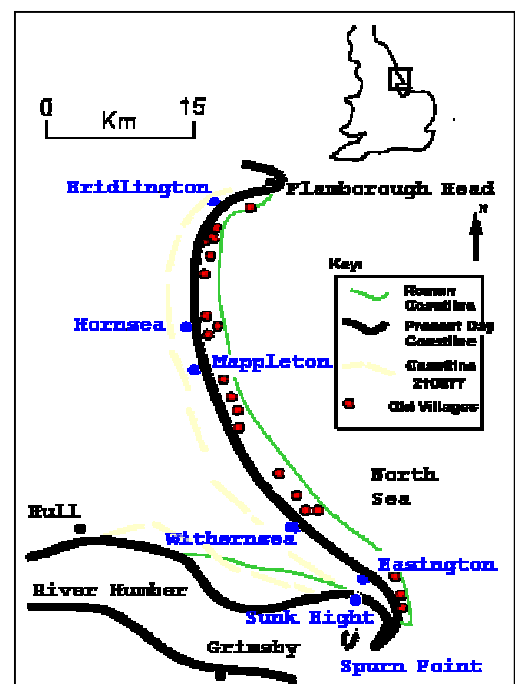
### 1.1.5 Erosion

#### Erosion type

The dominant south-westerly directed North Sea waves are trying to re-shape the coast between Flamborough and Cromer into a smooth bay. The waves produce southward bound long shore currents. The chalk headland of Flamborough Head prevents transport of materials from the north, thus little beach material is transported southward to the beaches of Holderness. The cliffs south of Flamborough Head are made up of loosely consolidated glacial till (there is no relationship between rates of erosion and type of till, nor with the height of the cliff). The sea attempts to build up an equilibrium gradient by eroding these soft cliffs behind the beach, to which the strong waves have easy access. This inevitably means that some of the Holderness coast will be eroded in order to achieve a more efficient coastal shape.

On average, the coastline of Holderness erodes at about 2 m per year. However rates fluctuate enormously, both over time and from place to place, so accurate prediction is often difficult. The erosion occurs mainly during storms and tidal surges; a loss of 6 m was recorded over two days at Barmston in October 1967. The coast actually recedes as a series of small slumping type landslips, which can take a 10 – 20 m bite out of the cliff top at one time followed by a period of several years in which no further movement takes place at that point.

At the northern extreme, the town of Bridlington is protected by Flamborough Head to the north and the Smithic Sandbank which lies just offshore; this sandbank is 10 km long and at spring low water rises 2.7m from the sea. Further south along the coast the 10 and 20 meters submarine contours lie close to the shore and there is no shelter from the maximum fetch across the North Sea from the north east. Therefore, erosion increases as one moves southward.



*Fig. 5: Historic erosion at Holderness.*



Historical evidence of incredible erosion rates is abundant: since Roman times over 30 villages have been lost to the sea between Bridlington and Spurn Head (see Figure 3). Remnants show that the coastline was roughly 5.5 km seaward of its present position. But contemporary evidence of this rapid erosion is also abundant, military pillboxes built in 1940-41 lie at the cliff foot, roads end precipitously at the cliff edge and the local press regularly covers stories of properties falling into the sea.

It is thought that human interference such as sea defences is one of the causes of the erosion. Groins at Mappleton and Hornsea and concrete seawalls at Withernsea dating to the late 19<sup>th</sup> century interrupt the evolution of the natural coast towards the formation of a large scale bay between the hard points of Flamborough and Cromer.

### **Sediment budget**

The erosion of the cliffs and the seabed results in vast amounts of sediment finding its way into the sea – every year about 1 million m<sup>3</sup> of sediment results from cliff erosion and 2 million m<sup>3</sup> from the erosion of the seabed up to 2 km offshore – 3 million m<sup>3</sup> in total. All this material is carried south towards Easington and Kilnsea by the wave driven currents creating the Spurn Head spit and supplying the Humber Estuary and the North Lincolnshire coast with valuable sediment. On a longer time scale, it was estimated that about 76,450,00 cubic metres of material have been lost from the Holderness coast in the last 100 years (Valentin, 1954). Only 3% of this material is deposited at Spurn Point. The remainder is deposited in deeper water offshore or is carried across the mouth of the Humber to be deposited within the estuary itself or on the North Lincolnshire coast.

The eroded material (mostly mud) causes a muddy appearance of the sea immediately offshore, this is characteristic for the Holderness coast. Smaller amounts of sand are eroded and transported in much the same way, although at a slower rate than the mud. Some of this sand is therefore able to form a beach in front of the cliff during calmer conditions. During stormier conditions, this sand is rapidly removed, most of it southwards where it drifts offshore into the North Sea. Some of it forms offshore bars – only to return to the cliff foot once the storm is over.

The larger stones and pebbles are dragged along the seabed but only during more extreme storm conditions since they require more energy to move. This material gradually moves southwards and eventually reaches Spurn, where in the past it added to the development of a shingle ridge.

## **1.2 Socio-economic aspects**

### **1.2.1 Population rate**

The East Riding of Yorkshire covers a predominantly rural area of 241,000 hectares and lies adjacent to the East coast (Holderness Coast) immediately to the North of the River Humber. The area has a population of more than 312,000 people over half of who live in rural communities compared to 20 per cent in England as a whole. This results in a relatively low population rate of 130 persons/km<sup>2</sup>.

### **1.2.2 Major functions of the coastal zone**



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Transportation within the area is reflective of its rural nature with only the South served by motorway (M62). Unlike adjoining areas the population of East Riding is growing.

The major functions along the Holderness Coast are:

- **Tourism and recreation:** Withernsea, Hornsea and Bridlington are the main resorts. Beach recreation is of great importance for this area. Fishing and caravanning are the other main tourist features at the Holderness coast.
- **Urbanisation (safety of people and investments):** There are four main towns - Beverley, Bridlington, Driffield and Goole, the biggest of which is the traditional coastal town of Bridlington, which has a population of 32,000. Other towns along the coast are smaller, Hornsea 8.000 (count 1991) and Withernsea 6.500 (count 1991). Concluding, the main towns population and investments at the Holderness coast are relatively small.
- **Fisheries and aquaculture:** The coastal waters encompassed within the East Riding coastal zone and the associated North Sea region support a high level of commercial and recreational fishing activity and Fishing and fishing-related industries continue to play an important role in the life of many communities in the East Riding coastal zone.
- **Agriculture and forestry:** The coastal area has a rural nature and a lot of high quality agricultural land (because of the deposits of glacial till), mainly used for large scale arable cultivation and intensive livestock farming.
- **Industry, transport and energy:** Easington houses the Easington and Dimlington Gas Terminals which account for approximately 25% of Britian's gas supply.
- **Nature and conservation:** Dunes and wetlands at Spurn Peninsula, the Lagoons at Easington and the freshwater mere at Hornsea are very important natural sites. Some have been designated as SSSI areas.

### 1.2.3 Land use

Most of the surrounding land is made up of deposits of glacial till and alluvium, which cloak the underlying Chalk strata, and create high quality agricultural land used predominantly for large scale arable cultivation and intensive livestock farming. However, in some places the hinterland land was, until quite recently, a boggy, wet area full of meres and lakes – just as it was left by the receding ice sheet. The meres have now almost all been drained – with the exception of Hornsea Mere – but the soils remain 'strong': heavy and lacking in many nutrients which other areas take for granted. To compensate for the lack of nutrients, many Holderness farmers grow crops such as broad beans which add nitrogen to the soil.

Interlacing the farmlands along the coast are residential areas, holiday homes and caravan parks. Over 90 % of the Holderness coast is undeveloped.

### 1.2.4 Assessment of capital at risk



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Erosion has led to the loss of 30 coastal villages since the Roman times and nowadays poses a threat to a number of other settlements such as Mappleton and Easington. Furthermore it causes the loss of farmland and coastal roads. The overall capital at risk at the Holderness coast is considered to be low. However, locally the risks can be high, for settlements and recreational, industry, nature and agricultural values.



## 2. PROBLEM DESCRIPTION

### 2.1 Eroding sites

As has been described in the previous pages, the whole coast experiences erosion except for the areas where coastal protection works have been carried out. The main sites are described below from north to south (see Figure 4 for locations).

#### ➤ Flamborough Head

On the most northerly point of the Holderness Coast lie the distinctly layered white chalk cliffs (topped by a layer of glacial till) of Flamborough. The cliffs are dotted with examples of erosion features such as caves, arches, stacks and stumps resulting from the presence of relatively more resistant limestone.

#### ➤ Bridlington

Bridlington is predominantly an urban development offering tourism related establishments and recreational watersports. It is an operational fishing community and nationally important for sea birds. The town of Bridlington at the northern extreme is protected by Flamborough Head to the north and the Smithic Sandbank which lies just offshore; this sandbank is 10 km long and at spring low water rises 2.7.m from the sea. Bridlington is protected against the north-easterly waves by the 4.7 km long Bridlington Promenade. The beach is sustained by sediment from the erosion process, although there is little net longshore drift, on balance it is in a direction from south to north.

#### ➤ Hornsea

Hornsea has 2.9km stretch of shoreline fronting the town. This high-density urban development is dependent on tourism and recreation as well as a small fishing industry. Hornsea boasts the only natural freshwater mere remaining in the area. Environmentally, Hornsea boasts the only freshwater mere within the study area and is designated a SSSI. Problems with occasional sea water inundation due to breaching of existing flood defences have



Fig. 6: Location of eroding sites at Holderness.



Fig. 7: Cliff retreat south of Hornsea.

arisen.

Net drift in a southerly direction is apparent with some significant onshore/offshore movement. Because the coastline of Hornsea has been fixed since the early 1900's erosion rates have not been high at this site in the last century. However, south of Hornsea this has caused an increase in erosion.

➤ **Mappleton**

Situated approximately 3km south of Hornsea lies the village of Mappleton. Supporting approximately 50 properties, the village has been subject to intense erosion at a rate of 2.0m per year, resulting in the access road being only 50m from the cliff edge at its closest point.

➤ **Withernsea**

A thriving holiday resort comprising 2.3km of developed frontage, Withernsea is recognized as a popular tourist and recreational site. Caravan parks, a golf course, residential and commercial developments add to the local economy. Surrounding land is put over to agriculture or open land.

The beach is EC designated and a variety of water sports are enjoyed offshore. Stability of the beach depends on the effectiveness of material to become trapped between groins established 120 years ago. These were built when the promenade was established.



*Fig. 8: Promenade of Withernsea, seawall and rip-rap.*

The main erosion occurs downdrift of Withernsea, downstream of the promenade the erosion is increasing. The situation is quite similar to that of Hornsea.

➤ **Easington**

Easington is the southern headland of the Holderness Coast. It marks the point at which the southwards travelling sand derived from the erosion of the cliffs moves offshore. This is a result of a combination of the change in the direction both of the coast at this point and of the tidal currents, the latter caused by the interaction of tides in the North Sea and those within the Humber estuary. The wider zone of shoal water immediately offshore here reduces the power of the waves, so that erosion rates are very slightly lower here than further north. This may not be a noticeable difference over short time periods – such as the past 50 years, but sufficient to cause a long term change in coastal shape. Not all the sand leaves the upper shoreline; a small proportion carries on along the shore towards Spurn where it forms an essential part of its natural maintenance. There is a strong net longshore drift in a southerly direction amounting to erosion at a rate of 1.8m per year at the Easington coastal stretch.

This section covers 1km of eroding coastline fronting the Eastington and Dimlington Gas Terminals. Owned by British Gas and BP, they account for approximately 25% of Britain's gas supply.

Potential updrift and downdrift effects of reduced erosion could put at risk the Geological Conservation Review site - Dimlington Cliffs, designated SSSI - located immediately to the north of Easington Gas Terminal. Furthermore, the site known as the Lagoons is situated south-west of Easington village. It comprises a variety of coastal habitats including saltmarsh, shingle, sand dune, swamp and saline lagoons. Maintenance of the integrity of The Lagoons requires a constant source of sediment from the north along established sediment transport pathways.

### ➤ Spurn Peninsula

The Spurn spit forms a sweeping curve which continues the line of the coast. The sand which forms the spit has been transported along the Holderness Coast by longshore drift. The energy in the waves transporting the material reduces where the North Sea meets the Humber Estuary. As a result the material is deposited. This process is known as deposition.

At the northern end of the spit lies the small, scattered settlement of Kilnsea, a permanently manned lifeboat station, together with residential properties for the crew and their families and some recreational sites. It can be reached by an access road built by the military in 1940. Beyond Kilnsea is a mosaic of dunes and wetlands of wildlife conservation importance, managed as a nature research by the Yorkshire Wildlife Trust. In addition to its wildlife interest, Spurn peninsula is included within the Spurn Heritage Coast and is covered by the Spurn Heritage Coast Management Strategy.



*Fig. 9: Indication of evolution Spurn Head.*

Although the spit is currently continuous with the coastline, historical records indicate a series of breaches of the peninsula. Since the most recent breach in the 1850's, the peninsula has been protected by a variety of hard sea defences. A consequence of these is that the central part of the spit has been frozen whilst the landward end moves westward, matching the erosion of the Holderness coast. The defences also serve to fix the mean high water level along the peninsula, delaying the erosion process, thereby affecting the natural evolution of the peninsula.

The stormy weather at the end of September 2003 led to further erosion of the sand-dunes near the northern (landward) end of the Spurn peninsula. As a result the road to the pilot station at Spurn Head was breached once again (it was last breached two years ago).

## 2.2 Impacts

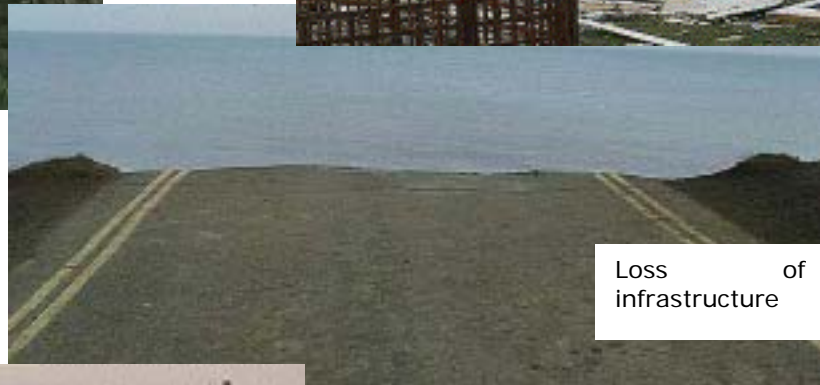
Examples of impacts of coastal erosion on socio-economic aspects at the Holderness coast are shown in the pictures below.



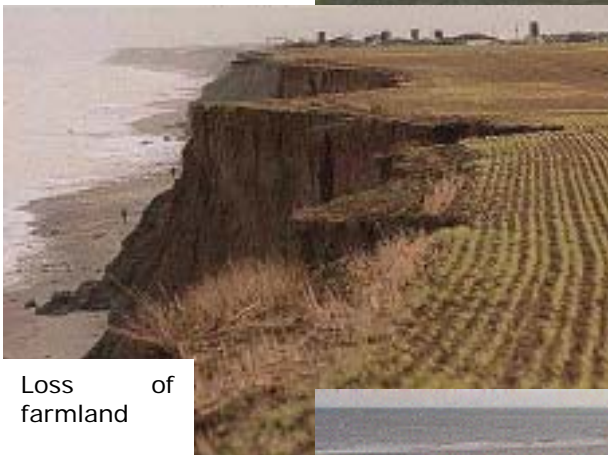
Damage to infrastructure



Loss of property



Loss of infrastructure



Loss of farmland



Danger for tourism



Damage to coastal protection

Fig. 10: Overview of impacts coastal erosion on different socio-economic aspects at Holderness.

### 3. SOLUTIONS/MEASURES

#### 3.1 Policy options

Since the late 19th century coastal protections have been used to enforce a 'hold the line' policy at the coastal towns of the Holderness coast. In between the coastal towns large areas are also eroding while no measures are taken. Nowadays the local and regional authorities are trying to set up integrated coastal zone management programmes for the whole Holderness coastline and the Humber estuary.

In the 'East Riding Integrated Coastal Zone Management Plan' the policy options (do nothing of hold the line) are given along the Holderness coast, these are shown in Table 3. The policy option managed realignment is being considered at Holderness for the future (see Strategy).

**Table 3: Policy options along the Holderness coast.**

Management Unit Number	Location	Preferred Option for Lifetime of SMP
1	Flamborough	Do Nothing
2	Bridlington Promenades	Hold the Line
3	Wilsthorpe/Fraisthorpe	Do nothing
4	Barmston/Atwick	Do nothing Hold the Line when needed at Atwick gas storage facilities Hold the Line at Barmston Drain pending more detailed economic analysis
5	Hornsea	Hold the Line
6	Rolston	Do nothing
7	Mappleton	Hold the Line
8	Aldbrough/Tunstall	Do nothing Hold the Line at Tunstall Drain pending more detailed economic analysis
9	Withemsea	Hold the Line
10	Holmpton	Do nothing
11	Easington Gas Terminals	Hold the Line (to be reviewed in 2020)
12	Easington/Kilnsea	Do nothing Retreat the line periodically at New Bank flood defences
13	Spurn Peninsula	Do nothing Local retreat or intervention where monitoring so requires
14	Sunk Bight	Hold the Line
15	Sunk Island	Hold the Line
16	Immingham	Hold the Line
17	Grimsby and Cleethorpes	Hold the Line
18	Humberston/Donna Nook	Hold the Line



## 3.2 Strategy

### 3.2.1 Historic measures

Over the entire coastline hard sea defences have been built along the coast to stop the erosion in places where the sea threatens lives or important installations. However the sea defences have a downside; they are unsightly, can be inefficient and in the long term can be found to encourage local erosion and erosion in other places. Furthermore, sea walls make access to the beach more difficult and can discourage tourism.

In the past, ad hoc also private sea defences have been put in place to protect assets, particularly at Ulrome and Skipsea. While these provide a short-term protection to the properties directly protected, their general nature and design is of concern. Private defences are often not of the same engineering standard of those publicly funded, and pose health and safety problems because of this –posing a danger to beach users. They can also often be easily undermined during periods of beach “drawdown”. In the future the presumption should be against permitting private sea defences due to these problems. For any private scheme to be considered it would have to be deemed by the Planning Authority to be technically sound and have no negative impact on the environment. Conditions relating to maintenance and eventual removal would also need to be considered.

### 3.2.2 Conflicts

Managing the beaches through 'soft engineering' involving the deposition with gravel and other materials to add to the natural protection provided by beaches (government policy in 1993) has been updated; nowadays it is accepted that the sediment from the erosion of cliffs is vital because it builds up the natural defences of beaches, mudflats and marsh. In the long term this sediment drift should be managed, not stopped. This conflict between the need to defend the coastline, and consequently the properties in the village, and the maintenance of sediment transport along the coastline was a problem at Mappleton. In 1990, Mappleton was under threat from losing 30 houses and its main road. Even though erosion problems would arise 'downstream' of Mappleton, a coastal management scheme was set up and blocks of granite were imported from Norway to build two groins and a seawall. The costs of these structures were very high, maybe even higher than the costs of a compensation arrangement.

Similar conflicts arise when local councils must protect certain areas and interests such as EC designated bathing beach and fishing activities, nature conservation, access channels for RNLI and fishing vessels and sewage treatment discharge whilst not being prejudiced by coastal defence policies. Where tourism and fishery are one of the only means of income in the town then saving the beaches and harbours become a very important part of the local policy.

Another example of such conflicting interests is the situation at Hornsea. The local council promised landowners facing the loss of their land and property that they would build a stone groin at the base of the cliffs to trap sediments and reduce the power of the waves. The inhabitants, however, were infuriated by the decision of the council not to take this action until the cliff edge is 30m from their front door. The main concern of the council had been to protect the British Petroleum oil and gas terminal further towards the south at Easington. Furthermore the Countryside Commission had argued that protecting the cliffs at Hornsea reduces the flow of sediment down the coast and into the Humber where it protects the



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riverbanks. Their research shows that this increases the risk of flooding in Hull. But following protests from the local Hornsea population, the stone barrier was anyhow extended to protect the village.

### **3.2.3 Future measures**

In order to make the above decisions easier it is important to have a better understanding of the processes, which play a role along the Holderness Coast. A large scale experiment has been set up, the 'Holderness Coastal Experiment' originating as a component of the UK LOIS programme, with the specific aim of understanding and ultimately predicting coastal erosion. Objectives were: (i) to quantify contemporary fluxes from a rapidly eroding coast to the adjacent sea and relate these fluxes to separate causative mechanisms via model simulations, (ii) to extend these simulations to predict wider scale, longer-term sediment motions and test against historical records of erosion and accretion, and (iii) to examine the associated impact of future and historical scenarios of climate change.

In the future management strategies may possibly depend upon cost benefit analysis and where the cost outweigh the benefits it is often thought that managed retreat is most appropriate with those losing their homes and livelihoods being paid compensation.

## **3.3 Technical measures**

### **3.3.1 Type**

Local authorities have tried various measures to tackle the problem of coast erosion. Where storm waves undermine cliffs physical barriers have been used to resist the waves. Some sea walls are vertical with overhanging lips so that they reflect the full force of the waves and prevent sediment from being thrown over the wall. Elsewhere walls have a gradual slope allowing them to absorb wave energy more gradually. Walls are usually built in conjunction with groins, which reduces the rate of drift along the coast. Longshore drift is not so dramatic as cliff collapse but it has potentially serious economic consequences in that it has to be dredged from commercial harbours and because it takes sand away from tourist beaches. Sometimes large boulders are placed at the top of a beach to gradually reduce wave energy and to reduce the backwash by encouraging percolation. Where cliffs are likely to collapse because they have become saturated, drainpipes are placed in the cliff to lower the water table and reduce the likelihood of failure.

Coastal protection is in place at the following settlements in the coastal zone - Bridlington, Hornsea, Mappleton and Withernsea, as well as the gas terminals at Easington. There are also some private defences at Skipsea and Ulrome that have had temporary planning consent. Away from these areas the coast is undefended. A total of 11.4 km currently has coastal protection.

### 3.3.2 Technical details

#### ➤ Bridlington

Bridlington is protected against the north-easterly waves by the 4.7 km long Bridlington Promenade. Existing coastal defences date to the late 19th century and comprise a series of reinforced concrete walls and a system of timber groins. A programme of maintenance has been in operation to ensure continued protection.



*Fig. 01: Bridlington Promenade.*

#### ➤ Hornsea

The position of the coastline at Hornsea has been artificially fixed (no erosion) since existing coastal defences were erected in the early 1900s. Large timber groins and rock armouring (concrete seawall) have been placed on the beach to reduce wave action and trap sediment, ensuring relatively steep beaches. More recently a stone gabion has been erected to the south of Hornsea. This helps protect the caravan park. The beaches are mostly made up of sand, boulder clay produces little sediment for the beach as it is easily washed down the coast and as a result of wave attack. This means that the beach remains relatively narrow. Nowadays an ongoing refurbishment programme ensures that the beach grows wider.

Sand has accumulated to the north of the terminal wooden groin, affording a barrier to sediment transportation. This has reduced erosion at Hornsea within the section but increased rates are evident downdrift. Cliff erosion has continued on either side of the Hornsea defences and the town now projects into the sea, forming an artificial headland. This headland will become more pronounced as time progresses, leading to an increase in its exposure to the forces of the waves.



*Fig. 02: Wooden groins, seawalls and boulders at Hornsea.*

#### ➤ Mableton

In 1991, two rock groins and a 500-meter long rock revetment were built, as a consequence a substantial beach accumulated between the groins halting erosion. The angle of the cliff behind the defences has been reduced to prevent further slumping of the face. However, further south the rate of erosion has increased significantly. This is because material that is being carried south is not being replaced (it is trapped within the groins). Therefore there is no beach to protect the cliffs. Even during a neap tide (a tide which is 30% less than the average tidal range) the sea reaches the base of the soft cliffs and erosion occurs. This is causing Cowden Farm just down the coast from the Mableton groin, to start falling into the sea. At the foot of the cliff the erosion increased as a direct result of the defences, ensuring



that there is almost no beach remaining. Many other properties have already fallen into the sea or are about to do so soon.

➤ **Withernsea**

At Withernsea, stability of the beach depends on the effectiveness of material to become trapped between groins established 120 years ago. These were built when the promenade was established. However, storms during the winter of 1992/93 caused the removal of most of the beach fronting the wall, in some places up to more than 4 m of sand were stripped away by the sea, exposing the foundations to the sea wall. This has led to cracks appearing in the wall and houses along the sea front experienced shock-waves large enough to be measured on the earthquake scale.

Emergency repairs have had to be undertaken here, and rocks, similar to those used for the Mappleton defences, have been placed along the base of the wall to provide further protection. But also in this case the sea defences cause less material to be carried down the coast.

➤ **Easington**

The Easington Gas terminal, which receives gas from the North Sea gas fields, is now within 25m of the cliff edge, with no beach to protect it. Plans are currently being drawn up for defence works for this installation and possibly for the village of Easington itself. A rock revetment at the base of the cliff incorporating the full length of the site has been suggested.

However, potential updrift effects of reduced erosion could put the Geological Conservation Review site - Dimlington Cliffs - located immediately to the north of Easington Gas Terminal at risk. Dimlington Cliffs have been identified as being of national geological importance. Continuous marine exposure is required to maintain the geological interest.

➤ **Spurn Peninsula**

Spurn Point is formed by deposition of eroded material, supplied by the longshore drift on the Holderness Coast. It reflects a balance between the erosion of the eastern shoreline and deposition on the western side.

Since the most recent breach of the peninsula in the 1850's, the peninsula has been protected by a variety of hard sea defences. The whole area is bounded to the north by Long Bank, a substantial sea defence bank. Along the eastern shore a combination of timber groins, timber breastwork and concrete/rubble can be found. On the western shore only



*Fig. 03: Rock groin and revetment at Mappleton.*



*Fig. 04: Easington gas terminal: close to the cliffs.*

isolated defences exist, in particular the concrete and masonry wall in the vicinity of the RNLI station.

A consequence of these is that the central part of the spit has been frozen whilst the landward end moves westward, matching the erosion of the Holderness coast. The defences also serve to fix the mean high water level along the peninsula, delaying the erosion process, thereby affecting the natural evolution of the peninsula.



*Fig. 05: Timber groin, destroyed by lowering of the beach.*

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## 4. EFFECTS AND LESSONS LEARNT

### 4.1 Effects related to erosion

In general the fixation of the coastline at the main towns with hard measures has been successful locally, but always causes an increase in erosion downstream. The beaches along the Holderness coast were already very small, as only 30% of the glacial till eroded is heavy enough to be deposited and form a beach. The beaches downstream of the defences began to shrink in size, as material usually deposited there was either not eroded, or stuck behind the groin. This meant that the waves concentrated all their energy on the base of the weak cliff, because the beaches were not big enough to absorb the waves. This caused the cliffs to erode at a faster rate, threatening many buildings once thought of to be safe.

The fixed headlands such as the artificial defences at Bridlington, Hornsea, Mappleton and Withernsea have been in place only for a relatively short time period, however some evidence already exists to suggest that they are causing bays to form between them. South of Hornsea, for example, a bay is already developing southwards towards Withernsea. Once this bay extends between the two hard points it will continue to develop until it is deep enough to prevent sand escaping around the headlands. At this stage the beaches within the bay will begin to widen and deepen and form an effective natural protection against further wave erosion – so that the bay may become stable. Research into the area between Hornsea and Mappleton indicates that a stable bay between these two hard points could have a maximum depth of up to 650m located 2km south of Hornsea taking approximately 250 years to develop. If these stable bays will indeed form between hard defences, then it could provide an obvious method of protecting Holderness against further erosion in the future. The present town defences, together with a few more strategically placed hard points, may be sufficient to reduce and eventually stop erosion along the whole coast.

However, two problems face such an apparently desirable conclusion: as the bays develop the wave pressure on the headlands will increase, and the cost and difficulty of maintaining these may become impossible to sustain. This pressure will be due partly to the concentration of wave energy on any projecting headland but also because the sea bed will continue to erode offshore and the resulting deeper water will allow more wave attack at the shore.

Although the erosion of the Holderness coast is seen by those who live or work there as an evil which must be prevented, it may be viewed entirely differently from the viewpoint of those who live or work on adjoining coasts. The mud and sand which is produced from the Holderness erosion is carried along the coast and helps to prevent erosion downstream. The Humber estuary needs all the mud it can receive from Holderness for accretion of the estuary bed to be able to keep up pace with sea level rise. Without such mud the estuary would become deeper and the tidal range, and hence flooding of the low-lying lands surrounding the estuary, would increase. Similarly the beaches of Lincolnshire may be fed by sand moving south from Holderness. Preventing Holderness erosion could cause even more dramatic erosion on this coast than is already occurring.

### 4.2 Effects related to socio-economic aspects

In some areas, like Hornsea, the measures taken to prevent erosion have proven to be efficient. In other areas, like Mappleton, the measures have proven inefficient or cause side effects. This results in a continued threat to the hinterland. The continued threat and the



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maintenance costs of the effective measures both claim their toll. A continued threat lays claim on the towns threatened by the erosion, as do the costs of maintenance. In the case of the Easington Gas terminal, the erosion of the coast results directly in a risky situation.

### **4.3 Effects in neighbouring regions**

As has been mentioned throughout this case study, the sea defences protect the beach locally, but do not stop erosion in the areas in between. In fact, in these areas the erosion was increased by the presence of the defences. The defences either prevent erosion or stop the long shore transport; by removing the sediment from the long shore drift in this way the beaches further downstream are starved from their natural sediment supply.

Further south of the case study area, the Humber estuary is very dependent on the sediment supply from erosion at the Holderness coast. The estuary needs sediment to feed the mudflats and banks of the Humber, which in turn protect Hull. When the Holderness coast is protected from erosion by coastal protection, the sediment supply towards the Humber estuary will decrease and intertidal areas in the estuary will be lost.

### **4.4 Relation with ICZM**

The relation with ICZM is as always difficult to assess and very dependent on the viewpoint one takes. The measures are taken to prevent erosion and safeguard functions of the hinterland. One could say an integrated coastal zone management strategy is adapted on a local scale, since there are several aspects of the coastal zone that interact. Holding the line assures the safety of the people living near the coast, defends the economical value of installations and maintains the current coastline. On a larger scale it becomes apparent that the local measures can have a negative influence on the development of the stretches of coast that are not or not as well protected.

Therefore, in 2000, East Riding of Yorkshire Council, and other interested parties agreed to develop an Integrated Coastal Zone Management Plan for the East Riding coastal zone, the fastest eroding in Europe. This is a plan that balances all the issues that are important on the coast, including the environment, tourism, fisheries, agriculture and rural isolation.

The East Riding coastal zone is a special place. It is a wonderful natural asset that is vital for the region 's economy and fundamental to our social well-being. It is also an area that provides particular challenges for those who live or work there, as well as the organisations involved in all aspects of its management. The East Riding coast experiences high rates of erosion, supports relatively isolated communities and has core industries in decline. But it is also an area with exciting opportunities –whether they are in developing tourism, the economic and social regeneration of our coastal towns and villages or in protecting and enhancing the environment.

### **4.5 Conclusions**

#### **Effectiveness**

The effectiveness of the measures taken at the Holderness coast are varying but in general the hard measures are successful in stopping or at least slowing down the erosion locally. However, due to the use of hard measures, downstream of the measures the erosion has



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increased. In between the towns with a fixed coastline, bays seem to be developing due to this erosion. The sea defences seem to be creating artificial headlands because erosion on both sides continues. As time progresses this could mean that the headlands (towns) become more and more exposed to the force of the waves, while the coast in between the headlands will erode more and more until a stable bay is formed.

### **Possible undesirable effects**

Human interference such as sea defences causes rapid erosion of the unprotected beaches and cliffs. Groins at Mappleton and Hornsea and concrete seawalls at Withernsea interrupt the evolution of the natural coast and trap the sediment transport needed to supply the downstream beaches.

To counter this, nowadays local and regional authorities are trying set up integrated coastal zone management programmes for the whole coastline. However, problems arise because there is an absence of a unified framework for managing the coastal zone and because of the lack of cooperation and coordination between the different organisations with administrative responsibilities for activities within the coastal zone. The policy remains 'hold the line' or 'do nothing'.

Furthermore, human coastal defence structures are often unsightly and in some cases make access to beaches more difficult discouraging tourism. Their maintenance costs are high and they sometimes impede other solutions up- or downstream.

### **Gaps in information**

No information was found on the costs for the construction of the different measures as well as for the maintenance costs of the constructions. Furthermore, information on the net sediment transport was not found.



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### **Figures:**

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