



Coastal Management – An Update Case Study of The Holderness Coast, Yorkshire

Introduction

A range of classic coastal features stretch over 50km, from the chalk cliffs of Flamborough, through the plain of Holderness, to Spurn Head where a large spit guards the entrance to the Humber estuary. The combination of clay geology and a high-energy environment has helped make this part of the Yorkshire coast one of the most rapidly eroding coastlines in Europe. Historical records show that some twenty-nine villages have fallen into the sea since Roman times (Fig. 1). This problem continues to challenge coastal engineers and as the pressure from population growth, economic development and recreation grows, choosing an appropriate management strategy is proving to be an increasingly difficult task.

What physical factors are at work along this coastline?

A wide range of contributory factors is shown in Fig. 1, and three of the most important are outlined below:

- **Weather** – Winter storms produce stronger waves and higher sea levels (surge). In addition, the rain they bring intensifies land-based (sub aerial) processes. The saturated clay cliffs suffer increased runoff leading to slumping and other forms of mass-movement.

- **Waves** – The dominant waves are from the north east which is also the direction of the largest fetch. Destructive waves erode the beaches and attack the foot of the cliffs, removing the clay in suspension. Longshore drift then carries this material southward. Tides and the lower energy environment of the Humber estuary allow sediments to collect forming a spit, mudflats and sand dunes near to Spurn Head.

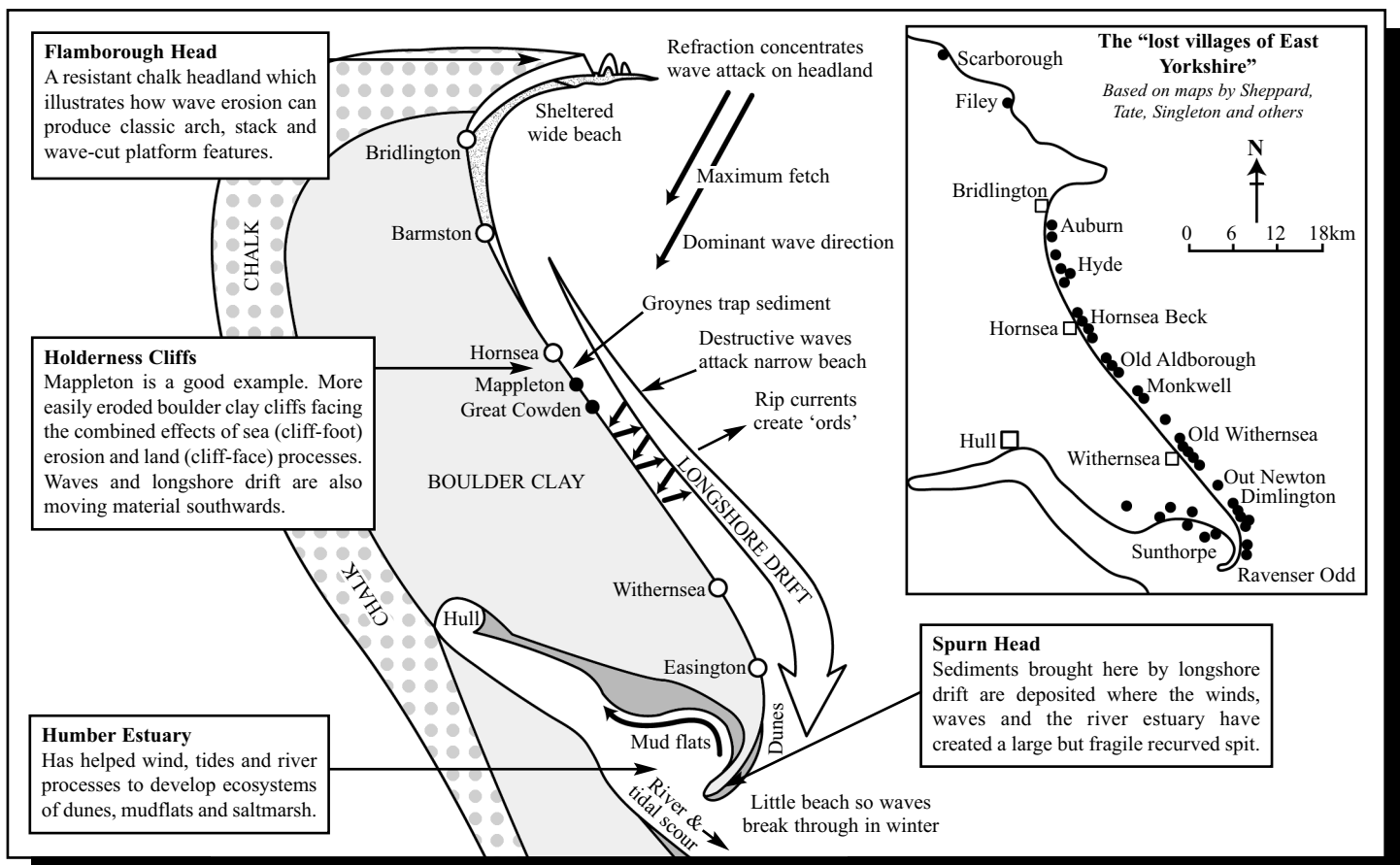
- **Geology** - The two main types of rock found along the coast are chalk and boulder clay. The more resistant chalk has survived large-scale erosion and this has created the classic features of Flamborough Head (see Fig. 2, page 2). The boulder clay cliffs to the south are more easily eroded and their retreat has formed the sweeping bay of Holderness. It is this **differential rate** of erosion that has given the coastline its distinctive shape.

What features and processes make this coastline so distinctive?

Three distinctive features stand out along this coastline:

- the impressive chalk headland and cliffs near Flamborough
- the retreating clay cliffs of the Holderness Bay
- the 6km spit at Spurn Point

Fig. 1 Physical factors that help create features along the Holderness Coast.



Flamborough Head

This headland (see Fig. 2) illustrates how wave erosion can produce the classic arch, stack and wave-cut platform features, often associated with chalk rock. The chalk is resistant to erosion and has a distinctive lithology. The horizontal bedding planes are seen in cliffs at Flamborough Head and North Landing where they assist in the development of **wave-cut platforms**. These form close to high tide levels when shingle carried in the waves increases **abrasion**.

Fig. 2 The features of Flamborough Head.

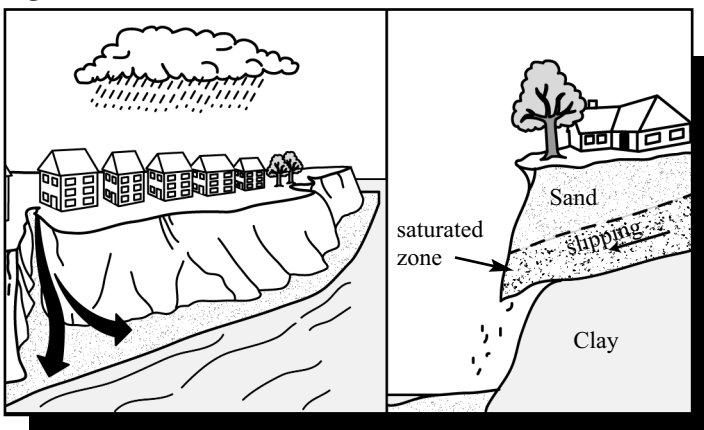
As the cliffs retreat a noticeable **notch** indicates how powerful wave energy can be. Vertical joints allow waves to penetrate the cliffs and together with faults these can lead to the formation of caves and geos. **Wave quarrying** can result from the sheer weight of the waves striking the cliffs (hydraulic pressure) or from air being trapped in faults and acting pneumatically as waves break. **Wave refraction** further concentrates waves on headlands allowing caves to develop progressively into **arches, sea stacks** and **stumps** (see Geo Factsheet number 129 *The impact of structure on coastal landforms*).

It should not be forgotten that cliff-face (sub-aerial) processes like **rock falls** are also important here and work together with cliff-foot (sea) processes to create these headland features.

The Holderness cliffs

These boulder clay cliffs are formed from material left by ice sheets. They are retreating at an average rate of 1.8 metres per year (ten times the rate in the chalk cliffs). This results from the combined effects of land (cliff-face) processes and sea (cliff-foot) erosion.

On land, rainwater enters the clay and the weight of water causes material to slide seawards. This may occur along natural **slip planes** in the cliffs or the saturated clay may **slump** forwards onto the beach. Removal of vegetation, and increasing urbanisation can accelerate these effects. Cliff-top housing or hotels may make matters worse (see Fig. 3).

Fig. 3 Processes at work on the Holderness cliffs.

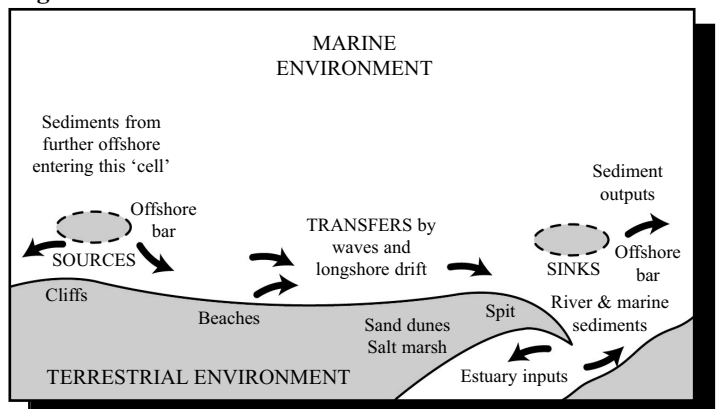
At the cliff-foot the fine clay is easily removed by waves and it is estimated that **longshore drift** carries half a million tonnes of sediment southwards each year in **suspension**. There is therefore little material left to form beaches and protect the cliffs from winter storms and high tides. At particular places along this coast strong **rip currents** may excavate '**ords**', or deep hollows, which can lead to catastrophic rates of cliff erosion. Recent examples have been documented at Great Cowden and Easington, with cliffs retreating locally at rates of over ten metres per year.

Building groynes to encourage beach deposition in one location may lead to erosion further along the coast. This may well be the case downdrift of holiday resorts like Hornsea, Mableton and Withernsea, where they have sought to protect their beaches from erosion.

Spurn Head

Sediments are deposited here where the winds, waves and river estuary have created a large but fragile **recurved spit**. Whilst the spit is currently growing at around 10cm each year winter storms periodically threaten to cut through the narrow neck and detach it from the mainland. Historical evidence suggests that changes in erosion and deposition happen in cycles. The spit is also the site of sand dune and saltmarsh ecosystems (see Geo Factsheet 119 on sand dunes and salt marshes).

Small sections of the coastline such as this running from Flamborough to the Humber estuary are referred to as **littoral cells**. They are open systems with inputs, transfers and outputs of water and sediment (see Fig. 4).

Fig. 4 The Holderness littoral cell.**What human factors play a part along this coast?**

There are three human influences at work here:

- **The presence of people along the coast** turns physical processes into hazards and threatens life and property. Increasing population levels due to retirement and the development of leisure and holiday facilities have occurred around Bridlington and Hornsea. Caravan parks are a particular feature of this area. The risks from erosion have been much publicised at Easington where the gas terminal has been under threat.
- **Interfering with natural processes** such as longshore drift or implementing unsuitable defence strategies can have adverse effects. The downdrift impacts of groynes at Hornsea, Mableton and Withernsea mean that sediment is being prevented from building beaches elsewhere. Rapid erosion rates at sites like Great Cowden may be due to this sediment starvation effect.
- Finally **global warming** and short-term changes in climate, an indirect human impact, are creating a rise in sea level and increasing storminess. Areas like Spurn Head and the shoreline of the Humber Estuary are at great risk in such conditions, from both coastal flooding and erosion.

Coastal management – What are the options?

Our thoughts about the suitability of different types of coastal management have changed over time. The full spectrum of options is listed in *Table 1*, together with some examples. **Hard engineering** (e.g. seawalls) with its high construction and maintenance costs is only used where there is no choice but to protect valuable buildings or business.

So-called **soft engineering** tries to cope with coastal processes using techniques like beach nourishment. It has lower costs and often some environmental benefits. Very few strategies are truly **sustainable** or future-proof, and currently tend to be small scale or only tried where land values are low.

Table 1 The spectrum of Coastal Management options.

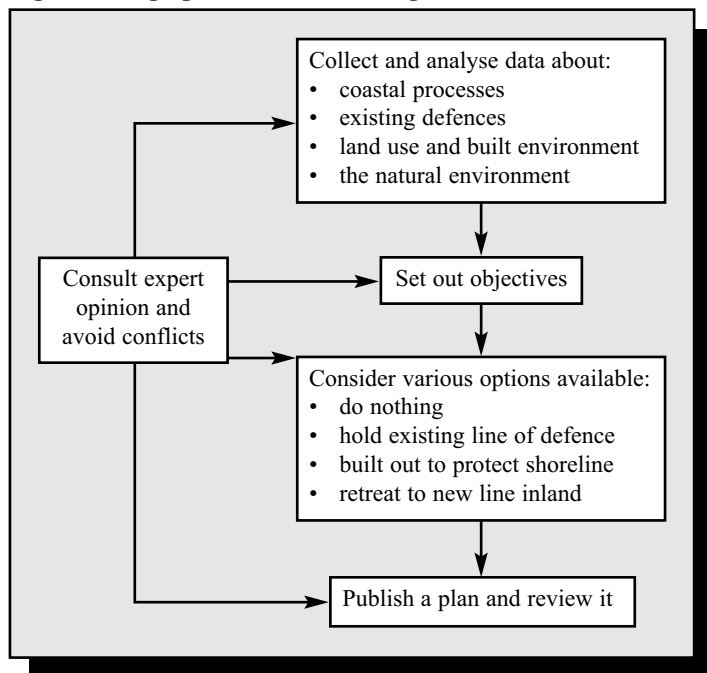
Strategy	Purpose or description	Strengths	Weaknesses	Yorkshire coast examples
HARD ENGINEERING	<i>This approach involves CONTROL. Traditionally (Victorian) used to overcome natural processes</i>			
1. Cliff-foot strategies	To protect the beach from sea erosion			
Sea walls	Massive, made of rocks or concrete, used to absorb waves. Some types can act as Baffles	Traditional solution to protect valuable resources, high-risk property or densely populated areas	Very costly, foundations easily undermined if built on beaches, or where LSD operates	Holiday resorts, e.g. Hornsea and Withernsea
Revetments	Massive, made of concrete, used to reflect rather than resist waves	As above though relatively cheaper	Costly and do not cope well with very strong waves	Easington gas terminal
Gabions	Wire cages holding smaller rocks	Cheaper version of above	Relatively lightweight and small scale solution	Skipsea
Groynes	Rock or wooden types, hold beach material threatened by LSD erosion	Low capital costs and repaired relatively easily	Need regular maintenance. Cause scour downdrift and have wider impacts	Hornsea, Withernsea and (famously) at Mappleton
Offshore bars (artificial reefs)	Reduce power of waves offshore	Mimic natural bars and reefs. Can be built of waste material	Possible ecological impacts and may not work at large scale	Only used as small scale pilot study so far
Rip-rap (rock armour)	Very large rocks in front of sea walls or cliffs to absorb waves	Effective and prevents large-scale undermining	No longer a relatively cheap option. May move in severe weather.	Withernsea and Easington
2. Cliff-face strategies	To reduce damage from sub-aerial erosion			
Cliff drainage	Removal of water prevents landslides and slumping	Cost effective	Drained cliffs can dry out and lead to collapse (rockfalls)	Small scale project at Easington
Cliff regrading	Lower the angle of cliffs to stabilise ground	Works on clay or loose rock where little else will	Retreat of cliff line uses up valuable land	Mappleton
SOFT ENGINEERING	<i>This approach involves ACCOMMODATION, working with natural processes</i>			
Beach nourishment	Sand pumped or transported to replace losses by LSD	Appears 'natural looking' process	Expensive and may soon erode. Possible ecological effects	Hornsea and Mappleton
'Do nothing'	Land no longer worth defending	Saves expenditure on defence	May allow problems to get worse.	Neck of Spurn head
'Red-lining' or zone management	Withdrawal or prevention of planning permission for new development	Cost effective in long term	Unpopular with residents and business. Politically tough	
SUSTAINABLE MANAGEMENT	<i>This approach involves ADJUSTMENT, working to secure the future of a coastline</i>			
'Managed retreat'	Incentives given through grants/buyouts to encourage re-location and 'set-back' schemes	Cost effective (as it saves construction costs) in longer term. May help reduce tides in estuary environments	Difficult to argue politically if residents involved	Suggested in 1994 for Hornsea but not implemented. Ideal for estuary around Sunk Island.
Coastal resilience (ecosystems)	Partial flooding allows salt marsh and wetlands to adjust to sea water. Allowing erosion in some places helps sand dunes develop in others	Very cost effective and environmentally valuable. Allows conservation of bird life especially	Loss of agriculturally productive land. Does this work on a large scale?	Plans to flood Sunk Island and plant in sand dunes south of Hornsea
Shoreline management plans	Detailed consultation getting local groups to work together to find best solution for each littoral sub-cell	Solutions tailored to specific places and particular needs of local community	May be seen as delaying tactic by those who want action now	Applied to coast further north in the Scarborough and Whitby areas

How are coastal management decisions made?

Decisions about how to defend each section of a coast can be taken using various types of assessments:

- **Cost-benefit analysis** considers the social and economic aspects of a strategy. The benefits of a scheme (new businesses or jobs and savings in lives and property) are divided by the costs of building and maintaining it.
- **Environmental impact assessments** try to assess the effects any strategy will have upon an area. It is especially important along coastlines as attractive scenery and ecosystems are valuable tourist assets.
- **Feasibility studies** look at the technical merits of a particular scheme and site. Is the engineering planned suited to the local geology or coastal processes?
- **Risk assessment** involves taking decisions in the light of the likely recurrence interval and what is at risk. Insurance and legal claims will make this an important consideration in the future.
- **Shoreline management plans** (see Table 1, page 3) try to decide upon the most appropriate scheme for each part of a littoral cell, in discussion with all parties. The mechanism is set out below (Fig. 5).

Fig. 5 Setting up a Shoreline Management Plan.



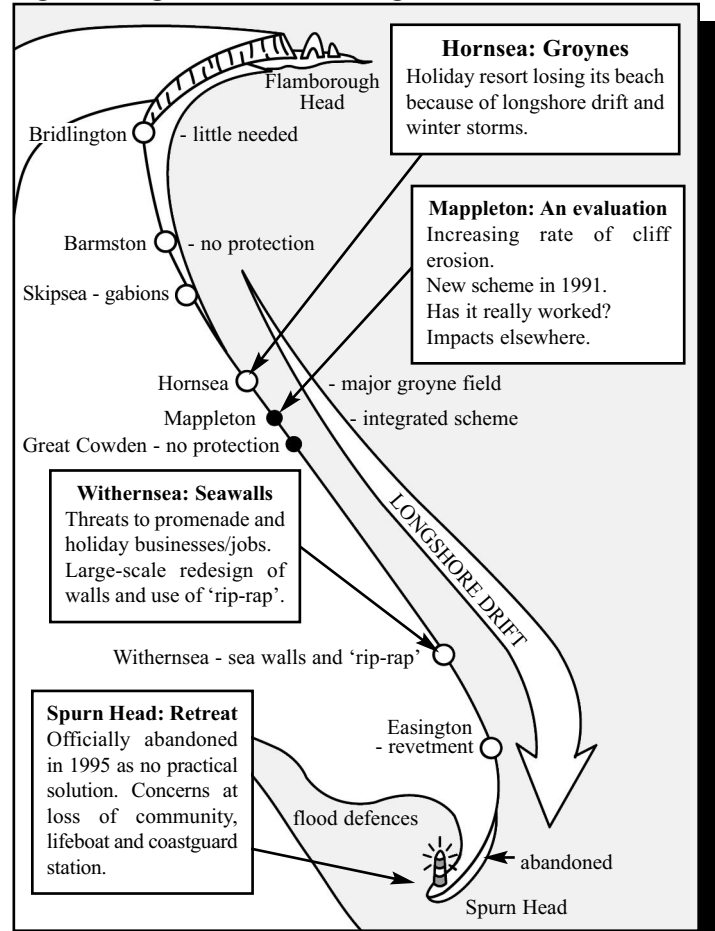
Defence strategies used along the Holderness coast (see Fig. 6):

In the northern part of the Holderness coast there is little need to protect the shore as much of the beach material is relatively stable, though removal of aggregate should be banned. Erosion increases southwards though there is still a balance between the rate of cliff erosion and sea removal. Beyond Hornsea the loss of sediment by longshore drift is considerable.

The coast at Skipsea has a series of **Gabion cages** built by the local landowner, though areas either side of his caravan and leisure site are still eroding.

Barmston today has little protection with some dumping of rock waste being the only defence.

Fig. 6 Management schemes along the Holderness coast.



Exam Hint: Practice drawing a very simple Holderness outline and then design three separate maps to mark on:

- physical features of erosion and deposition
- physical factors influencing coastal processes
- management strategies

Hornsea however is a holiday resort with a promenade and hotel frontage. Here the beach is of great importance both as a tourist feature and a means of protecting the seawall from wave erosion and winter flooding. **Groynes** have been repaired and new ones built at a cost of over £5.2 million. In addition steel ‘doors’ guard the entrance to the beach and the old seawall has been raised slightly. Sand dunes in the south beach are being planted with trees.

- **Advantages** – groynes seem locally effective, they are relatively low cost, they are acceptable visually and development of low-lying land has now been possible
- **Disadvantages** – this trapping of sand may have caused scour at Mappleton. Groynes rarely work on their own, maintenance is continual and groynes do not hold mud.

Withernsea is another resort further south. Here there are also groynes and a sea wall, though the emphasis has been on a more comprehensive approach. To prevent wave erosion a new wave **return wall** has been built. The wall is further protected by **rip-rap** or rock armour and some **beach nourishment**. The natural beach has all but disappeared leaving a wave-cut platform in the clay beneath. At £ 6.3 million this appears good value if it can halt the fall in local property prices.

- **Advantages** – this will hold the line, calm concerns of local residents and hoteliers and save seasonal jobs in the resort
- **Disadvantages** – costs have limited the length of the sea wall, the rocks have reduced access to the beach and views are restricted. There is a problem of wave noise.

Easington is the latest location to receive help. A **revetment** of rock armour has been placed at the foot of the cliffs to protect this natural gas terminal which handles 25% of North Sea production. This recent £4.5 million scheme remains untested. Though the site qualified for protection as 'being in the national interest', the scheme fails to protect the actual village despite a public enquiry. There are important SSSI sites to the south and there is considerable conflict with environmental groups.

Spurn Head is a rather different environment from the rest of the coastline though here again the problem is one of erosion. The management strategy here is perhaps best described as '**abandonment**'. Following successive winters when storms enabled the sea to wash over the neck of the spit, Holderness Borough Council decided that it could no longer afford to repair the damage. It was officially abandoned in 1995.

- **Advantages** – the growing annual costs of protection were saved, some evidence suggests that it may repair itself, and not all environmental groups were against it becoming an island. There may be no other long term solution.
- **Disadvantages** – the community of lifeboat men and coastguards and their families may have to move elsewhere. There may be loss of a 'heritage coast' site and an important bird habitat (Yorkshire Wildlife Trust)

In the **Humber estuary** the problem is one of flooding. The predicted rise in sea level threatens the half a million or so people who live less than two metres above current sea level. In addition the decreasing supplies of sediment from the Holderness cell and the Humber catchment are reducing the formation of new land. More sustainable solutions such as **managed retreat** near Sunk Island and selective breaching of saltmarsh embankments will be needed to reverse recent increases in erosion, salinity and pollution.

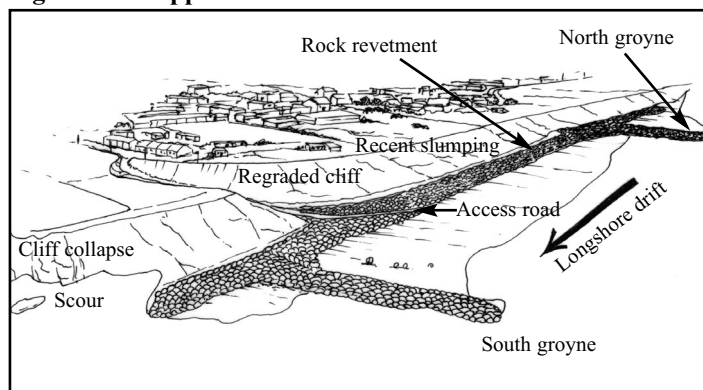
How successful are these schemes?

Mappleton provides a useful case study of the costs and benefits of coastal defence. Whilst this scheme was not traditional hard engineering it nevertheless raises a number of issues regarding the wisdom of interrupting the natural processes along a coastline.

Erosion rates at Mappleton have long been recorded, and in 1786 the village was 3.5 kms from the sea. By 1988 the sea was on its doorstep, access to the beach was impossible and houses in Cliff Road were quite literally falling into the sea. There was tremendous pressure from local residents to save the village, though in the end it was the threat to the coast road that won the day. In 1991 a scheme was implemented at a cost of £2.1 million supported by EU funding.

Features of the scheme included two rock groyne designed to trap beach sediment, a rock revetment to prevent erosion of the cliffs. The cliffs themselves were **re-graded** to reduce slumping and there was some **nourishment** of the beach to encourage deposition. In addition a new access road was built and a car park and toilets for visitors.

Fig. 7 The Mappleton sea defences.



In 2002 all is not well. The houses and the beach looks secure, but the regarded cliffs behind are showing early signs of slumping. Beyond the second groyne the large rocks are being undermined and the cliff face below the car park has begun to erode (**terminal scour**). More worrying is the very rapid erosion of beaches, cliffs and farm buildings at Great Cowden 3 km to the south which may be linked to Mappleton's growing beach. Evidence for this is not conclusive however.

Practice Exam Question

Below is a sketch of the coastline at Flamborough.



- Identify three of the (landforms) features of coastal erosion shown. (3 marks)
- Explain how each of these may have formed. (9 marks)
- Define the term 'cost-benefit analysis' and explain how it is used in decisions about coastal management. (8 marks)
- Answer one of these questions: (10 marks)
 - Either (1): For a named coastal management scheme which you have studied, evaluate its success.
 - Or (2): Referring to named examples, suggest what factors influence the choice of coastal defence strategy.

Answer Guide

- Wave-cut platform, sea stack, cave and cliff are obvious choices.
- Ensure that you include a full range of technical terms such as explanation of processes such as abrasion, hydraulic action and differential erosion.
- Look at benefits – especially the adjacent land use and environmental quality, and costs – especially economic costs of the types of defences.
- Either – use Mappleton framework as a guideline
Or – use the section on Coastal Management options.

Further Research

Bishop and Prosser (1997) Landform Systems. Collins.
Cook et al.(2000) Geography in Focus (chapter 11). Causeway Press.
Manuel et al.(1995) Coastal Conflicts. CUP.
Hordern, R. (1995) Geography of Yorkshire. Hodder.
Geo Active – Mappleton, unit 30, Mary Glasgow 1991
Geography Review articles – Philip Allan Updates
February 1993, September 1995, and March 2002
Geo Factsheets – Numbers 100 (Coastal management at Selsey), 119 (Geography of coastal sand dunes), 124 (Salt Marshes), 129 (Impact of structure and lithology on coastal landforms).
Edexcel Geography B GCSE - A decision-making Exercise based on Easington set in May 2000

Useful websites

www.learn.co.uk - lots of ideas inc. coastal erosion
www.geography.learnontheinternet.co.uk
www.bennett.karoo.net - excellent photo gallery
www.pml.ac.uk/lois/Education - basics plus photos

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