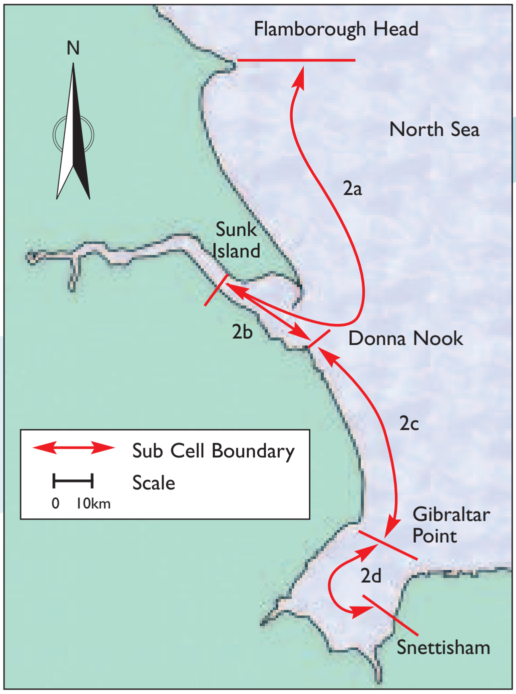
2 Coastal Processes

In attempting to understand the coastal processes underway along a particular stretch of coastline each of the numerous controlling factors that shape its ongoing development needs to be determined. To try and achieve this understanding for the whole of the UK's coast as a single unit would clearly be far too complex a task. To simplify things the UK's coastline has been split into a number of separate discrete units called Coastal Cells. The location and size of these cells is such that coastal processes within each are totally self-contained, i.e. changes that occur within a cell should not significantly affect the coastlines of adjacent cells.

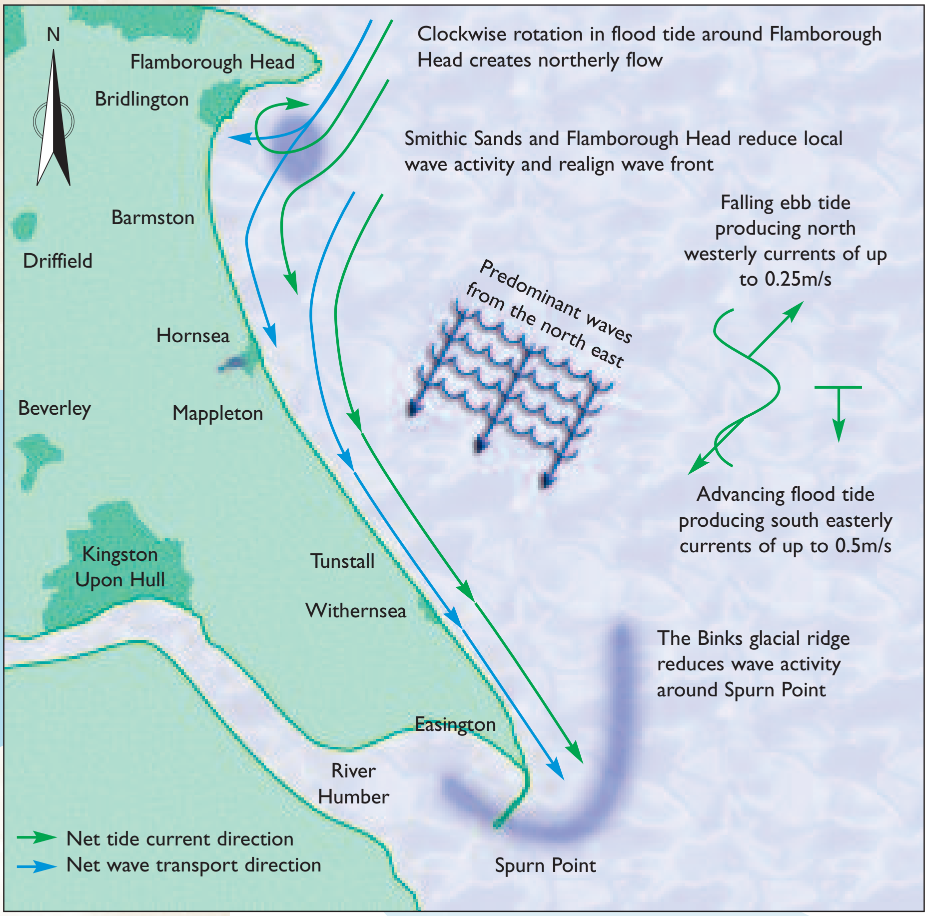
To reduce the size of these cells, mainly to allow for easier management as each normally contains several local authorities and a variety of coastal issues, they have been further sub divided into Sub-Cells. These sub cells are as self contained as possible but it is understood that they are not totally 'sediment tight'. The East Riding coastline has been designated as sub cell 2a, which extends from Flamborough Head to Sunk Island.

Now that these cells have been set up it becomes possible to describe the coastal processes within a particular region with some degree of confidence. Thus it also becomes possible to realistically model and anticipate the extent and likely impact that a coastal development or other such interruption may have upon the natural flow of beach sediment.



Erosion

As we have seen the rapid erosion of the East Riding coastline is not a new phenomenon, the people of this area have had to deal with its consequences since early settlements began to develop following the ice age. Documentary evidence records the loss of up to 14 villages so far since Roman times, all that now remains is a legacy of road names leading to long lost villages. With such a long history it might be expected that the processes that lead to erosion would be well understood, this is not the case however. Numerous studies have attempted to determine the causes and suggest solutions to this erosion problem but as yet no conclusive answer has been found.



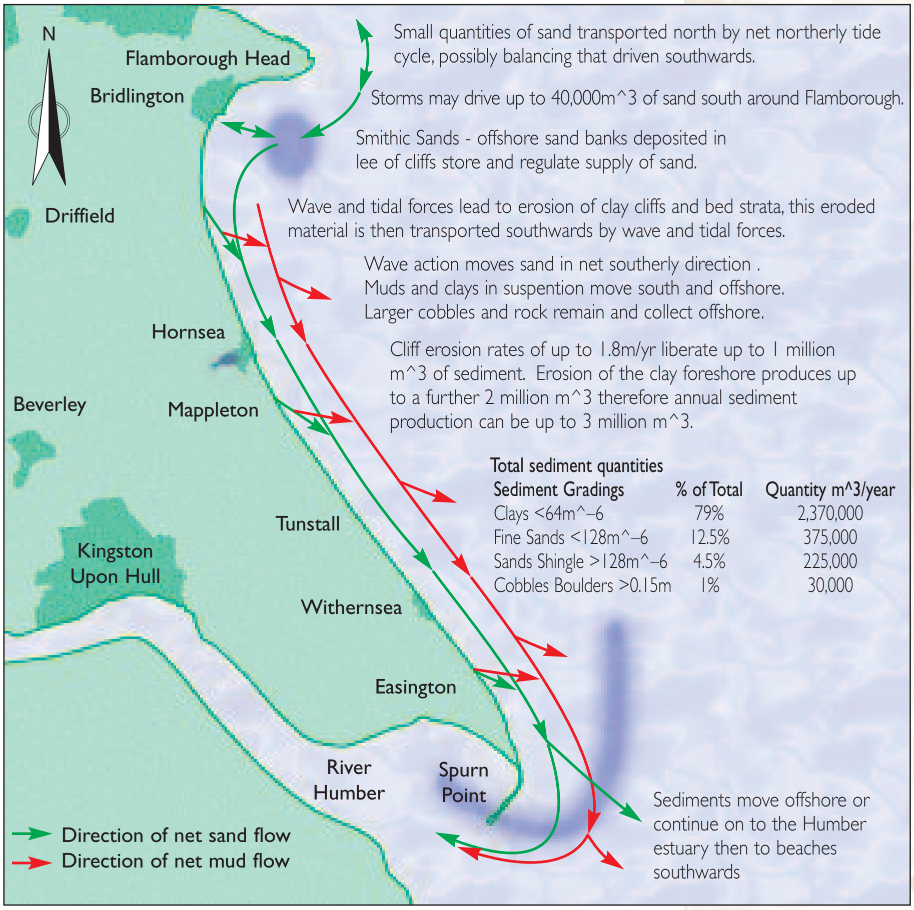
This situation is understandable however as it turns out that the coastal processes that lead to erosion are far more complex than may appear at first sight. The difficulty lies in the fact that cliff recession is not a static measurable quantity but a dynamic system driven by a random mix of wave and tidal forces.

To complicate things further the erosion that these forces generate is then in turn controlled by the sediment that it produces. This second system relies upon the formation and retention of a stable beach as in absorbing wave energy a beach protects the underlying clay strata and cliffs, thus preventing erosion. Ironically reducing erosion in this way slows down the production of sand, which then reduces beach levels leading to increased erosion. Thus cliff erosion is ultimately driven by storm seas and is governed by the cycle of beach growth and loss.

North Landing, Flamborough

If beach sand could be contained through effective beach control systems such as a groyne field or the development of a stable bay, cliff erosion would locally stop. Beach levels however tend to fluctuate due to interruptions in the southerly supply of beach sand or following storms that temporarily draw sand offshore. If this lowering of beach levels leads to exposure of the underlying clay surfaces then irreversible erosion will occur.

Since cliff erosion is tied to so many unpredictable quantities accurate prediction of future erosion is impossible. The only means available to forecast erosion is through analysis of historical records. If coastal processes remain unchanged then it can be assumed that past and future erosion rates at each location will remain fairly similar. So to foretell erosion it is first necessary to establish past erosion. The East Riding of Yorkshire began this exercise in 1951 and has since built up an extensive record of historical erosion data for the entire East Riding coastline. This erosion record is now updated every six months, and is becoming more accurate as the data set increases.

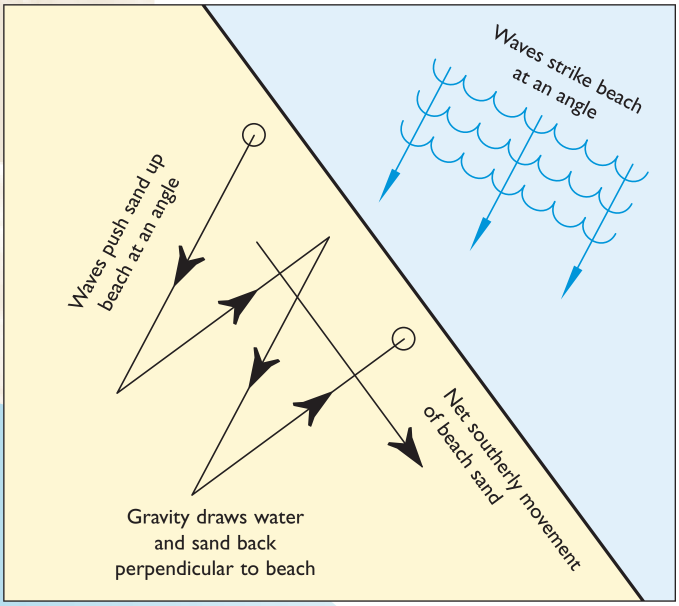


Long term control of erosion would require permanent protection of the cliff and foreshore clays. Simply defending the cliff toe through construction of a seawall or other such defence would still allow the foreshore to erode, ultimately undermining the structure. Maintaining a beach through effective sand control is therefore the aim when defending a frontage, the beach itself also provides a valuable amenity asset. Once established a beach can be contained through construction of a groyne field, the physical barrier that these structures provide prevents sand moving along and past the frontage. Storms can still draw sand directly seaward so beach sand is still lost and foreshore erosion does occur but at a much reduced rate.

Defending a frontage through the construction of a beach control system can however lead to problems immediately down-drift, as following their construction these structures promote the retention of sand which then reduces the supply down-drift. However this initial response is relatively short term as once the defences are filled, sand will overtop and bypass them, leading to the restoration of the drift system. In the longer term cyclic reductions in defended beach levels will recreate the post construction conditions as the defences attempt to restore sand levels, also in raising foreshore sand levels sand movement will tend to move offshore, the net effect is a destabilising of down drift sand supply.

Mechanics of Cliff Erosion

Beach levels fluctuate constantly in response to changing sediment supplies and sea conditions, however these changes in beach profile only become permanent following erosion of the underlying clay substrate as once lost this material cannot be regained. Erosion of these clay surfaces occurs whenever they are exposed either to the direct shearing force of moving water or the abrasive action of moving sand. Either way erosion only occurs when wave or tidal forces are of sufficient strength to transport sediments. In the near-shore zone waves which strike the beach at an angle dominate whereas in deeper water tidal currents take over, both producing a net southerly drift.



Movement of beach sand due to wave action

Beach sediments found along the East Riding coastline are derived from erosion of the cliffs and foreshore. This glacial till material is mainly composed of clays but it also contains a mixture of fine to course sands and a small amount of larger cobbles and rocks.

Once released by the sea these sediments are first sorted and then transported away by wave and tidal forces. Fine clays and muds that form the bulk of this material are put into suspension then rapidly carried south and offshore, most ending up within the Humber Estuary. Sands move more slowly southwards mainly under wave action and remain within the near-shore zone, forming the beaches that can be seen at the base of the cliffs. Larger cobbles and rocks tend to be drawn offshore where they remain and gather, as in deeper water waves are no longer capable of moving them. Over time a blanket of such material develops, helping to protect the underlying clay.

Clay Erosion

Of the four distinct zones identified on the profiles overleaf erosion of clay surface can be seen to be occurring in three of them:-

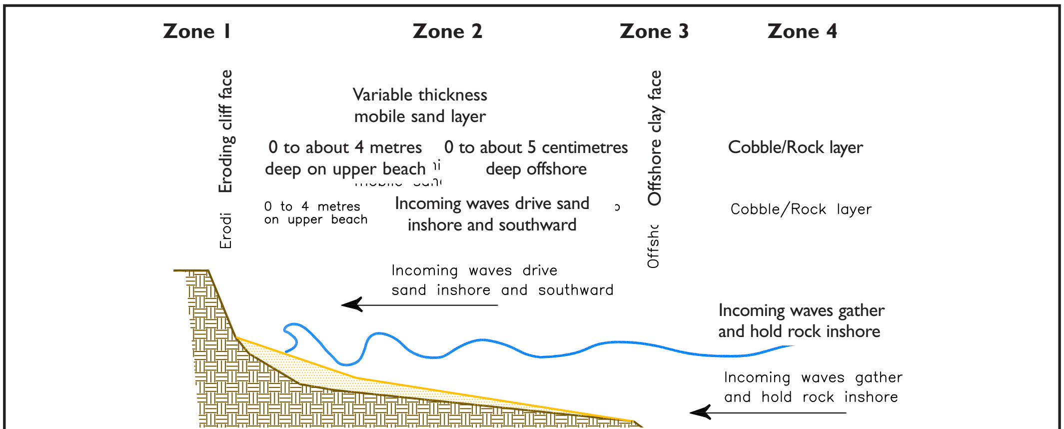
Zone 1 - The cliff face:

Cowden

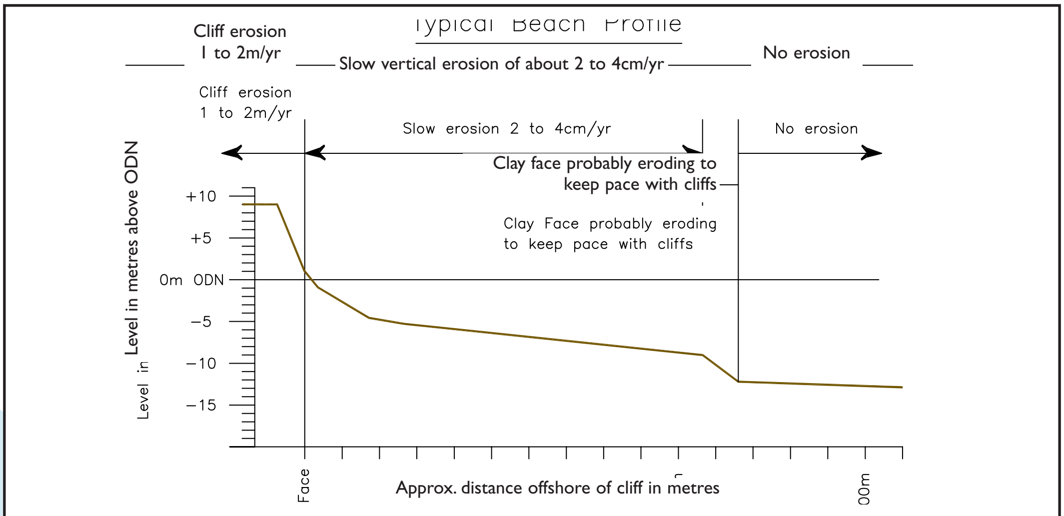
The most visible of the erosion zones, the cliff face undergoes erosion whenever the tide is high enough to allow wave action to strike its base. Wave impact and abrasion forces are then capable of removing material so steepening the cliff face to a point where it collapses spilling material onto the beach, this clay is then rapidly removed by subsequent tides. If beach levels are particularly low then a higher number of tides will reach the cliffs and more erosion will occur. This erosion state will usually continue until beach levels recover, which can be anything from months to several years. A period of relative calm will then follow until the cycle repeats again which may be in years or even decades time.

As unpredictable beach levels play such an important roll in controlling cliff erosion rates there is considerable variation in erosion over time and at each location. Opposite stable managed frontages erosion has been reduced to near zero, whereas on exposed stretches erosion rates have on occasion been consistently recorded at over a metre a month. The average rate however for the Holderness area south of Atwick has in the long term been fairly consistent at just over 1.7m/year.

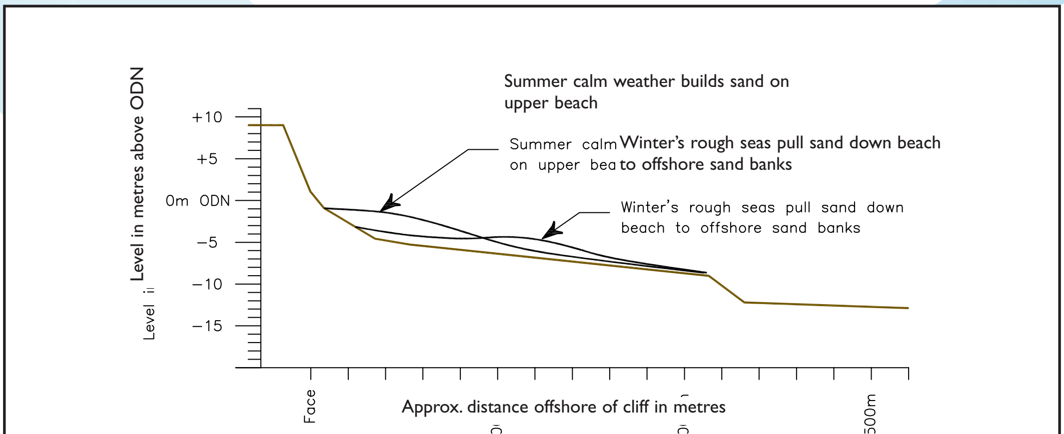
Tunstall



TYPICAL BEACH PROFILE



TYPICAL CLAY EROSION RATES



CHANGES IN BEACH PROFILE IN RESPONSE TO CHANGING CONDITIONS

Zone 2 - The near-shore zone:

Fronting the cliffs and covering the underlying clay is a wave driven highly mobile layer of sand and shingle, that can be anything from several metres deep to entirely absent, depending upon sediment supply and wave conditions. As erosion of the clay only happens when it is exposed to wave and tidal forces the depth and profile of this beach determines where and when erosion can occur.

Normally a typical beach will develop and dissipate on a steady cycle lasting several years as littoral transport drives waves of sand southwards, this allows intermittent but steady erosion of the foreshore. Storm conditions can however cause rapid changes in beach profile by drawing sand offshore, possibly stripping a beach of all its sand in a single tide. During this time continued rough seas can cause rapid erosion of the newly exposed clay. Recovery from such an event can then take several months as calmer seas return sand to the upper beach. As can be seen opposite these changes in beach profile can be seen as a seasonal beach response, this accounts for the increased erosion rates recorded over the winter months.

Further offshore in deeper water wave forces reduce in power so the sand layer tends to be more stable, however it is often only a few centimetres thick. Erosion over this area occurs as a result of the steady movement of this thin sand layer as it leads to abrasion of the under lying clay surface.

Few measurements have been taken of the long-term erosion rate of this clay strata however it can be assumed that since the overall profile remains fairly constant then erosion of the foreshore matches cliff erosion rates. This gives an erosion rate lowering of between 2 to 4 centimetres per year.

Skipsea

Zone 3 - The offshore clay face:

A feature of the Holderness coastline that has been observed along most of its length during hydro-graphic seabed surveys is the presence of an offshore submerged clay cliff face that can be up to several metres high. It has been suggested that this cliff may be a fossil cliff line dating to the early Holocene times.

This cliff forms the boundary between the eroding inshore zone and the stable offshore seabed. Due to its inaccessibility few if any measurements of the erosion of this face have been made. Evidence suggests however that it is eroding at approximately the same rate of retreat as the main cliff line i.e. approximately 1.7m/year.

Zone 4 - The offshore seabed:

Offshore of these eroding surfaces the seabed is protected by a thin rocky layer formed by the collecting together through onshore wave forces, of larger eroded materials. In isolation waves are able to move quite large obstacles however when grouped together they act as one and become immobile. Over time the thickening of this layer will provide protection to the underlying clay preventing any further lowering. Thus the depth, location and likely-hood of the formation of this layer depends upon the quantity and size of rock contained within the original clay body.

The total erosion volume is therefore the sum of these onshore and offshore volumes. Erosion of the cliff is readily measurable and has been calculated to be just under one million metres cubed per year. Estimates for the unseen offshore erosion vary but suggest a volume of twice that of the cliff erosion, giving a total of approximately 3 million metres cubed per year.

North Landing, Flamborough