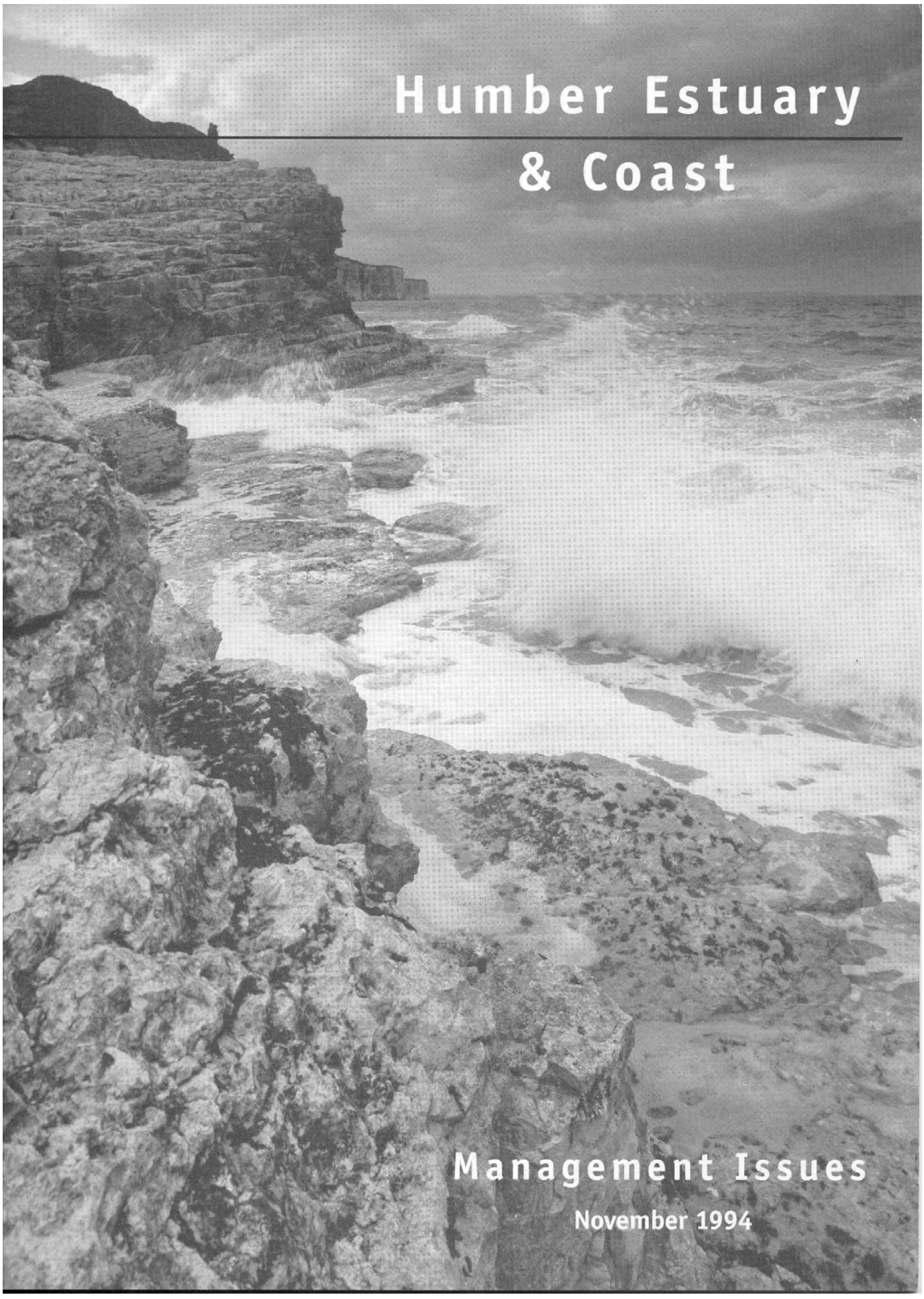

Humber Estuary & Coast

Management Issues

November 1994

Contents

This report provides guidance to assist coastal planners, managers, engineers and environmental scientists involved in the management of the Humberside coastline.

An accompanying report - Humber Estuary and Coast - provides an overview of the current knowledge on coastal processes and landforms in the Humberside and Lincolnshire coastal zone.

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Foreword

The coast of Humberside presents some of the most difficult and challenging problems of coastal management in this country. Erosion and flooding, water quality and conservation are familiar terms to those associated with this coast and estuary; effective management of the coast demands, however, a detailed knowledge of the mechanisms which control these issues.

The present report, commissioned by Humberside County Council's Environment Sub-Committee sets out to provide an examination of management issues. A companion volume – Humber Estuary and Coast – reviews the physical background to the coast and its natural processes, providing background material upon which this report is based.

The scope of the two reports differ slightly. Coastal processes are not limited by administrative areas and consequently, in the companion volume, a wide view is adopted in which the Humberside coast and estuary is considered together with its adjacent coastal areas and the interactions with the North Sea. In this present report, however, the focus is on the Humberside coast and its management, although the implications for other coastal areas of the management decisions taken within the county are emphasised.

The report is not intended to act as a detailed manual for effective coastal management, but rather as a general guide, for coastal planners, managers, engineers and environmental scientists, to the problems and policies on the Humberside coast.

Introduction

The Humber coast and estuary extends, for administrative purposes, from Reighton to the north of Flamborough Head to Humberston south of Cleethorpes, although its physical boundaries are far more extensive and less well defined. This coastal area includes a wide variety of scenery – beaches, cliffs, dunes, mudflats and marshes – but possesses, nevertheless, a unity both of character and process which form the basis of the discussion in this report.

South of Flamborough Head, the character of the coast changes abruptly. The rocky coves and bays of the North Yorkshire coast and the dramatic cliffs of Flamborough with their wealth of shoreline details, give way to the much simpler shape of Holderness, whose long smooth shore stretches for 40km from Bridlington to Spurn without any interruption. The low shores of the Humber estuary appear to continue this simplicity, with mudflats and sea walls stretching to the horizon. And yet this apparently simple coastline provides some of the most complex process and management problems of any coast in Britain or, indeed, the world. The problems and complexities arise from three main causes; these are set out below.

- Shoreline units in the Humber coast and estuary are large. Interactions between components of the coast are not contained within small bays, as in North Yorkshire for example, but occur over considerable distances and are driven by correspondingly powerful forces whose mechanisms we are only just beginning to appreciate.

- This coast is of enormous ecological significance: much of its area is protected by national and international conservation legislation. There are extensive Sites of Special Scientific Interest (SSSIs), National and Local Nature Reserves (NNRs and LNRs) Ramsar and Special Protection Areas (SPAs) and a Marine Sensitive Area (MSA).

- Industrial, urban and agricultural use of this coast is of the greatest importance to the regional and national economy leading to major changes in the configuration of the shoreline in the past and attempts to compromise between the impact of human needs and the natural evolution of the coastline.

The interdependence of these three issues provides the complexity of this coast and the need for careful and informed management. The coastal zone provides important locational advantages both for humans and wildlife. But these very attractions bring with them certain risks – from sudden storms, flooding, erosion and deposition. In particular, the coast is not a static area on which development can take place unhindered, but is constantly changing in response to the enormous power of the sea. We must recognise its dynamic nature if we are to manage the coastal environment both for our own use and for the wildlife which we value so highly.

In the past we have tried to manage the coast by resisting the power of the sea – with sea defences of various kinds. Only recently have we begun to realise that not only is this extremely costly but also that in many cases it merely increases the risks both to ourselves and our ecological heritage.

We are now entering a new phase of coastal management in which we attempt to understand and work with the natural forces of the coast rather than to resist them. This report summarises the present state of our knowledge about the Humber coast and estuary and presents some management guidelines for the future which may assist with this new approach.

Policies

Coastal and shoreline management has undergone a major change in recent years in this country. The publication of several documents marked this dramatic change. First the House of Commons Environment Committee's report on *Coastal Zone Protection and Planning* posed important questions concerning our past management practices. Next the publication of PPG 20 *Coastal Planning* set some basic guidelines for planners with responsibility for the coast.

Two MAFF reports followed: *Coastal Defence and the Environment* in which the need to work with rather than against the natural forces at the coast was emphasised, and the *Strategy for Flood and Coastal Defence*. In stressing the importance of taking a strategic approach to coastal management, this latter document outlined the need for detailed Shoreline Management Plans (SMPs) for each section of the coastline and for Catchment Management Plans (CMPs) for estuaries. These SMPs are to be developed by coastal groups, comprising the maritime operating authority (normally the local maritime council) and other bodies with coastal responsibility (including, amongst others, the National Rivers Authority (NRA)). These SMPs are presently under review along many areas of the English coastline and represent the first stage in the practical implementation of the new strategic and environmentally aware approach to coastal management in this country.

These documents established a change in the national approach to coastal management and have given rise to changes in regional and local approaches to these issues. In the case of the Humber coast and estuary, the sections on the coastal environment (EN5–EN8) in the Consultation Draft of the *Replacement Humberside Structure Plan* emphasise the need to control development which may adversely affect the natural coastal processes or damage wildlife habitats. More significantly, however, the Structure Plan outlines the manner in which such an environmentally sensitive approach may have important economic repercussions for our own use of the coast and estuary. It introduces, for example, the concept of sustainable use in which the achievement of a balance between the needs for development and the needs of the environment may actually reduce the necessity for costly engineering intervention in the future.

The importance of the natural coastal processes are stressed in all of the above documents. Disruption of these processes, by any future development, should be avoided if at all possible – not only to maintain the natural coastal character or its associated wildlife, but because the most permanent and inexpensive method of reducing risks to our own use of the coast is by maintaining and enhancing its natural trend towards an equilibrium. The Humberside Structure Plan, for example, argues that interference with the natural processes of saltmarshes or mudflats can actually increase the risks of flooding on the lowlands bordering the Humber estuary, since these coastal features act as natural flood defences.

The impact of this new approach to coastal management can also be seen in the approach taken by the National Rivers Authority to the provision of flood defence in the Humber estuary. In their *Humber Estuary Tidal Defence Strategy*, the NRA are considering a range of alternatives to the problem posed by sea level rise in the estuary which may maintain or even restore the natural processes rather than merely oppose these with ever higher flood embankments.

One of the essential features of the new approach to coastal management is that a broad, strategic view is taken of the coast before any more detailed plans are initiated. The production of a Shoreline Management Plan for the Humber coast and estuary should provide one element of such a strategic overview and the coastal group responsible for its initiation has already been constituted (The Humber

Estuary Coastal Authorities Group or HECAG). One of the pressing issues facing HECAG in its preparations for the SMP is defining the coastal area which it should encompass. This is an issue which will be discussed later in the report when the physical boundaries of the coastal processes are reviewed but the problem necessarily presents itself at the outset.

One major task of any strategic view of a coast is to define the physical and administrative boundaries within which it should apply. Unfortunately, however, these boundaries are set prior to any strategic plan thus pre-empting any further discussion. This circular argument was recognised by MAFF who commissioned a review of coastal cells along the English and Welsh coasts. A coastal cell is defined as an area of coast within which sediment movement is contained. Thus little or no movement of sand or shingle will take place across its boundaries. Unfortunately, the coastal cell for the Humber coast and estuary area, as defined by this review, explicitly omits all of the Humber estuary west of a line between Sunk Island and Immingham. If upheld, this boundary would appear to preclude the development of a strategic plan for this coast since it is clear that the Humber is an integral part of the coastal system as a whole and indeed may even be considered to be the most important part of that whole.

The MAFF *Strategy for Flood and Coastal Defence* does provide for the strategic planning of estuaries within the framework of the Catchment Management Plans. The Catchment Management Plan for the Humber has recently been prepared as a consultative document by the NRA. Although the outer boundary of the Humber, as defined for the CMP, is drawn between Spurn Point and Donna Nook and thus precludes any integration between coast and estuary it is significant that the plan notes the need:

> To improve our knowledge of the relationship between sedimentary processes, rising sea levels and the natural boundaries of the Estuary. (NRA, 1994. p.ii)

It also raises a number of key Issues, one of which (Issue 12) is stated as follows:

> Coastal erosion along the Holderness Coast is linked to the overall sediment balance in the Humber Estuary. Demands to provide coastal protection along that coastline may conflict with the flood defence and environmental needs of the Estuary. (NRA, 1994. p.69)

This explicit statement of the importance of sediment movement between Holderness and the Humber, stresses the need for a strategic overview which includes both coast and estuary. Neither the SMP nor the CMP approach advocated in the MAFF Strategy for Flood and Coastal Defence consider this basic interaction which is central to both the economic and ecological use of the coast.

There are many reasons why the Humber and its adjoining coast should be considered as part of a single unit and many of these are reviewed later in this report. It is already apparent, however, that the implementation of the new approach to coastal management in this country should not be flawed at the outset by the existence of administrative boundaries which do not correspond with natural process divisions. The purpose of this report is to review the available evidence for these processes so that policy decisions such as these may be taken which will work with, rather than against the forces of nature.

Processes and Problems

COASTAL RISKS AND STABILITY

The coast is not merely the line dividing the sea from the land. Rather it is an area over which the energy of the sea is expended so that it acts as the buffer zone between land and sea. This concept of energy dissipation is central to any coastal management and one which is emphasised in this report. If all of the tidal or wave energy is not dissipated in the shore zone then long term erosion of the coast may occur. This results in a wider shore zone with greater capacity for energy expenditure so that eventually erosion will cease naturally. Such a process may take a considerable time – at least as measured by human time standards – and in many cases the history of coastal evolution has been so short as to preclude the development of such a stable form.

This is especially true of the Humber coast and estuary. The coast of Holderness, Lincolnshire and most of the Humber did not exist before the last ice age but is built from the debris carried here by the last glacier advances – thus most of the area is less than 12,000 years old. The coast itself is even younger. The last ice age lowered sea levels by over 100m and, subsequently, our present sea level was not attained until less than 6,000 years ago when the open coast and the Humber itself were formed. Since then there has been continuous change in sea level mainly due to tectonic movements of the land relative to the sea so that the coast has had continually to adjust thus preventing any long term stability.

As a consequence, the Humber and its coast have not yet evolved the stable form which may be expected eventually to develop. Instead they continue to erode in places and to flood and accrete in others, changes which can therefore be regarded not as short term problems but as long term solutions.

Despite this long term geological goal, we may be excused if, in our continued use of this coast we regard erosion and flooding as risks rather than benefits. Our response to such risks has always been to prevent them as far as we are able, by building a variety of coastal defence works. Thus the Humber is almost entirely lined with flood embankments while the Holderness and Lincolnshire coasts have extensive lengths of coastal defences.

Such defences, although they may provide short term reduction in the risks involved in a coastal location, prevent the long term development of a naturally stable coast. They may also actually increase the medium term risks, as when flood embankments are built which prevent flooding of the low lying land beside the estuary. This means that natural accretion cannot take place on these areas, so that, as sea level rises outside the embankment, the land inside becomes relatively lower and so the risk of flooding increases.

This is particularly marked in the Humber estuary where reclamation began as early as the 15th century, so that much of the Humber lowlands now lie between 1m and 2m below the present high water mark. Over 0.5 million people now live in these high risk areas – which include most of the city of Hull – this risk being further exacerbated by the attraction that these flat, extensive, reclaimed areas have for further urban and industrial development.

In order to reduce these risks it is essential that we review our policies for coastal defence. In particular we should reconsider the way in which sediments (muds, sands and shingle) are produced by erosion and carried to accreting areas. This process not only benefits the receiving areas by raising the land levels but also the contributing areas which gradually develop natural,

stable forms which can resist the power of the sea without the need for costly and transient defences.

Consequently, for a relatively immature coastline such as the Humber and its adjacent shorelines, sediment transport may be seen as the most crucial of all the coastal processes, leading to the short term reduction in risk from flooding and the long term development of a stable coast. Any interference with the sediment transport processes, such as those associated with coastal defences, must be seen as potentially damaging to the coastal system over a very wide area, an outcome of which coastal management must be aware.

CELLS AND SEDIMENTS

Defining the physical boundaries of a coastal area is a difficult, some would say impossible, task. The driving force at the coast is the energy from the tides and waves of the sea, forces which do not act within boundaries. Nevertheless, as discussed above, administrative boundaries for areas of the English coast have been defined using the concept of coastal cells.

The definition of a coastal sediment cell is 'based on the idea that interruptions to the movement of sand or shingle along the beaches or near shore sea bed within one cell should not significantly affect beaches in an adjacent cell.' (HR Wallingford, 1993. p. 2). Boundaries to cells as defined by HR Wallingford are of two types:

- littoral drift divides : a point, usually a headland, on each side of which sediment moves in opposite directions;

- sediment sinks : a point or area where sediment transport pathways meet and consequently sediment accumulates.

HR Wallinford emphasise that their definition of cells is based only on the movement of sand and shingle; muds are not included since these are transported by entirely different processes to sand and shingle. Consequently estuarine areas, characterised by fine sediment movements, are not included in their review.

The division of cells into component sub-cells also poses some problems. Where major cells are too large they may 'contain too many local authorities for a single group to manage. Within these major cells therefore, a number of sub-cells have been defined' (HR Wallingford, 1993. p. 3). This appears to mean that the division of cells outlined in the report, and which it must be emphasised are used as the basis for all strategic coastal planning in this country, may be based upon *a priori* administrative considerations rather than the natural processes involved.

The coast between Flamborough and Gibraltar Point is part of Cell No 2 as defined by HR Wallingford (1993). It consists of four sub-cells, three of which occur between Flamborough and Gibraltar Point: Cell 2a extends between Flamborough Head and Sunk Island; Cell 2b between Immingham and Donna Nook and Cell 2c between Donna Nook and Gibraltar Point.

In the case of the Humber and its adjacent coasts all of the above problems are encountered. The exclusion of the estuary, the division into sub-cells possibly for administrative purposes, the omission of any consideration of fine sediments which form the largest part of the sediment load

along the Humber coast, all suggest serious flaws in the analysis and that a division of the coast along the lines proposed should be questioned.

A brief review is given below of the main attributes of the sediment transport pattern in the area – including the transport of fine grained muds.

FILEY AND BRIDLINGTON

Although Filey Bay is not included in the Holderness sediment cell (HR Wallingford, 1993) there is nevertheless some evidence that sand transport takes place between Bridlington Bay and Filey Bay around Flamborough Head. In summary it appears that extreme storm events from the north or north east are capable of moving sand from the sea bed in Filey Bay to the Smithic Sand in Bridlington Bay. The Smithic Sand lies at the centre of a marked tidal gyre in Bridlington Bay and probably receives sand derived from the erosion of Holderness cliffs as well as from Filey Bay. The tidal gyre in Bridlington Bay runs clockwise on the flood tide and anticlockwise in the ebb with a marked ebb tide residual current on spring tides. This residual current causes a very small northerly movement of sand from the Smithic into Filey but, since it is a regular spring tide occurrence, appears to return most of the material moved south from Filey during the large intermittent storm events.

The outcome is that a balance exists between Filey and Bridlington Bay sands with a time period of <50years. Any interference with these sand bodies in either bay could therefore be expected to have a serious effect on the other. Proposals such as that made recently for aggregate extraction from these bays must therefore be very critically reviewed.

The importance of the Smithic Sand to Bridlington is fundamental; not only does it act as an offshore breakwater, upon which the largest north-easterly waves break before they reach the shore, but the sands of the Bridlington beaches are an integral part of the Smithic. Any deterioration in the offshore sands would almost inevitably mean a deterioration in the volume of sand at the shore – leading to erosion as well as loss of amenity which is crucial to Bridlington's economy.

HOLDERNESS AND THE HUMBER

The soft glacial till cliffs of Holderness are eroding at a rapid rate. The reasons for such erosion are, however, less to do with the soft sediment of the cliff than with the lack of beach material and the poorly developed nearshore zone. Retreat of the cliff line here is matched by progressive lowering of the sea bed to give a wide shallow platform stretching several kilometres seaward. Eventually this platform will be so extensive that most of the incident wave energy will be expended here rather than at the cliff so that erosion rates will decrease or even halt. Since this may take several thousand years, it cannot form part of any management plan for this coast – yet it is important to recognise that the natural erosional processes here are neither random nor pernicious.

The process of cliff retreat along the Holderness coast is more complex than appears at first sight. Mass failures of the cliff are triggered by wave action at the cliff toe. Such failures may be 50 to 100m wide and up to 30m deep giving a scalloped edge to the cliff. The retreat rate varies temporarily, a large failure may produce a 10m retreat in one year but no further retreat will then occur for 3 or 4 years – giving a periodicity of 4 or 5 years in total. This means that attempts to measure erosion rates over periods less than 10 years, that is over 2 cycles, can be extremely misleading, resulting in massive over- or under-estimates of the long term retreat rate which is remarkably constant at 1.8m per year.

Sediment source	Annual Total (m^3x 10^6)	Sands/shingle (m^3x 10^6)	Muds (m^3x 10^6)
Cliff erosion	1.0	0.28	0.72
Nearshore erosion	2.5	0.70	1.80
Total	3.5	0.98	2.52

Table 1: Sediment output from the Holderness erosion.

The sands and muds released by the erosion of the cliff and, perhaps even more important, from the nearshore seabed (see Table 1), form an important part of the sediment budget of the local and regional coastline and may have even wider importance to the southern North Sea. Three issues may be highlighted here.

• The beaches of Holderness are thin veneers covering the underlying glacial tills. The beaches do not increase in volume since, south of Hornsea, a balance exists between the input of sand by erosion and the removal of the sand by wave action, principally from the north east, which drives sands south. To the north of Hornsea the protection of the shore from north easterly waves afforded by Flamborough Head, means that sands tend to move north into the Smithic Sand as noted above. Any inhibition of the output of sand from coastal erosion disturbs these balances and results in a decrease in beach volume. In turn the thinner beaches allow wave action, and therefore the erosion rate, to increase so that eventually the sediment balance is restored.

• The sediment balance on the Holderness coast is maintained by the action of storm waves from the north east. These waves approach the coast obliquely, the angle between wave crest and shore being critical for the sediment transport rate. A clockwise movement would increase the transport and erosion rate while an anti-clockwise swing would decrease both of these. Random changes in the orientation of the shore are quickly eradicated by changes in the sediment balance, but any permanent change in the orientation of the coastline, such as that caused by the introduction of hard sea defences as at Hornsea, Mappleton and Withernsea, means that the sediment balance is disturbed.

• Hard defences can have two long term effects: first, although erosion is halted at the defence itself, several kilometres to the north erosion continues as before. This causes an anti-clockwise re-orientation of the coast, sand transport is reduced and sand accumulates immediately north of the defences – as can be seen north of Hornsea. Second, the accumulation of sand north of the defences starves the beaches to the south causing an increase in erosion there. Where a stretch of coast lies between two hard defences, as between Hornsea and Mappleton, the sand accumulation north of the southerly defence and erosion to the south of the other leads to the formation of an asymmetric bay which eventually will become so deep as to prevent further erosion – a stable bay. Preliminary calculations suggest that such a bay north of Mappleton will become stable when it is 700m deep and will take 250 years to develop. A similar bay was beginning to form between Hornsea and Withernsea prior to the construction of the Mappleton defences and it is assumed that this will now resume its development south of these new defences.

The fine grained sediments from the Holderness cliff and sea bed erosion are not transported along the beaches as are the sands and shingle but are moved in suspension. Research is presently under way which is intended to chart the precise movement of this material but it is clear that its dominant movement is south towards the Humber. A large proportion may enter the estuary and become deposited there. The remainder is moved south and east into the North Sea where the transport pathway is towards the Dutch and German coast.

The sediment budget of the North Sea is dominated by this input of fine grained material from Holderness. At any one time approximately 30 million m^3 of mud are held in suspension in the southern North Sea. Each year between 15 and 20 million m^3 of this material are deposited on the coasts and nearshore areas of Eastern England and in the Wadden Sea – an output which must be balanced by inputs from other sources. These sources are principally from the North Atlantic and the English Channel and from erosion within the North Sea itself. A very small proportion comes from rivers such as the Rhine, Elbe and Thames. The output of 2.52 million m^3 of fine grained muds from Holderness therefore represent between 12.6% and 16.8% of the entire suspended sediment flux of the southern North Sea.

The Holderness coastal and associated seabed erosion is consequently of crucial importance to adjacent coastlines and to the wider area of the southern North Sea. Management plans for the coast must take this wide interaction into account when considering any future development for Holderness.

THE HUMBER ESTUARY

The outer Humber estuary, east of the Humber Bridge, has developed since the last glaciation and is consequently an extremely immature landform. This means that it is still in the process of development, a process which entails the accumulation of large amounts of sediment so that an efficient estuarine form may evolve in which tidal range is reduced inland. Failure to achieve such an equilibrium form would mean higher tidal ranges than necessary and consequently an increased flood risk for those who live or work on the low lying hinterland.

Sediment accumulation in the Humber is also necessary due to the rise in sea level which is presently occurring and which is predicted to increase over the ensuing decades. Present sea level rise is calculated at 3.5mm per year and is mainly caused by the tectonic sinking of the land surface. Global warming may increase this rate to between 6mm and 15mm a year by 2030 AD depending on which of the many current predictions are accepted. As a consequence, in order to maintain its present channel form the Humber must accumulate over its entire bed area between 4mm and 15mm a year of muds and sands if present levels of flood and storm risk are not to increase. This would mean that a minimum of 20 million m^3 and a maximum of 90 million m^3 per year of sediment accumulation must take place in the Humber. Any short fall on these massive figures will mean that channel depths will increase relative to the tidal frame, wave activity will increase in the deeper water and tidal range will increase and progress further inland along the estuary.

The history of sediment accumulation in the Humber suggests that such a response to sea level rise will not be possible. There are two reasons for this: first, insufficient sediment is available from natural sources to meet such a massive requirement. Second, the natural sediment sources have been interrupted over the past 50 - 100 years so reducing the inputs into the estuary to levels which do not meet present needs quite apart from the future increased demands.

Sediment accumulation in the Humber at the beginning of the present century has been estimated using the excellent series of navigation charts for the estuary. These indicate that approximately 6 million m^3 of muds and sands were laid down in the inter-tidal and sub-tidal channel each year. The sources of such sediment are shown in Table 2. While these data indicate only the volumes of sediment potentially available for Humber sedimentation and not the actual deposited volumes, it is apparent that the Holderness coast provides a potential 45% of the total available sediment for the estuary.

Such calculations reinforce the critical role of the Holderness coastal erosion in the development of the Humber and emphasise the need for continued sediment outputs from that source if increased risk from flooding and erosion are to be ameliorated.

Sediment source	Sand $m^3 \times 10^6\ yr^{-1}$	Silt/Clays $m^3 \times 10^6\ yr^{-1}$	All sizes $m^3 \times 10^6\ yr^{-1}$
North Sea	?	4.00	4.00
Holderness	0.98	2.52	3.50
Fluvial (Ouse /Trent)	?	0.20	0.20
Total	0.98	6.72	7.70

Table 2: Estimated amounts of sediment input into the Humber from three major sources.

These figures indicate that, at the beginning of the present century, the Humber estuary was characterised by massive and continuous accumulations of sediment. Analysis of the most recent charts suggest that this level of sediment accumulation has now fallen so that in the past decade (1980-90) zero accumulation has occurred in the estuary and that a net loss has occurred in the critical inter-tidal zone.

Although the reasons for this decline in sedimentation rate have not been determined, there are three possible causes:

- reduction in the background sedimentation from the North Sea;
- reduction in sediment output from Holderness cliffs and nearshore zone or
- interruption of the sediment transport pathways into the estuary, perhaps by dredging activity at the mouth.

Changes in the background sediment supply from the North Sea are probably outside the control of local, regional or even national management, but nevertheless should be investigated as a matter of the greatest importance. The other two possible causes are within the control of local and regional administration. Loss of sediment from the Holderness coast due to defence construction over the past century is not considered to be significant as yet although this can be expected to become more important as the stable bays between Hornsea, Mappleton and Withernsea develop – a rate of loss which will be exacerbated by any additional defences. The possibility of loss of sediment due to the

interruption of transport pathways at the mouth of the estuary by dredging activity, suggested here only as an hypothesis, should be investigated further.

Even if the cause of the present shortfall in sedimentation to the Humber is identified and corrected the long term prognosis presented here is a serious one. If sedimentation levels are increased to those which apparently obtained in the last century – 6 million m^3 per year – then this would still leave a short fall of 14 million m^3 per year given the minimum sea level increase over the next 50 years. The consequences of such a short fall have been outlined above and do not need repeating here. What is clear is that a radical change in the management policy of the Humber is necessary if such an increase in flood risk is to be prevented.

Managed retreat

One alternative strategy that could be adopted for the future management of the Humber involves a reconsideration of the effect of past management practices. In particular the extensive reclamation which has taken place of Humber inter-tidal areas since the 15th Century may be considered to have had a significant effect on the hydrodynamics of the estuary and could be responsible for the present enormous sediment demands in the estuary.

Reclamation of estuary inter-tidal areas removes large shallow areas from the tidal channel. The effect is to increase the mean depth of the channel and thus to increase tidal propagation and range as well as increasing storm wave activity on the estuary banks. In order to accommodate this loss of its shallow water areas, the remaining estuary channel would have to experience a massive decrease in its depth – a process which requires significant amounts of sediment. This may be the explanation for the present demand for sediment in the Humber and the predicted shortfall if the rate of sea level rise increases.

It is possible that, if some of these inter-tidal lands were restored to the estuary – a process now referred to as *managed retreat* – the sediment demand would be reduced and that tidal range and propagation would also be reduced. In order to test this assumption a preliminary research project has looked at the effect which Sunk Island has had on the hydrodynamics of the Humber. Prior to 1800 A.D. the Patrington Channel ran from the tip of Spurn to the north of the Sunk Island and re-entered the Humber at Stone Creek, but was finally reclaimed in 1808. Using a computer simulation model this channel was reinstated. The effect was dramatic: tidal levels at Hull fell by a maximum of 0.5m.

It appears that the removal of the Patrington Channel may have been responsible for the well known increase in tidal levels between Immingham and Hull. Tidal range increases from 6.0m at the mouth of the Humber to 7.2m at Saltend and this was always assumed to be part of the natural hydrodynamics of the estuary. The research outlined above, although no more than introductory at this stage, suggests that this tidal increase is in fact artificially induced and could be corrected.

Sunk Island is only one of many areas of reclamation in the Humber which could be examined carefully to ascertain whether their presence has a deleterious effect on the flood risks in the estuary. Managed retreat of these areas may allow a more natural lower tidal range obviating the necessity for an increase in sedimentation rates.

It is important to stress here that the process of managed retreat suggested above is concerned primarily with the restoration of the natural hydrodynamics of the Humber and the necessity to take urgent and drastic action in the face of the predicted threats of sea level rise. It is not primarily concerned with the restoration of ecological habitats in the estuary. Nevertheless, it is clear that the managed retreat of

significant areas of the Humber flood embankments would, as well as providing a solution to the flood risks facing the inhabitants of the Humber lowlands, also provide important new areas of inter-tidal habitats and must be seen as a major positive impact of the proposal.

Issues

The outline of sediment processes given above allows the identification of several important issues which management of this coastal region should consider as a matter of urgency.

BRIDLINGTON BAY

This report has stressed the sensitive nature of the Bridlington Bay sands, especially the Smithic Sand, and the importance to these sands of the output of sediment from the Holderness erosion and from Filey Bay. Any interference with either the Holderness erosion rate or that of the Filey Bay sands could result in significant loss of sand to Bridlington with consequent erosion of the sea walls and serious loss of amenity value.

THE HOLDERNESS COAST

The Holderness coast is finely adjusted to its present processes. Any changes to its configuration must result in a dis-equilibrium which could have serious negative impacts both within the Holderness coast itself and in adjacent coastal areas within the southern North Sea.

The construction of isolated sea defences can have short term implications for erosion especially to the south of such works due to inhibition of sediment supply.

The gradual emergence of a bay between pairs of defences will have the effect of increasing the forces on the defences as they begin to emerge as pronounced headlands – a process which was probably the cause of the recent loss of sand at Withernsea. The continued erosion of the seabed in front of sea defences will further exacerbate these increased stresses on them, necessitating costly maintenance programmes.

The emergence of stable bays between defence works will reduce the sediment supply from the Holderness coast. This will have implications for the Humber of the most serious nature, already recognised by the NRA in their Catchment Management Plan.

Reduction of sediment output from Holderness can also have an effect on other coastal systems in the southern North Sea since at the present time it is estimated to provide between 12% and 17% of the entire sediment flux in this area.

THE HUMBER ESTUARY

The Humber estuary is experiencing a shortfall in the supply of sediment necessary for its continued development. This shortfall may be partly due to interruption of the sediment transport into the estuary by such factors as dredging activity. Any increase in the inhibition of sediment from Holderness must however be viewed with the greatest possible concern. Holderness provides 45% of the potential sediment of the Humber, an increase in sea defences along this coast would prevent the estuary maintaining its channel form in the face of continued sea level rise.

Even if the rates of sedimentation in the Humber are restored to their previous levels it appears unlikely that the estuary can respond adequately to the predicted increase in the rate of sea level rise. This would result in an increase in tidal range, an increase in tidal propagation further inland into the estuary and increase in storm wave activity along the flood embankments.

POLLUTION

Although this report has not been directly concerned with water quality, two issues may be raised here:

Reduction in suspended sediment levels in the Humber and North Sea may have an indirect effect on water quality. Suspended sediment acts as a scavenger of dissolved contaminants in sea water, these are held on the sediment particles some of which are then deposited on the bed of the sea or estuary where they are rendered relatively harmless.

Sea level rise can have a effect on the flushing time of the Humber estuary causing changes in the residence times of sewage and other pollutants.

SEA LEVEL RISE

The possibility of an increase in the rate of sea level rise from its present value of 3.5mm per year to 15mm per year must be viewed with great concern. The implications are:

- increased rates of coastal erosion both along the Holderness coast and in the Humber estuary;
- the increased sediment demand in the Humber estuary necessary in order to keep pace with increases in sea level cannot be met from present sources;
- increased flood risks in the Humber lowlands;
- massive shortfalls in the rate of sediment accumulation in the Humber causing further increases in tidal and wave action and increased flood risks;
- changes in the residence times of pollutants in the Humber, outlined above, and
- increased salinity in the inner estuary may affect water tables further inland.

Solutions

The identification of coastal management issues given above suggests that a strategic management plan for the area is urgently needed. This could partly be met by the preparation of a Shoreline Management Plan (SMP) although it is urged that such a plan should include both open coast and estuary in its remit. Coastal Zone Management (CZM) should however include consideration not only of the shoreline but the wider area of sea and hinterland. The economic development of the entire Humberside region depends on the careful management of its coast. A Coastal Zone Management Plan should subsume the Catchment Management Plan of the NRA and any Shoreline Management Plan. It should also consider a regional and national strategy for coastal development, a scope which was considered essential by the House of Commons Environment Committee in their report on Coastal management but subsequently rejected by the Government.

Some of the issues which should be considered by this strategic plan have been addressed above. Their solution must be the primary task of the SMP and a wider CZM strategy. Some possible solutions are, however, outlined below.

BRIDLINGTON BAY

Any proposals for future coastal defences in the north of Holderness must be viewed with great concern since they are likely to inhibit sediment supply to the Smithic Sand with serious consequences for Bridlington and Filey.

Aggregate extraction in either Bridlington or Filey Bay is likely to have a serious negative impact on the sand body both in the near shore and the inter-tidal areas, thus affecting erosion rates, amenity and fisheries. Such aggregate extraction should not be permitted.

THE HOLDERNESS COAST

The economic justification for further sea defences along the Holderness coast should take into account their potential impact on adjacent coasts, including the Humber estuary. A programme of research into the costs and benefits of the various options, including retreat, defend and do nothing, should be implemented as a matter of urgency.

Temporary defences should be considered for the protection of finite life industrial plant such as the Easington gas terminal.

Areas below high water mark or threatened by coastal erosion should be regarded as presenting high risks for people and property. The PPG20 on Coastal Planning advises against further development in such areas and this advice is being incorporated in the Replacement Humberside Structure Plan.

Notwithstanding any embargo on future development in high risk coastal areas, the future status of the present defences should be carefully assessed. The increased stresses on these defences as they emerge as headlands may necessitate a recalculation of their economic justification in view of increased maintenance programmes. The effect of the present defences at Hornsea, Mappleton and Withernsea on sediment supply to adjacent coasts should also be carefully assessed. If these are found to be a serious cause of sediment inhibition it may be necessary to consider some form of long term retreat.

One of the most difficult issues on the Holderness coast is the transfer of property from one owner to another leading inevitably to one owner sustaining a considerable loss through erosion. A break in this ownership chain is necessary if long term planning is to be able to manage the coast. The acquisition of coastal property by the coastal management authority and its lease letting back to the owners for their lifetime may allow the chain to be interrupted. This could be used as a form of indirect compensation to coastal property owners, perhaps funded nationally or, since sediment output from Holderness is an international issue affecting the entire seaboard of the southern North Sea, compensation could be forthcoming from European Union funds.

THE HUMBER ESTUARY

The reduction in sedimentation in the Humber over the past 50 years must be looked at with the greatest concern. Three urgently required programmes are recommended.

- A research investigation to confirm the sediment deficit within the estuary at the present time.

- A review of the dredging procedures in the estuary designed to identify any interruptions of sediment movement and, if these are shown to exist, to recommend a more environmentally sensitive procedure for the maintenance of adequate channel depths in the Humber, perhaps by deposition of dredged spoil further inland than at present.

- A review of the changes in the sediment output from the Holderness coast over the past 50 years due to coastal defence works or other causes and predictions of the likely effect of any future defences on the sediment budget.

The possibility of managed retreat in the Humber should be considered as a method of meeting the changes imposed by an increase in the rate of sea level rise. Possible managed retreat sites such as Sunk Island, Skitter Point and Broomfleet Island should be subjected to rigorous investigation using available modelling techniques.

Geomorphological modelling of the long term response of the Humber to such factors as sea level rise, managed retreat and sediment supply inhibition requires the development of a new generation of numerical models. These are currently being reviewed by the NRA but should be considered within any coastal management strategy for the area.

Conclusions and recommendations

This report has stressed the unity which exists within the Humber coast and estuary. Despite the superficial contrasts between the landforms of the Humber and those of the open coast they are unified by a common process of sediment transport and the complementarity of the erosional cliffs and the depositonal mudflats.

The recent innovatory proposals for coastal zone management in this country have emphasised the need for strategic planning in which a widely based view is taken, in both space and time, of the functioning of the coastal system and the manner in which we can ensure its sustainable use for the future.

Such a strategic view is urgently needed for the Humber coast and estuary. The history of coastal management for this coast has unfortunately been characterised by a parochial view in which no regard has been taken of the implications of individual actions for the whole coast. A strategic management plan must take into account the complementarity of coast and estuary – but it also should consider the impact which decisions made within the region can have on adjacent areas, and even areas which have up till now been considered as remote from the Humber region, possibly encompassing the entire southern North Sea.

This coast is of the greatest importance for industry, agriculture, urban development and its ecological diversity. It faces many problems at the present time most of which are a direct consequence of mis-

management in the past, but these can be overcome if a more enlightened view is taken in which we work with rather than against the natural processes of the coast.

The prognosis is, however, more gloomy. Predictions of sea level rise over the next 50 to 100 years suggest that the risks associated with a coastal location will be magnified many times. It seems unlikely that natural processes alone can cope with some of the predicted changes which will accompany sea level rise. In particular the Humber estuary may experience a demand for more sediment in order to keep pace with increased water levels which will not be met from present sources.

Maintenance of the natural processes as they exist at the moment will not be sufficient to counter these changes. What is needed is a more radical approach to the problems which will ultimately face us. Several options are open to us.

- Accept the increased risks associated with the changes.
- Avoid such risks by locating further inland.
- Prevent an increase in risk by enhancing natural processes using such techniques as managed retreat.
- Protect against risk using a combination of hard and soft engineering techniques.

The recommendations from this report are that all such options must be considered within the framework of a strategic plan for our coast at a local, regional national and even international level. Such a plan is urgently needed.

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