Overstrand to Walcott Strategy Study

Strategy Plan - Main Report

Report EX 4692
Release 2.0
September 2005

HR Wallingford

Document Information

Project	Overstrand to Walcott Strategy Study
Report title	Strategy Plan - Main Report
Client	North Norfolk District Council
Client Representative	Mr P Frew
Project No.	CDR3214
Report No.	EX 4692
Doc. ref.	EX4692-Executive Summary rel_2-0.doc
Project Manager	Mr M Wallis
Project Sponsor	Mr PB Sayers

Document History

Date	Release	Prepared	Approved	Authorised	Notes
31/08/05	1.0		mwa	pbs	
19/09/05	2.0		mwa	pbs	

Prepared ....

Approved ....

Authorised ....

Summary

Overstrand to Walcott Strategy Study

Strategy Plan - Main Report

Report EX 4692
September 2005

The North Norfolk coast is characterised by soft cliffs and dunes, with discrete towns and communities fronted by defences built and maintained over many years. The Shoreline Management Plan (1996) reflects this with a succession of 'Hold the Line' and 'Do Nothing' policy options. The sustainability of a selective 'Hold the Line' / 'Do Nothing' management policy has been shown to be unsustainable through the studies undertaken as part of the Strategy and revised policies and actions identified.

The North Norfolk coastline has been subject to erosion and retreat since the end of the last Ice Age, when the North Sea basin filled (again) with water. The construction of coastal defences, especially seawalls, has significantly altered these natural processes. Whilst intervention results in a temporary reduction in natural cliff recession rates, history demonstrates that the natural cliff positions are ultimately re-established. It is also clear that selectively defending generates increased recession on the undefended, downdrift sides of the coastal defences, as the beach is starved of sediment.

This study was therefore tasked with answering the following most critical questions:

- Can the 'Hold the Line' policies be sustained in the medium to long term whilst adopting 'Do Nothing' / 'Managed Retreat' policies between?
- If yes, how is this policy best achieved?
- If no, over what timescales will this remain viable; what management actions are required to maximise the period of viability; and what is the preferred long-term approach?

To support decisions a series of state-of-the-art models coupled with local expert knowledge have been used. In particular, the shoreline evolution modelling has focussed on predicting clifftop position in the long term (100 years) and taking account of climate change. This analysis has been completed for the 'Do Nothing' scenario and a range of possible management interventions and the potential economic and environmental impact of each approach determined.

The Strategy study has confirmed the need to manage this stretch of coast at a regional scale. It is not possible to consider the discrete Management Units in isolation due to the strong process interactions between one area and the next. It is also clear that in the long term it is not in the national interest (based on current priorities) to attempt to hold the existing cliff line. This conclusion is reached on both economic grounds (the engineering cost would outweigh the benefits) and on process and environmental grounds (the North Norfolk cliffs are both an important sediment source - that if stopped would lead to a rapid reduction in beach volumes locally and further field - and geological exposure). Ultimately, therefore, the shoreline will retreat and the cliff top communities will need to progressively, over an extended but finite time period, relocate.

Summary continued

This Strategy recommends a number of significant changes to current policy. In particular the Strategy recognises the unsustainable nature of the shoreline position through Trimingham and in the longer term Overstrand. The significance of this change for those affected can not be under-estimated and the transition will need to include a combination of progressive planning, consultation and monitoring.

For further information please contact HR Wallingford or North Norfolk District Council.

Glossary

Acronym	Name	Definition
AONB	Area of Outstanding Natural Beauty	A designation that allows for tighter planning control so that the landscape is not damaged by development and can provide funding to grant aid landscape improvements.
BCA	Benefit Cost Analysis	The methodology for calculating a BCR.
BCR	Benefit Cost Ratio	BCRs are used to identify the relative worth of one approach over another. It is the ratio of the PV benefits to the PV costs for each option.
CDSP	Coastal Defence Strategy Plan	This is the plan that is produced at the end of a CDSS.
CDSS	Coastal Defence Strategy Study	A CDSS investigates the defence options within a specific study area and establishes the preferred options to comply with the policy options for any specific stretch as defined in an SMP.
CIRIA	Construction Industry Research and Information Association	n/a
DL	Defence Length	The smallest unit identified along the coastline. A defence length contains a single contiguous defence type (man-made or natural).
Defra	Department for the Environment, Food and Rural Affairs	Governmental department. Supplies grant aid to support the implementation and development of projects that are needed to support that Government's flood and coastal defence policy.
EA	The Environment Agency	The Environment Agency has permissive powers relating to the minimisation of flood risk. Many coastal and fluvial flood defences are owned and maintained by the EA.
FCDPAG	Flood and Coastal Defence Policy Appraisal Guidance	Government policy guidance for flood and coastal defence.
FHRC	Flood Hazard Research Centre	University of Middlesex research centre for flood hazards
HRW	HR Wallingford	Coastal and Fluvial Engineering Consultant.
LiDAR	Light detection and ranging	A system that uses a light beam in place of a microwave radar beam to obtain measurements of speed, altitude, direction and range of a target.

Glossary continued

LISFLOOD	-	A numerical flood –spreading model.
LMU	Local Management Unit	Where adjacent defence lengths are of a similar type and / or the coastal processes they are exposed to are similar they have been grouped together to form Local Management Units.
MAFF	Ministry of Agriculture Fisheries and Food	Now Defra.
MU	Management Unit	MU refers to the Management Units used in the Shoreline Management Plan. Within each MU there is a single management policy.
NNDC	North Norfolk District Council	NNDC owns and maintains the majority of the coastal defences in the study area.
ODN	Ordnance Datum Newlyn	Benchmark datum from which marine water depth and land levels are measured.
PV	Present Value	The monetary value of ongoing or future costs, discounted to provide equivalent present day costs.
–	Ramsar	A worldwide recognised site, dedicated to the protection of a wetland ecosystem.
SAC	Special Area of Conservation	A special area of conservation designated under the EU Habitats and Species Directive.
SMP	Shoreline Management Plan	A general appraisal of the defences and assets in a large coastal area. An SMP establishes the preferred management policy for different stretches of the coastline.
SSSI	Site of Special Scientific Interest	A nationally designated site of special interest by reason of any of its flora, fauna, geological or physiographical features.
–	Study Area	The study area extends from Overstrand to Walcott on the Norfolk coast. This can be seen graphically in Figure 1 in this report.
TRANSCO	-	The UK gas transportation service.

Contents

Contents continued

Tables

Contents continued

Figures

1. Introduction and background

1.1 OVERVIEW

This report summarises the studies that make up the Overstrand to Walcott 'Strategy Study' commissioned by North Norfolk District Council.

The coastline under consideration is shown in Figure 1 and covers the following Shoreline Management Units (from west to east):

- TRI1 between Cromer and Overstrand
- TRI2 fronting Overstrand
- TRI3 between Overstrand and Trimingham
- TRI4 fronting Trimingham
- TRI5 between Trimingham and Mundesley
- TRI6 fronting Mundesley
- BAC1 between Mundesley and Bacton
- BAC2 fronting Bacton and Walcott

As shown in Figure 1, the study area has had a history of recession and landslide. This Strategy Study aims to identify the most appropriate and sustainable approach to managing the above length of coast over the next 100 years, and where necessary, of protecting land from flooding, erosion and environmental degradation in so far as it affects or is affected by shoreline management and can be justified in terms of benefits (accrued to the nation) against costs incurred.

Figure 1 Cliff recession and landsliding in the study area

1.2 AIM OF THIS REPORT

This report provides a summary of the studies undertaken as part of the Strategy Study and presents key conclusions arising with respect to the future management of the Overstrand to Walcott shoreline.

The study approach recognised that coastal management decisions are best served by considering how the physical coastal processes of waves and tides affect the morphodynamics of the coastline and what changes they are likely to bring about with and without intervention. It is then possible to attribute impacts to these changes and express these impacts in economic, environmental and social terms based on recommended practice in the Government's 'Flood and Coastal Defence Policy Appraisal Guidance' (FCDPAG, Defra) supported by the 'Multi-coloured Manual' developed by the Flood Hazard Research Centre (FHRC, 2003).

Given the complexity of a Strategy Study, a series of interim reports focusing on specific issues were produced during the course of the study. These reports form the basis of this report and are summarised below:

- Hydrodynamics – Review of waves, surges and tides along the study coastline (HR Wallingford, 2002).
- Littoral sediment processes – Reviews of beach processes and longshore and cross shore sediment transport along the study coastline (HR Wallingford, 2003a).
- Cliff processes – Review of the history and processes responsible for erosion of the soft cliffs of the study area and reflected in the episodic nature of the cliff top retreat (HR Wallingford, 2003b).
- Defence condition survey – Review of the condition of the existing defences through both visual inspection and insitu measurement (HR Wallingford, 2003c).
- Predictive cliff top modelling – the key feature of interest in terms of predicting future change is associated with the likely position of the cliff top. Given the significant uncertainty in the rates of cliff recession a state-of-the-art probabilistic model was used to provide predictions of future cliff position (HR Wallingford, 2003d).
- Economic valuations – Assessment of the present value of cliff top assets, tourism and other tangible benefits using data provided by local estate agents and the council's valuation office (HR Wallingford, 2004a).
- Environmental value – Reviews of the environmental, geological and aesthetic value of the study area (HR Wallingford, 2003e).
- Assessment of 'do-nothing' erosion impacts – An assessment of what would happen assuming no further management of the shoreline was undertaken to provide a baseline against which to assess the benefits of various possible future interventions. The future recession of the cliff top, and possible future impacts, has been investigated and reported (HR Wallingford, 2004b).
- Assessment of 'do-nothing' flood impacts – As for erosion, the possible future flooding impacts under a do nothing management scenario (primarily influencing Bacton to Walcott) have been investigated and reported (HR Wallingford, 2004c).

- Consultation – The discrete coastal communities that are characteristic of this coastline are well aware they lie on an eroding coastline. The strategy study consultations ran in parallel with on-going consultations by NNDC and the review of the Shoreline Management Plan (HR Wallingford, 2004d).
- Option identification and appraisal – flood and coastal defence options were assessed to establish whether or not they were technically sound, economically viable and environmentally acceptable, and to identify the preferred future management option (HR Wallingford, 2004e).

The key findings from these interim reports are summarised within this report and form the basis from which the overall conclusions regarding the most appropriate management strategy are drawn.

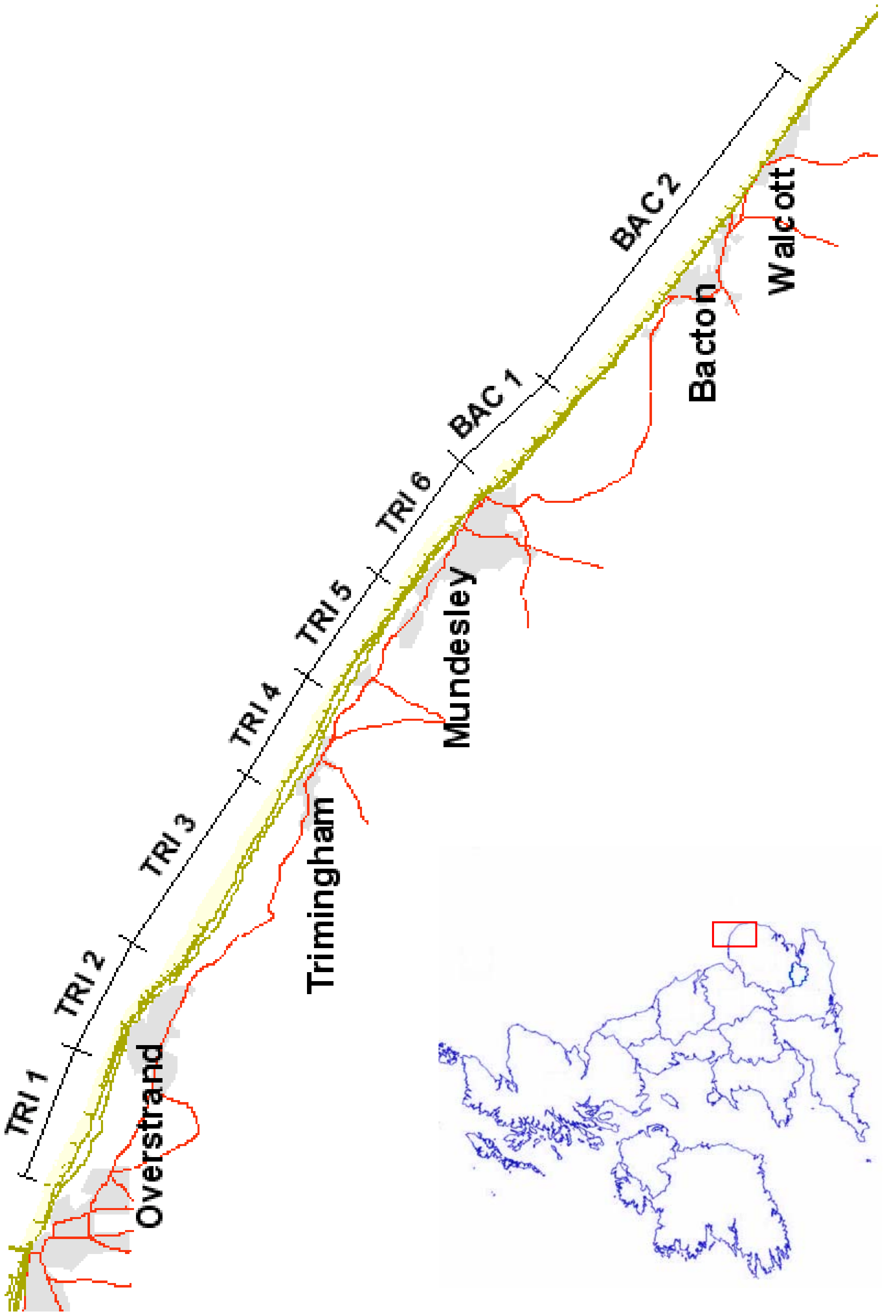

Figure 2 *Study area and existing management units*

2. The study framework

2.1 RESPONSIBILITY FOR FLOOD AND COASTAL DEFENCE

Obligation and responsibility for management of the shoreline requires explanation. Defra has overall responsibility for coastal defence policy in England and Wales and has published guidelines for indicative standards of defence for a range of land use types (MAFF 1999). The intention of the Defra guidelines is not to indicate entitlement to protection at a certain level, but only to indicate design targets for shoreline managers. (Note: The return period indicates the expected frequency of a particular extreme event.)

Local Authorities with a maritime frontage, as defined under Schedule 4 of the Coast Protection Act (1949) have permissive powers under the Act to carry out work to protect land in their area from erosion. The Environment Agency has a statutory obligation to exercise supervision over all matters related to flood defence under the Water Resources Act (1991), and has permissive powers in respect of the shoreline where the hinterland is liable to tidal flooding. However, these responsibilities and powers to act do not imply a duty to prevent erosion or flooding.

Owners of property along the shoreline, including government bodies, local authorities, and private landowners are responsible for their own frontage, but must act within the applicable statutory planning and other legislation.

In some circumstances, a Local Authority or the Environment Agency will undertake shoreline management operations along privately owned frontages, particularly where the risk from flooding or erosion extends beyond the frontage owners property. In general, Local Authorities and the Environment Agency will only act where:

- there is clear economic justification,
- an appropriate engineering solution is achievable, and
- environmental legislation is not contravened.

Construction of defences by a Local Authority or the Environment Agency does not imply a continuing responsibility for prevention of erosion or flooding. However, such construction does entail subsequent responsibility for ensuring public safety in relation to the structures themselves (e.g. supporting or removing unstable structures and marking navigational hazards).

2.2 A STRATEGIC APPROACH

In 1993 the Ministry of Agricultural Fisheries and Food (MAFF) and the Welsh Office published their “Strategy for Flood and Coastal Defence in England and Wales”. This publication identified the need to manage the shoreline from the perspective of coastal processes rather than in accordance with the administrative boundaries of the coastal operating authorities.

To assist this process, Defra (then MAFF) (2001) provided guidance that outlines the approach to developing management strategies that is consistent with their stated policy objective of reducing risks to people and the developed and natural environment from flooding and coastal erosion. To enable management decisions to be taken within such a strategic framework, a hierarchy of ‘Plans’ and ‘Appraisals’ has evolved that consider the shoreline in progressively greater detail. This hierarchy comprises Shoreline

Management Plans (SMPs), followed by Strategy Plans, followed by Scheme Appraisal (Figures 3a and 3b). Each of these approaches becomes progressively more detailed and site specific, leading ultimately to the implementation of an appropriate management scheme for a stretch of coastline. This study is focused on the middle tier of the planning process.

Using the SMP as a foundation, this study considers the concepts proposed for each length of coastline in more detail. To facilitate this process of refinement, MAFF issued their 'Interim Guidance for the Strategic Management of Coastal Defences' (MAFF 1997) that sets out the principles of a Coastal Defence Strategy Plan. As for the SMP, the aim of the Strategy Plan is to achieve a technically, environmentally and economically sustainable coastal defence system. However, unlike SMPs, Strategy Plans aim to provide a detailed understanding of the regional coastal processes, likely economic consequences of various coastal management scenarios, and ultimately seek to identify the preferred generic management solution(s) for each Management Unit.

Strategy Plans do not, however, aim to provide detailed management strategies for specific frontages. Instead, they seek to identify the preferred generic form of management solutions, leaving the detailed design and appraisal to be undertaken at the following Scheme Appraisal stage.

Following possible acceptance of these recommendations by Defra, and approval for grant aided funding, a more detailed scheme appraisal / scheme design would be undertaken prior to any construction works commencing.

2.3 AIMING FOR SUSTAINABLE SOLUTIONS

The aim of a SMP, as set out by the Defra guidelines, is

'*to provide the basis for sustainable coastal defence policies within a sediment cell and to set objectives for the future management of the shoreline*'.

The guidelines go on to define sustainable schemes as those:

'*which take account of the inter-relationships with other defences, developments and processes within a catchment or coastal cell or sub-cell, and which avoid as far as possible, tying future generations into inflexible and expensive options for defence*'.

This definition of sustainability is open to different interpretation depending on the perceptions of different interest groups and is subject of on-going research (http://www.sfcm.org.uk/). These different perceptions are at the root of many of the conflicts over preferred strategic defence options.

The sustainability of each option is evaluated using the three key considerations of engineering, environmental and economic performance. This ensures that only realistic solutions are considered and increases confidence that the most advantageous option is chosen to be carried forward for detailed assessment through follow-on studies. The approach to each of these three key considerations is summarised below.

- **Approach to option selection – engineering (technical) issues**
  For each defence length a number of possible solutions are considered, based on the generic policies of *maintain*, *sustain* and *improve*. The results from the engineering analysis provide a broad brush but strategically reliable costing for

each option and an understanding of any technical or safety issues associated with construction/maintenance. The technical analysis also provides an understanding of the likely performance of the option in terms of structural and non-structural failure and of any potential change in time.

- **Approach to option selection – Economic issues**
  Once an option has been technically assessed and costed the economic appraisal seeks to identify the relative worth of one approach over another. For each option, the associated benefits are derived by comparison to the *do nothing* case. These are then compared to the associated costs to provide a Benefit Cost Ratio (BCR). For each Management Unit the BCRs for all the options are then compared to determine the most economically advantageous option using the procedures laid out in Defra's Flood and Coastal Defence Project Appraisal Guidance (FCDPAG 3 – Economic Appraisal 2001)

- **Approach to option selection – Environmental issues**
  The UK Government is committed to encouraging biodiversity and social well being. To ensure due recognition of environmental concerns, within the appraisal process, each management option is assessed based on its impact with respect to four key environmental areas, namely: nature conservation and geological designations; tourism and leisure; archaeology and cultural heritage; and built environment.

2.4 SHORELINE MANAGEMENT PLAN (1996)

The Sheringham to Lowestoft Shoreline Management Plan was completed in 1996 and covers Sediment Sub-cell 3b (SMP 1996). It considers the management objectives pertaining between Sheringham and Lowestoft as a whole and sub-divides the coastline into *Management Units*. The Management Units identified within the SMP were intended to cover lengths of the shoreline with coherent characteristics in terms of coastal processes and land assets.

Within the SMP, the open coast between Cromer and Walcott was divided into two Management Areas (TRI and BAC) and eight Management Units (TRI 1 – 6 and BAC 1 & 2). Each Management Unit was then assigned a preferred policy option, selected from one of the available options as identified by MAFF (1995) as follows:

- **Do nothing** Allow natural processes to act with no intervention (the consequences of this option are used to assess the benefits arising from the other options).
- **Hold the line** Maintain or improve the existing shoreline defences.
- **Retreat the line** Managed landward realignment of the shoreline defences to a pre-determined and more sustainable position.
- **Advance the line** Reclamation of land by shifting the shoreline defences seaward.

Eight Management Units were identified between Cromer and Walcott (see Figure 1) with the following policies:

- TRI 1 – Do nothing
- TRI 2 – Hold the line

- TRI 3 – Do nothing
- TRI 4 – Hold the line
- TRI 5 – Retreat the line
- TRI 6 – Hold the line
- BAC 1 – Do nothing
- BAC 2 – Hold the line

2.5 GOVERNING ASSUMPTIONS

Within the Overstrand to Walcott Strategy Plan, the following general principles have been applied to assist in the interpretation of sustainability:

- The Strategy Plan is assumed to apply over a period of 100 years, although uncertainty over future coastal processes may result in revision of policies within a shorter period.
- The Strategy Plan is based on present day economic, social, and political values. However, it recognised that these values may evolve as they have in recent decades with respect to issues such as the natural environment, farmland, public access, and shorefront residential property.
- In the absence of coastal erosion existing residential areas would remain.
- It is assumed that existing planning policies, restricting development, will be retained and that there will be no further development in the restricted areas.
- Existing commercial and private holiday property within areas at risk will not necessarily be retained.
- Agricultural or recreational land will not necessarily be retained.

If a preferred strategic defence option cannot be agreed at present, then any works required to maintain the existing situation should be flexible.

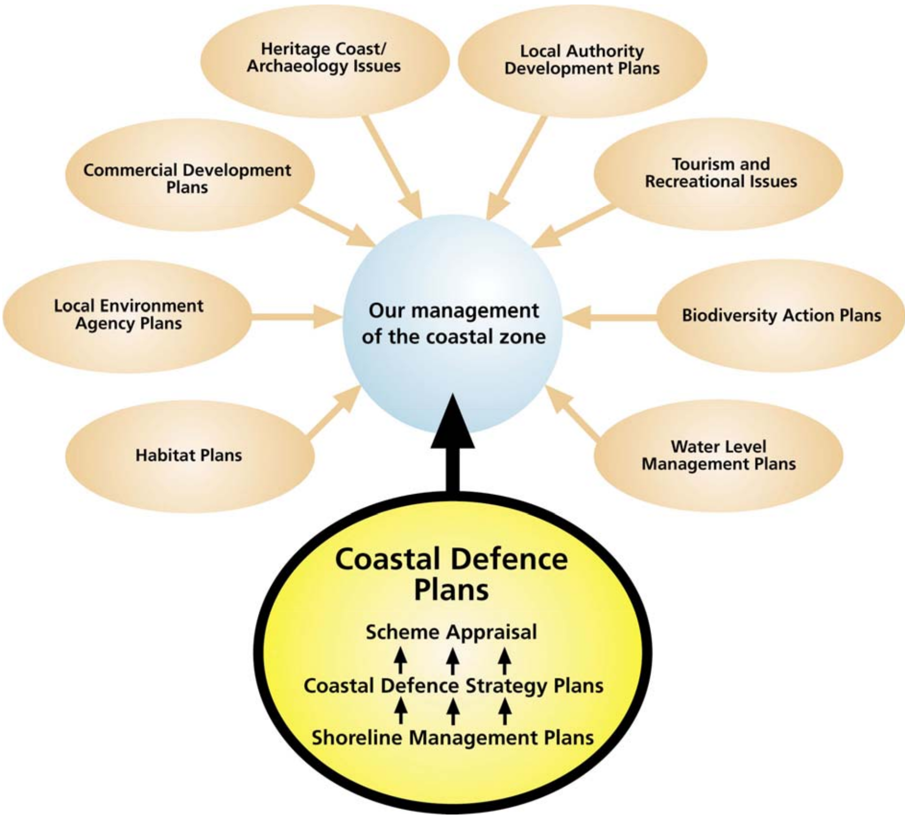

Figure 3a ***Linkage between coastal strategy plans and other coastal management initiatives***

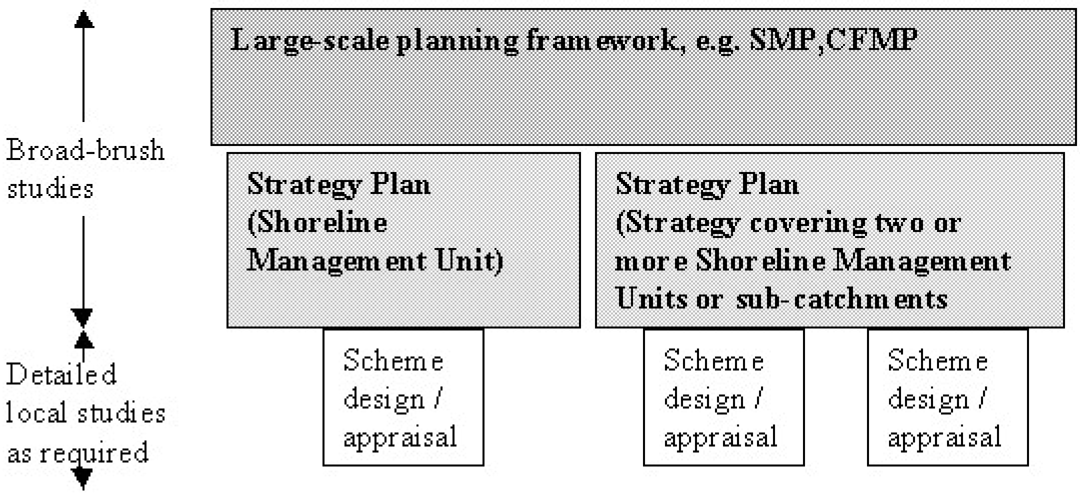

Figure 3b ***Hierarchy of coastal management plans***

3. The study area in context

The 15km of coastline from Overstrand to Walcott is predominantly cliffed - made up of unconsolidated Pleistocene sand and gravel glacial deposits which overly an eroded chalk platform. The cliffs vary in height being over 70m to the west of Overstrand, and over 50m between Mundesley and Trimingham, but elsewhere lower, at around 20 to 30m. The observed cliff processes are either 'actively unstable' or 'actively retreating' with existing defences such as palisades only having reduced the rates of erosion – allowing the propagation of hydrodynamic forces sufficiently to continue to erode and undercut the base of the cliffs (Figure 4).

Figure 4 Undercutting and erosion induced cliff failure

Land use along this coastline is predominantly agricultural and recreational in nature, with a number of discrete coastal settlements located on the cliff tops.

Figure 5 The rural nature of the coastline with discrete settlements

Figure 6 Coastal view looking west towards Overstrand

There are over 650 residential properties between Overstrand and Walcott presently sited within 100 metres of the cliff tops and the potential for loss due to coastal erosion and cliff failure is significant.

There has been a long history of sea defences being built along this coastline with the earliest records dating from the late 18th century. Initially these were instigated by landowners striving to protect their own property. Later, defences were also built to protect hotels as tourism increased, and extensions were built at the flanks of seawalls defending the towns as they also grew. There is a continuous record of recurrent building, maintenance and extension of all the defences ever since as physical processes have continued to act. Immediately fronting the towns, coastal defence is provided by seawalls, revetments and groynes in varying states of repair.

These defences have not served to fully protect the land from erosion but have slowed the process. Ironically in many places the structures themselves have been damaged by landslips, slides and geological failures, from the very cliffs they were built to protect (see Figure 4). The action of the sea eventually removes cliff toe material from behind revetments and continues to promote cliff instability, erosion and retreat. Arresting cliff and land erosion by the construction of seawalls has reduced the supply of sediments to adjacent beaches, and extensive groyne construction has reduced its transport by longshore drift to others. Over time this 'drift starvation' has resulted in a self perpetuating demand for more and more defences to prevent erosion of beaches and undefended lengths of cliff line; to the point that today the only stretch of coastline in the study area not defended by some kind of structure is a 2km length between Sidestrand and Trimingham.

The environmental and geological value of the area of the area is dependent on the prevailing physical processes and ongoing erosion. Three sections of cliff between Overstrand and Mundesley are designated Sites of Special Scientific Interest, one of which is also a Special Area of Conservation. There are three County Wildlife Sites and the geology of the coastal cliffs has an intrinsic value in contributing to the understanding of 'earth heritage'. The dynamic nature of the soft cliff stratigraphy results in varied colonising flora and fauna, including specialised species that depend on recurrent disturbance of the ground to survive. Thus many of the cliff tops and slopes form important habitats for wildlife including rare invertebrates and plant communities.

Figure 7 Cliff-top plant communities and wildlife habitat

Tourism within the area grew in importance in the late 18th Century and the villages of Overstrand, Trimingham and Mundesley still depend on tourism for a substantial part of their income. As the character of the towns depends partly upon their seafront, any coastal defence schemes need to reflect this interrelationship as well as take into consideration the safety of the large numbers of people that visit the seafronts and beaches in this region.

4. Overview of coastal processes

The Norfolk coastline has been 'under attack' and subject to erosion and retreat since the end of the last Ice Age when the North Sea basin filled (again) with water. The principal processes causing these coastal changes can be summarised as follows:

- Variations along the coast in the rate of beach sediment transport (longshore drift);
- Erosion of the nearshore seabed, which is of similar soft rock to the cliffs;
- Landwards migration of the beach profile in response to sea level rise;
- Loss of sand from the beaches to the nearshore seabed;
- Wave attack on the cliff face at and above the high water mark;
- Cliff weathering and erosion, e.g. by winds, rainfall, freeze-thaw etc; and
- Landslides of the cliff faces due to saturation caused by groundwater flows.

The linkage between these processes is shown schematically in Figure 8.

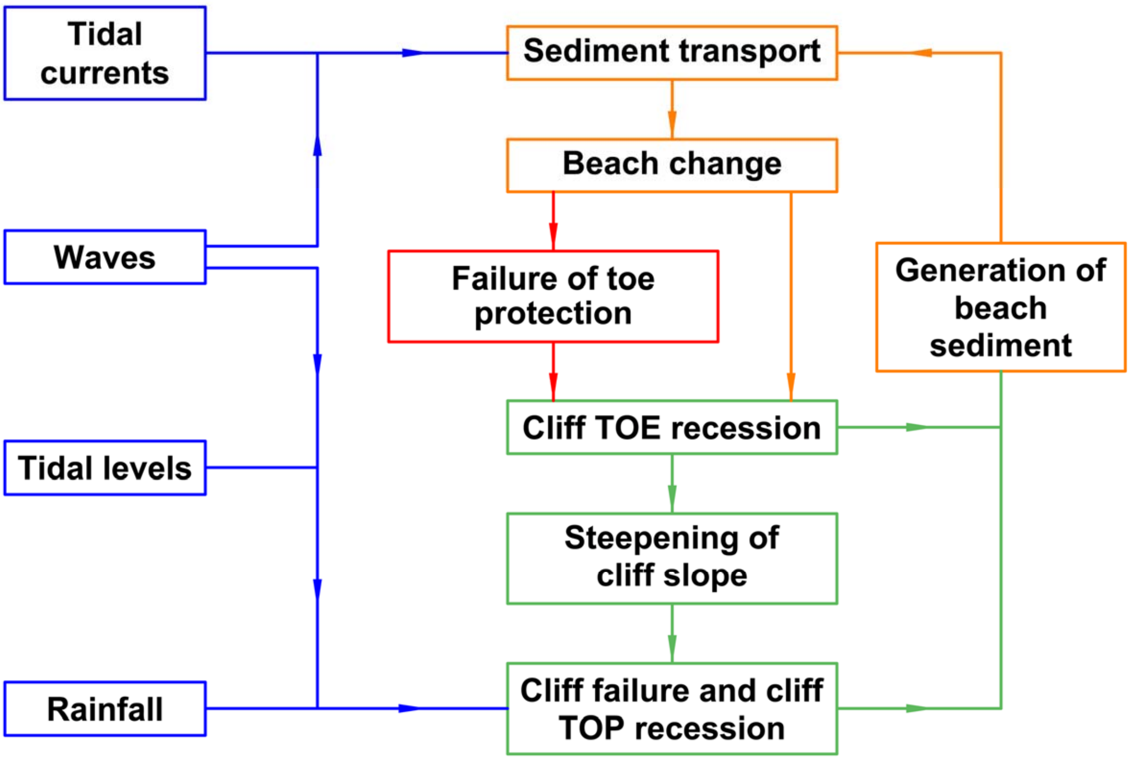

Figure 8 Conceptual process model

All of these processes have been investigated in detail as reported in the Interim Reports (HR Wallingford, 2002, 2003a, 2003b, 2003d). An overview of the findings from these reports is provided below.

4.1 WAVE CONDITIONS – PRESENT DAY

The largest waves come from the north, north-east, and east and the largest surges tend to be associated with winds from the north-west and north. Broadly, therefore, northerly sea conditions are likely to be the worst case for potential impacts at the coast. This direction includes most of the largest waves and more of the highest water levels than other wave direction sectors with significant dependence between the two. The joint probability assessment is therefore based on all sectors combined, but in the knowledge that the worst such conditions are likely to come from the north.

A summary of the marginal extreme significant wave conditions is provided in Table 1 together with a wave rose in Figure 9.

Table 1 Extreme wave conditions for Overstrand, Trimingham, Mundesley, and Bacton

Return period (years)	Significant wave height (m) and mean wave period (s)							
	Overstrand		Trimingham		Mundesley		Bacton	
	H_s	T_m	H_s	T_m	H_s	T_m	H_s	T_m
0.1	3.4	6.3	3.2	6.1	3.1	6.0	3.1	6.0
1	4.6	7.3	4.2	6.9	3.9	6.7	4.1	6.8
5	5.4	7.9	4.8	7.5	4.5	7.1	4.7	7.4
10	5.7	8.1	5.1	7.7	4.7	7.4	5.0	7.6
20	6.0	8.3	5.3	7.8	4.9	7.5	5.3	7.8
50	6.4	8.7	5.6	8.1	5.2	7.8	5.6	8.1
100	6.7	8.9	5.9	8.3	5.4	7.9	5.8	8.2
200	7.0	9.0	6.1	8.4	5.6	8.1	6.0	8.3
500	7.4	9.2	6.4	8.7	5.9	8.3	6.3	8.6
1000	7.7	9.4	6.7	8.9	6.2	8.5	6.6	8.8

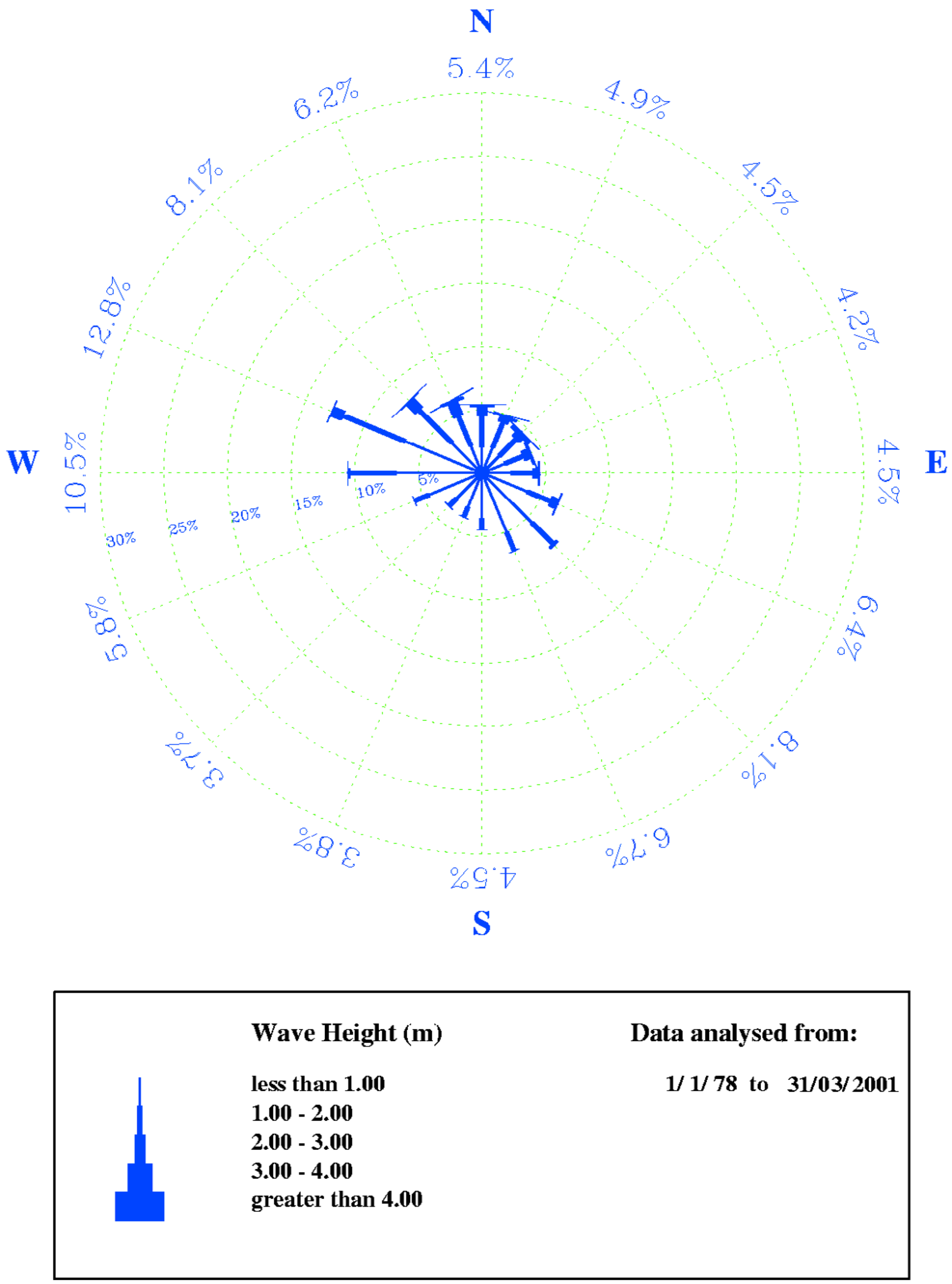

Figure 9 Wave rose showing offshore wave conditions

4.2 TIDAL CURRENTS – PRESENT DAY

Current data were obtained from published sources and supplemented using a state-of-the-art tidal flow model. This enabled results to be produced through the tide and throughout the study area (see Figure 10 for illustrative results).

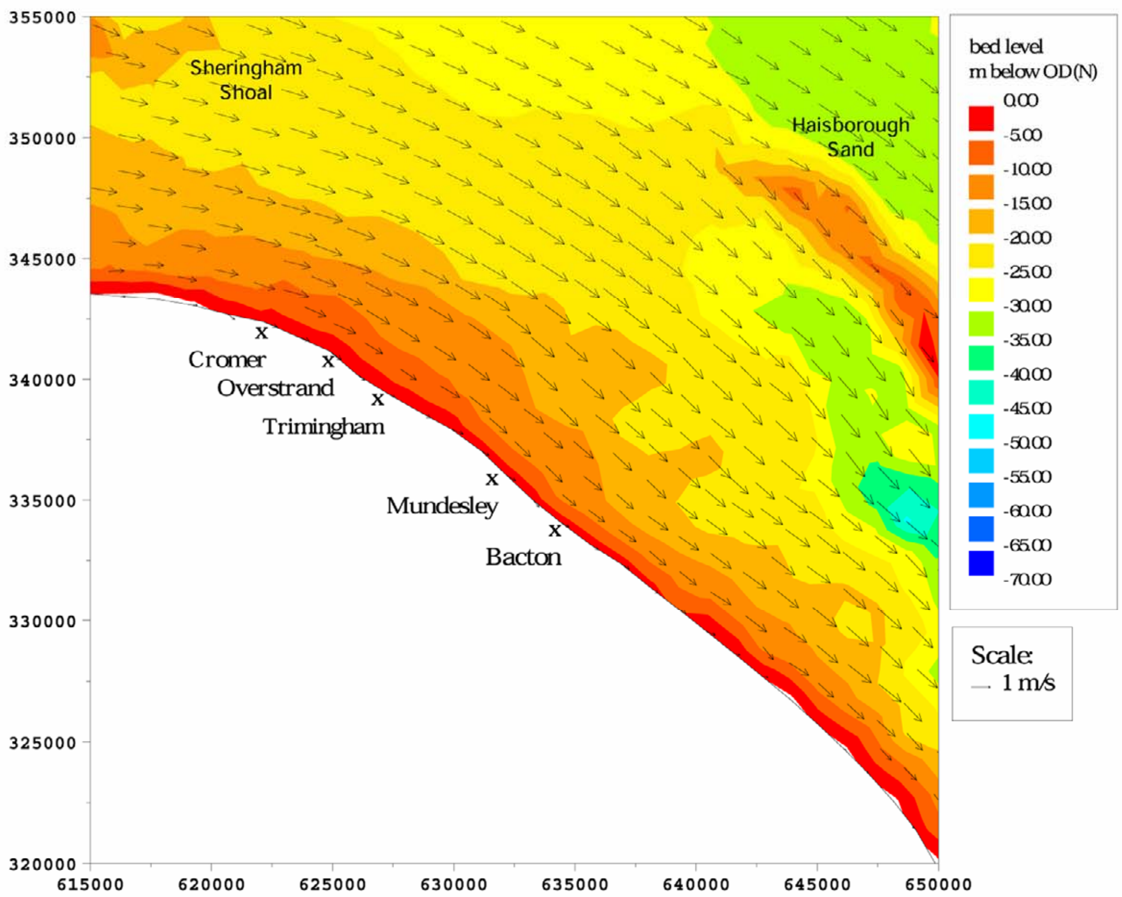

Figure 10 Example map of tidal currents

Tidal range data, extreme sea level predictions and information on future sea level rise were collated from several published sources; including Admiralty tide tables. Tables of extremes of waves and water levels were also produced for the four locations of Cromer, Overstrand, Trimingham, Mundesley and Bacton (Table 2).

Table 2 Extreme (present-day) water levels for Cromer, Overstrand, Trimingham, Mundesley and Bacton (mODN)

Return period (years)		1	10	25	50	100	250	500
Water level (mODN)	Cromer	3.17	3.70	3.91	4.04	4.25	4.45	4.58
	Overstrand	3.08	3.61	3.82	3.95	4.16	4.36	4.49
	Trimingham	2.99	3.52	3.73	3.86	4.07	4.27	4.40
	Mundesley	2.86	3.39	3.60	3.73	3.94	4.14	4.27
	Bacton	2.71	3.24	3.45	3.58	3.79	3.99	4.12

4.3 CLIFF AND LITTORAL PROCESSES

4.3.1 Historical cliff recession

Prior to the construction of coastal defences the rate of cliff recession was approximately 0.65m to 0.75m/year (Cambers, 1976). However, there have been substantial variations in this rate along the coast in response to variations in exposure to storm conditions, glacigenic sediments in the cliff material and the frequency of wave attack on the cliff base. For example, Clayton and Coventry (1986) investigated the recession rate between Overstrand and Trimingham between 1885 and 1985 and found that it reached a time averaged maximum rate of 1.75m/year (see Figure 11).

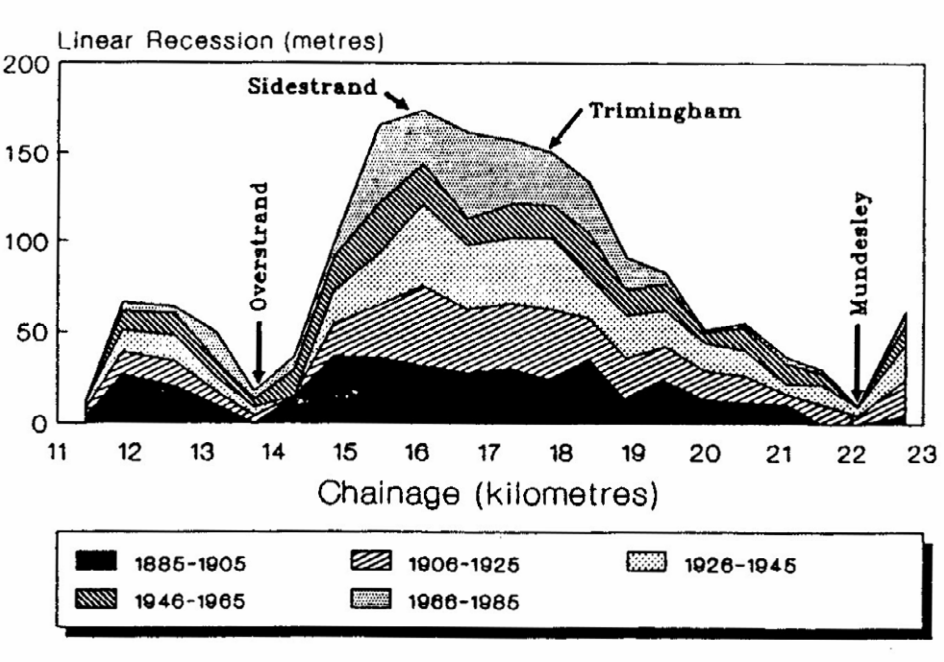

Figure 11 Summary of the cumulative recession along the North Norfolk Cliffs (Clayton and Coventry, 1986)

Following construction of coastal defences, especially the seawalls at Overstrand and Mundesley, the cliff recession rates reduced. However, this generated increased recession on undefended downdrift sections for the following reasons:

- The coastal defences reduced the erosion of the cliffs behind them, thus reducing the supply of sediment to the beaches locally.

- The defences, particularly the groynes, tend to trap beach sand travelling along the coast, typically from the west to the east and hence restrict the supply of sediment to the downdrift coast (today however the effect is limited due to the poor condition of many of the defences).

Both of these effects reduced the amount of sand arriving on the beaches in front of the cliffs immediately east of the defences, a phenomenon known as 'drift starvation.' The reduced sediment supply to the unprotected coast causes the beaches (and shortly afterwards the cliffs) to erode resulting in the need to construct more coastal defences, typically groynes and sometimes seawalls or revetments, further down the coast.

In contrast to this, a positive effect on beaches updrift (i.e. to the west of defended frontages) has been observed, where beach material tends to accumulate. Even this effect, however, can have disadvantages as it reduces cliff erosion and hence the supply of extra beach material to the system.

4.3.2 Classification of cliff behaviour

The approach adopted here is based on the notion of a Cliff Behavioural Unit (CBU) as being a stretch of cliff-line which behaves in broadly the same way.

Four different cliff types have been identified, 'Relatively stable', 'Marginally stable', 'Actively unstable' and 'Actively retreating'. These are summarised in Table 3 and shown spatially in Figure 12.

4.4 FUTURE CHANGE – WAVES AND WATER LEVELS

Continuing climate change, particularly the increase in temperature of the world's oceans, has lead to an increase in mean sea level. Predictions from various numerical simulations of the world's atmosphere in the coming few decades, and other sources, seem to agree that the present rate of rise in mean sea level will accelerate. Since this will occur over the expected lifetime of the coastal strategy plan it is therefore necessary to anticipate higher tidal levels when considering appropriate management actions.

Table 4.4 of MAFF (1999) recommends an appropriate precautionary allowance for future mean sea level rise of 6mm/yr for the study area region. In the absence of any information to the contrary, it would be normal practice to assume that the future change in the highest water levels will be the same as the change in mean sea level an approach confirmed as a fair approximation by a recent study commissioned by Defra (HR Wallingford, 2001).

To apply the allowance of 6mm/yr, all the predicted present-day water levels have been raised by 6mm times the number of years ahead being considered. For example, at the end of a 100-year appraisal period, all levels have been assumed 600mm higher.

Table 3 A summary of the main features of the cliff units between Cromer and Walcott

Unit	Defences	Condition	Cliff Width (crest to toe) (m)	Estimated Cliff Height (m)	Recession Model*
24. Cromer Undercliff	Groynes	Actively unstable	70-80	25-35	A
23. Lighthouse Hill	Groynes	Actively unstable	120-170	40-50	B
22. Overstrand (Golf Course)	Groynes	Actively unstable	70-80	30-40	B
1. Overstrand W (Golf Course)	Timber palisades and groynes	Actively unstable	30-40	20	A/B
2A. Overstrand (W)	Timber palisades and groynes	Marginally stable - Actively unstable	25-30	15-20	A
2B. Overstrand (Slipway)	Seawall and groynes	Marginally stable	25-30	15	A
3. Overstrand (C)	Seawall and groynes	Marginally stable - Actively unstable	30-50	15-20	B
4. Clifton Way	Seawall (part) or timber palisades, groynes; rock revetment at Clifton Way slide	Actively unstable	150 (max)	35	B/C
5. Overstrand (E)	Timber palisades	Actively retreating	60-90	25	B
6A. Sidestrand (W)	Timber palisades	Actively retreating	70-100	20-25	A

Table 3 A summary of the main features of the cliff units between Cromer and Walcott (continued)

Unit	Defences	Condition	Cliff Width (crest to toe) (m)	Estimated Cliff Height (m)	Recession Model*
6B. Sidestrand Hall	No defences	Actively retreating	75-110	20-30	A
7. Sidestrand (E)	No defences	Actively retreating	70-150	25	B
8. Trimingham (W)	No defences	Actively retreating	70-110	25	A
9. Trimingham (C)	No defences	Actively retreating	50-100	30-40	B
10. Trimingham (E)	Concrete seawall, timber palisades and groynes	Actively unstable	100-160	60	B
11. Beacon Hill	Timber palisades and groynes	Actively unstable	60-100	55-60	A
12. Marl Point	Timber palisades and groynes	Marginally stable – Actively unstable	50-100	45-50	B
13. Cliftonville	Timber palisades and groynes	Marginally stable – Actively unstable	20-40	17	A
14. Mundesley (W)	Concrete blocks (within steel railing frames) and groynes	Marginally stable – Actively unstable	20-30	18	A

Table 3 A summary of the main features of the cliff units between Cromer and Walcott (continued)

Unit	Defences	Condition	Cliff Width (crest to toe) (m)	Estimated Cliff Height (m)	Recession Model*
15. Mundesley (C)	Seawalls and groynes	Relatively stable	10-15	7	A
16. Mundesley (E) to Bacton Terminal (W)	Timber palisades and groynes	Actively unstable	30-50	20	A
17. Bacton Terminal (W) to Bacton Terminal (C)	Timber palisades and groynes	Actively unstable	20-25	15-20	A
18. Bacton Terminal (C) to Bacton Terminal (E)	Timber palisades and groynes: regraded and drained slopes	Relatively stable	20-25	15-20	A
19. Bacton Terminal (E) to Bacton Green	Timber palisades and groynes; sheet pile wall at the cliff foot	Marginally stable	15-20	10-15	A
20. Bacton Green to Walcott	Concrete seawall and groynes. Seawall obscures low cliff face	Stable**	Not seen	5	A
21. Walcott to Ostend	Timber palisades and groynes	Actively unstable	10	10-20	A

Note: ** The seawall extends to the top of the cliffline.

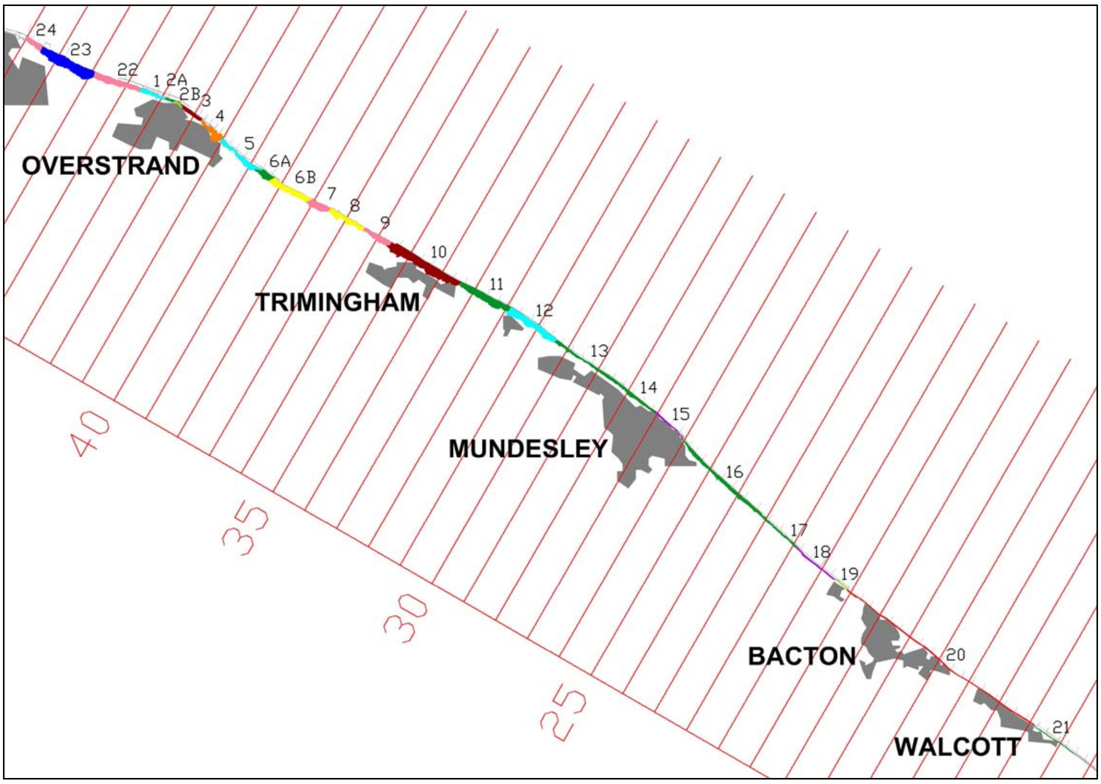

Figure 12 Location of Cliff Behavioural Units described in table 3.

At present, the annual chance of the water level rising to over 4.0m ODN at Cromer is approximately 2%. However, by 2050, this probability will have increased five-fold to approximately 10%.

The change in beach level, defence deterioration and subsequent recession of the cliffs along the frontage between Overstrand and Mundesley has therefore been calculated taking these future predictions of climate into account.

4.4.1 Present day littoral processes and sediment budget

As part of the Strategy Study a regional beach volume analysis was undertaken based on beach profile data gathered between 1992 and 1999. The results of this analysis are shown in Figure 13 and supported the creation of a conceptual model of the sediment transport budget in the study area (Figure 14).

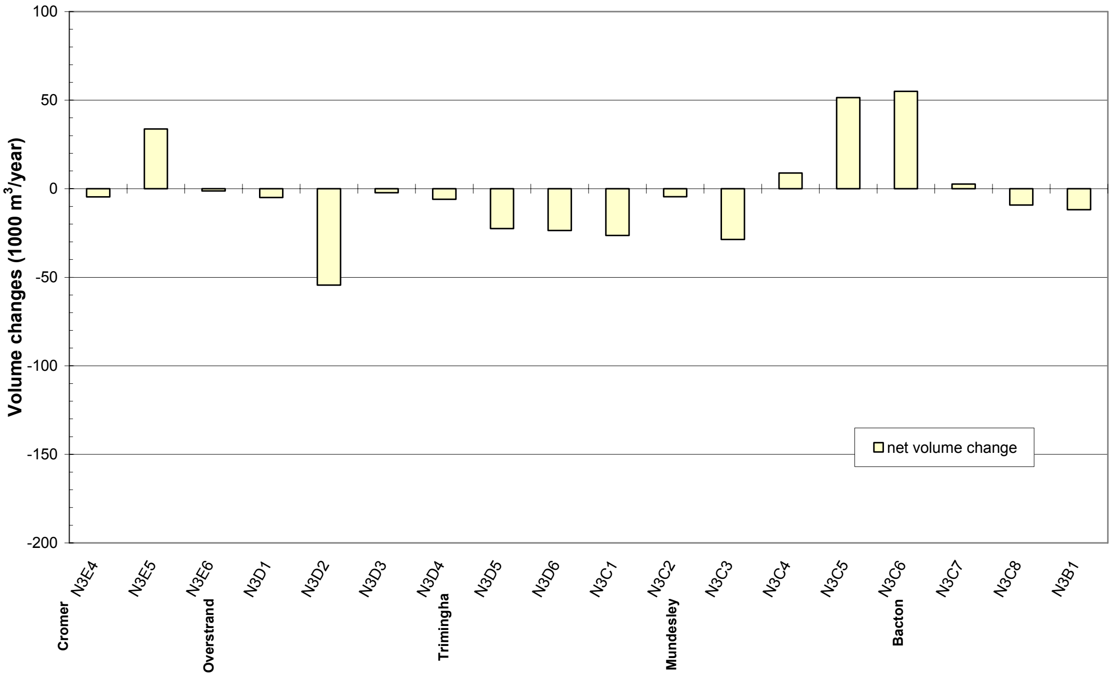

Figure 13 Net beach volume changes in the study area

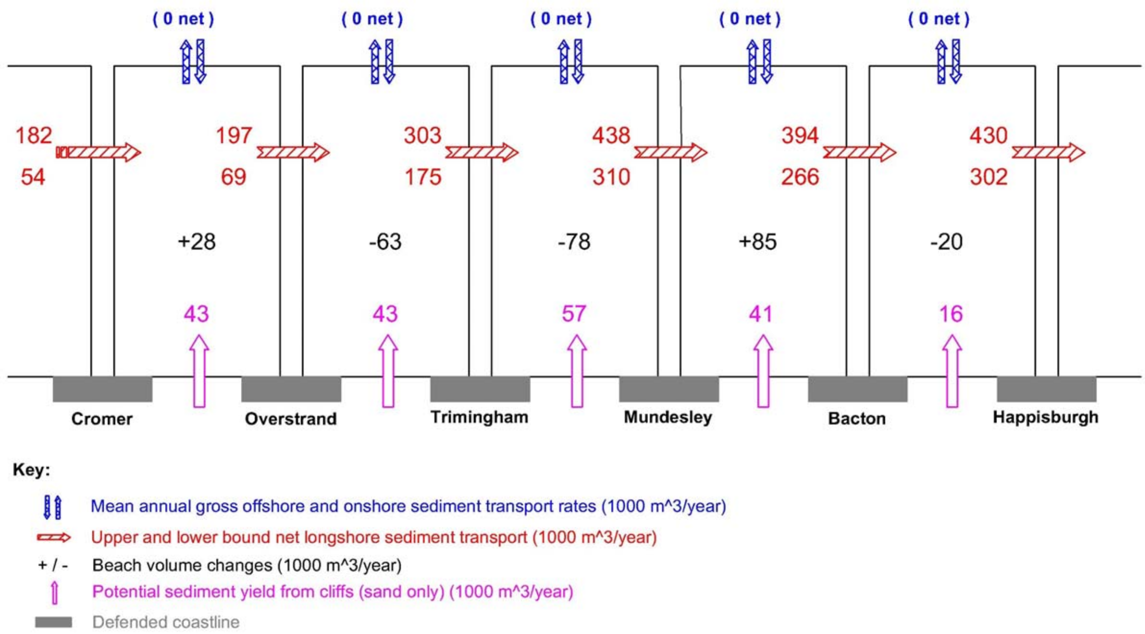

Figure 14 Sediment budgets in the study area

Influence of dredging

Other causes of beach loss have also been mentioned in connection with the continuing problems of coastal erosion in the study area. Of these the most frequent concern is the effect of offshore dredging for aggregates. The nearest area of seabed where dredging has taken place in recent years is offshore from Caister, about 50km distant to the southeast. This dredging is too far away and in water too deep to affect waves, tidal currents or sediment transport processes in the Overstrand/Mundesley area.

4.4.2 Future cliff toe position

A regional-scale beach process and shore platform model was established covering the study area as shown in Figure 15. The cliffSCAPE model (based on a model jointly developed by Newcastle University and HR Wallingford) enables the response of the shoreline (cliff toe) to changes in coastal management and other long term coastal changes (for example climate change) to be predicted. The model includes the processes of shore platform lowering and cliff toe recession that governs the retreat of soft coastlines and their response to coastal management interventions. As well as representing the in-situ shore platform and cliff toe, cliffSCAPE models the mobile beach, its role in protecting or abrading the platform and the contribution that cliff and platform sediments make to the mobile beach.

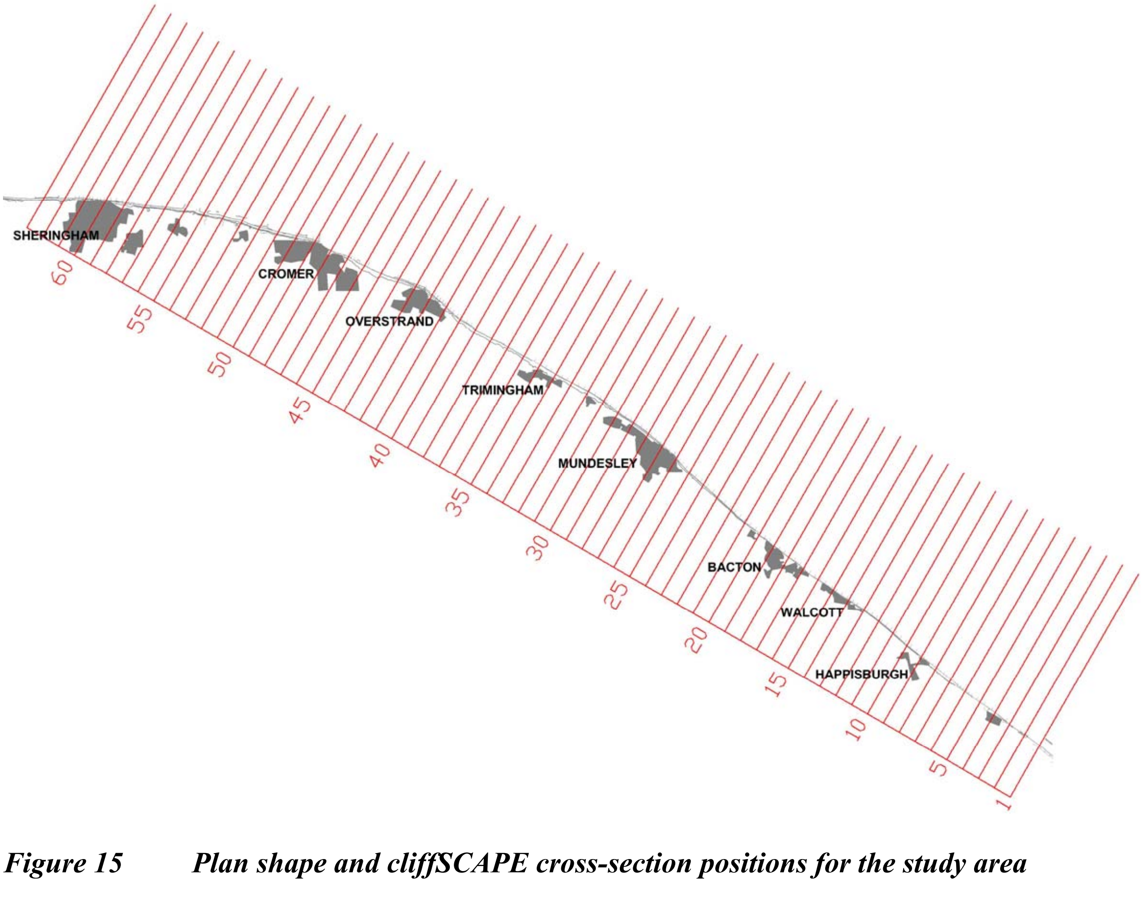

Figure 15 Plan shape and cliffSCAPE cross-section positions for the study area

CliffSCAPE describes a two-dimensional shore section, which is made quasi-3D by using a series of such sections and allowing interaction between them. The model time-step is 12.47 hours, i.e. one tidal period. A flow chart of processes included in the cliffSCAPE model is shown in Figure 16.

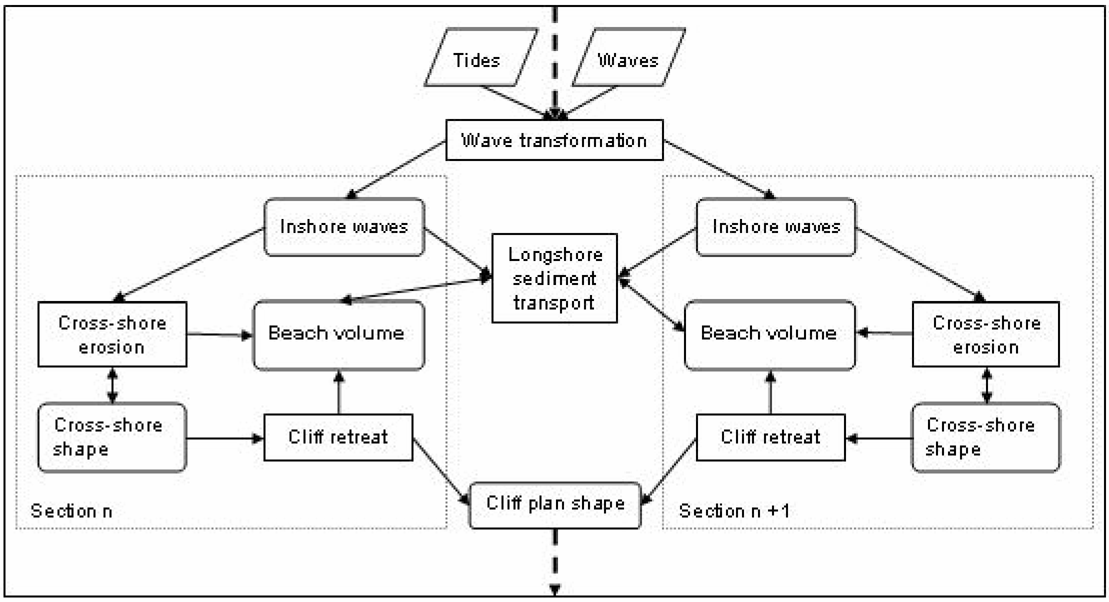

Figure 16 Flow chart representation of cliffSCAPE

As with any model, cliffSCAPE was calibrated against historic recession rates. CliffSCAPE is attractive in that, whilst it has to be calibrated in order to reproduce past average recession rates, differences in recession up and down the coast or across the shore platform are predicted by the model and can be compared with measurements. In this study, comparison between differentials in average recession rates along the north Norfolk coast were used as the main criterion for model evaluation; model output was compared to long-term recession rates.

At a regional scale the key shoreline management infrastructure was represented in the model through the following rules:

- seawalls - a position behind which the cliff profile was not allowed to retreat.
- groynes - a 50% reduction in the applied coefficient of sediment transport.
- revetments - a line behind which wave energy was reduced by three-quarters.

The locations of the structures and construction dates were established in consultation with local engineers and reproduced in the model, after appropriate simplification.

The results of the cliffSCAPE modelling were then moderated through expert judgement in areas of higher complexity or uncertainty.

Model validation

Ensuring the correct profile development

Figure 17 shows ‘snapshots’ of profile evolution, every 25 years at Mundesley. The dots indicate the limits of beach coverage, i.e. the beach covers the platform between the dots. The axes have been distorted by a ratio of about 1:25, which makes the platforms appear artificially steep. Later profiles are higher due to rising sea-levels.

The early profiles (towards the right of the figure) are all similar. The cliff face is very steep, and its junction with the platform is located at approximately the upper limit of the beach. Below this junction the platform slope becomes increasingly gentle, with a marked change a little below the lower limit of beach coverage. The effect of the construction of a seawall in 1910 can be seen in the convergence of the later profiles into a vertical line. This reveals the face of the seawall in front of which the platform continues to drop. The continuing lowering of the platform represents an increase in the vulnerability of the seawall and the cliff it protects.

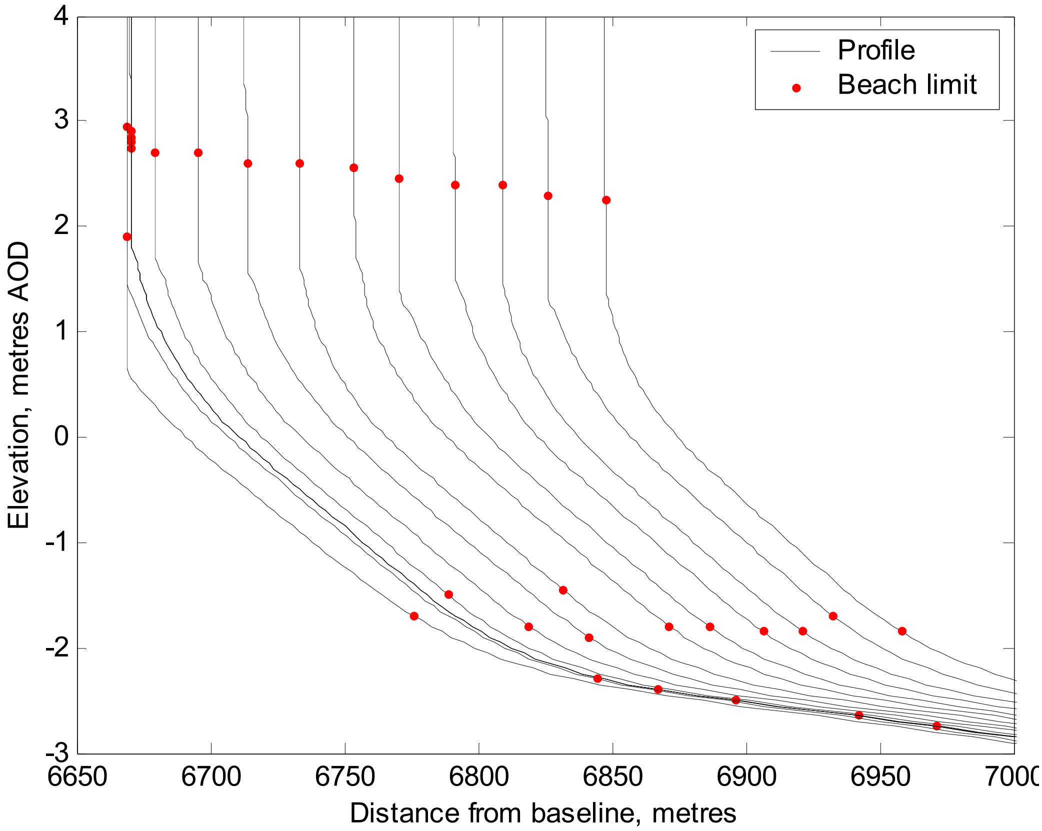

Figure 17 Model profile evolution at Mundesley, 25 year stages from 1600 to 1925

Plan shape development

The evolution of planshape was compared to the historic development of the North Norfolk coast, as measured by Cambers (1976). The comparison, which is shown in Figure 18 is made over three eras, 1880 – 1905, 1905 – 1946 & 1946 – 1967. There is some asynchrony between the model output and the historic measurement period for eras 2 and 3 since data was output from the model at 5 year intervals, e.g. era 2 as modelled spans 1905 to 1945. The results are good, both in terms of magnitude and temporal and spatial variation. The fit is least good in era three. The cause is not clear but it can be attributed, in part, to the short duration of this era, (21 years) and some asynchrony between the recession periods (1946-1967 measured and 1945-1970 modelled). In addition there is an anomaly in the measured data at Overstrand (Chainage 21 km). A seawall has been present there since 1920, but the measured recession over the period 1946 – 1967 is given as approximately 0.7 m/A. The measured data also shows high recession south of Mundesley in the third era that contradicts local knowledge.

As with all models the reliability of model results reduces away from the primary area of interest between Overstand and Mundesley.

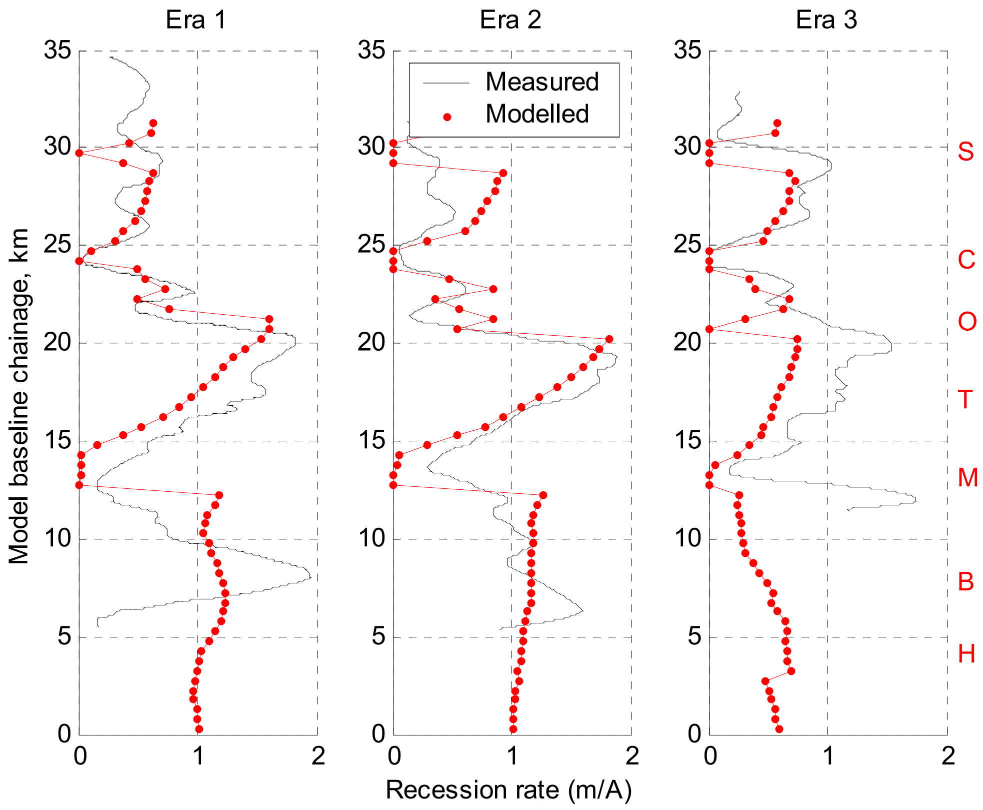

Figure 18 Comparison between model recession rates and measurements provided by Cambers (1976)

4.4.3 Future cliff top position

Coastal landsliding is a consequence of a combination of cliff toe recession and geotechnical processes within the cliff slope. On the north Norfolk coast landsliding on unprotected coasts proceeds by a process of marine removal of material from the cliff toe, resulting in steepening the coastal slope. Eventually the slope becomes geotechnically unstable and a landslide occurs. This reduces the coastal slope and delivers debris to the beach. The timing of the landslide is a function of the rate of removal of material from the cliff toe and other processes, primarily connected with pore pressure distributions within the cliff, that influence cliff stability. The timing of a landslide cannot be predicted precisely. However, knowledge of the rate of shoreline retreat (from cliffSCAPE) can be combined with an assessment of the geotechnical characteristics of the slope to generate an approximate prediction of cliff top location (Walkden *et al*. 2002).

Within a CBU, the cliff can be expected to fail when it reaches an average angle α_f and will, after failure, adopt an angle α_s. Of course neither α_f nor α_s can be predicted precisely. They will vary because of temporal variations in pore pressure and local variations in cliff strength and composition. Even if all the required information were available, they could still not be predicted precisely because of uncertainties in our understanding of the processes of coastal landsliding. The uncertainty in α_f and α_s has been included in the analysis by representing both values as normally distributed random variables, with means and variances obtained from geomorphological assessment of the CBU (see Figure 19 and Table 3).

Further uncertainty is apparent in the initial cliff angle at the site. Within a CBU there will be a range of initial angles, whilst in this analysis (other than for very long CBUs) a prediction of cliff top recession has been generated for entire CBUs or, where appropriate, sub-sections thereof. The initial cliff angle has therefore also been represented as a normally distributed random variable, with mean and variance based on measurements of cliff angle within the CBU (Table 3).

The stochastic model outlined in Figure 19, uses predictions of cliff toe position from cliffSCAPE together with information from cliff surveys to generate a probabilistic prediction of cliff location that can be used in the economic appraisal of strategic coastal management options, based on:

- Predicted recession of the cliff toe
- the cliff height,
- the initial cliff angle
- geomorphological assessments of the pre and post landslide angles

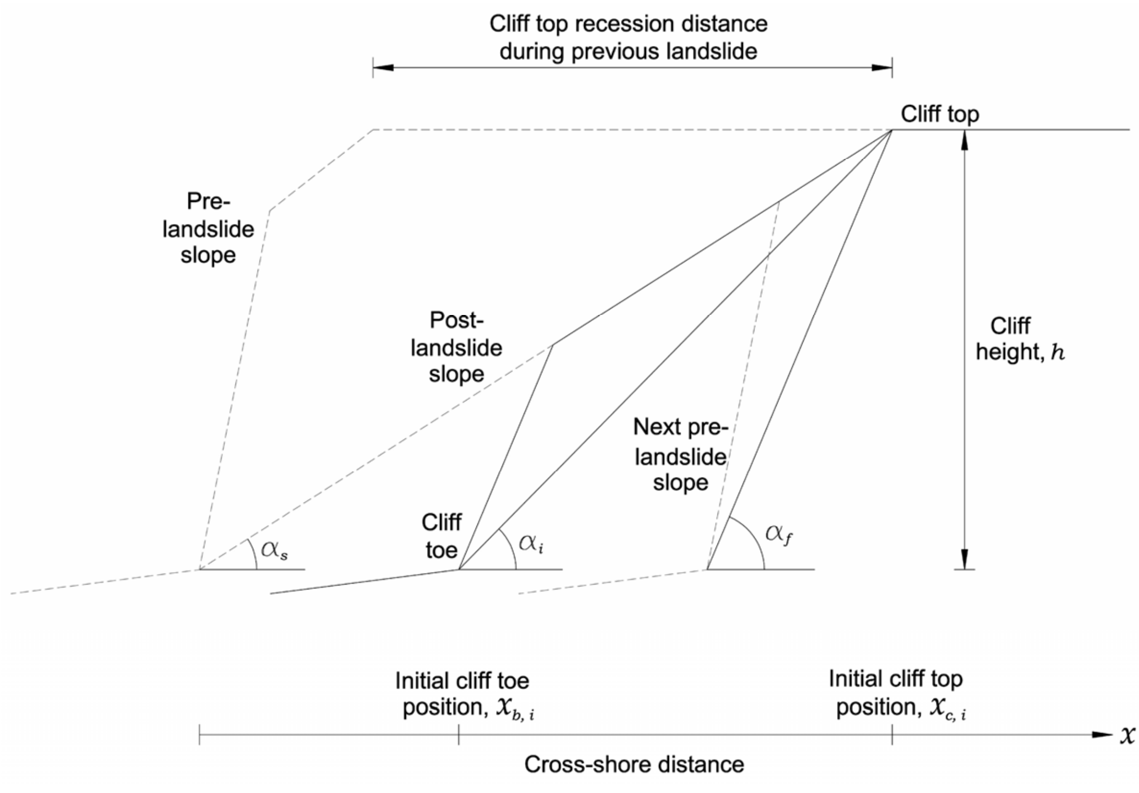

Figure 19 Diagrammatic representation of the coastal landsliding model

Given the variation of angles α_f and α_s a large sample of possible angles were simulated within the probabilistic model and a histogram of predicted cliff top position at any given year in the future generated. A smooth probability density function was then fitted to the histogram of simulation results. This analysis was repeated for each CBU and the range of management scenarios used in the estimation of cliff toe position.

Expert judgement, based on professional experience and site specific survey, was then used to ensure that this provided a convincing model of cliff top recession. An example of a typical output from the analysis is shown in Figure 20.

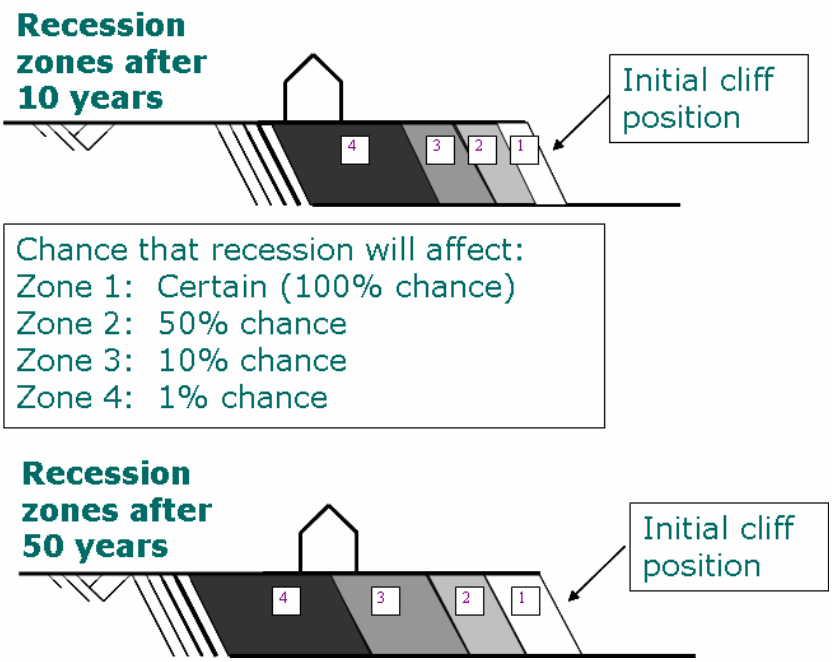

Figure 20 Probabilistic cliff recession - format of model results

The results of this work then formed a key input to the option appraisal (Section 9).

5. Overview of existing defence infrastructure

Visual inspection of the sea defences was undertaken to determine the structural robustness of the sea defences and their probability of failure. These visual assessments were supplemented with ultimate and serviceability limit state calculations of the stability of various wall sections supported by simple geotechnical investigations. These calculations were in turn used to establish a relationship between beach level and the probability of wall collapse (a so-called fragility curve). Under a "do nothing" management scenario this relationship clearly changes with time as the structural components deteriorate. Fragility curves have therefore also been established for future years (see Figure 21 by way of an example) and used to support an estimate of effective residual life for each defence.

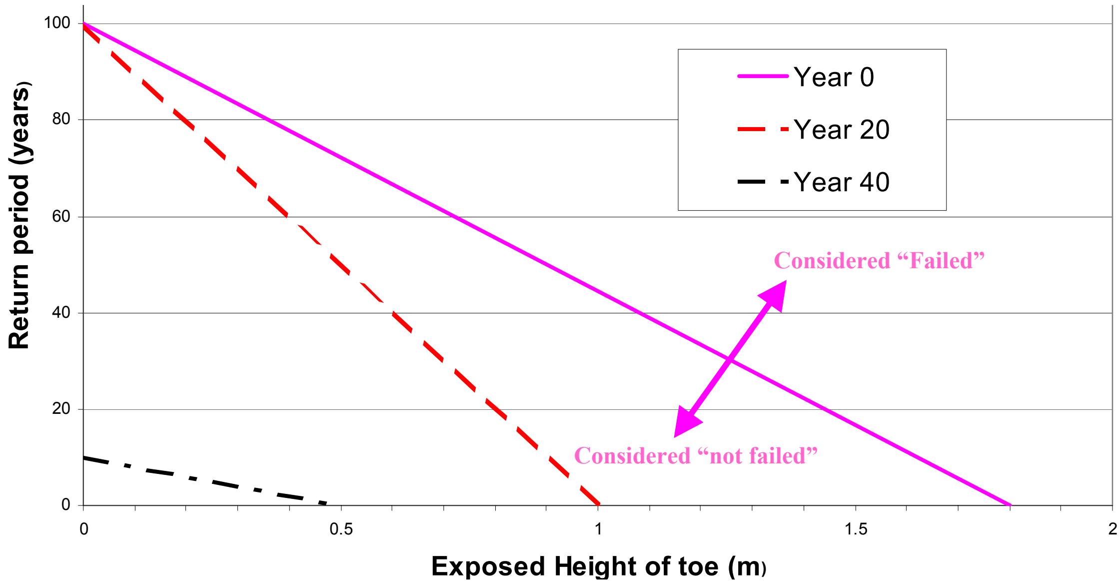

Figure 21 ***Typical fragility curve used to express the probability of defence fragility in support of the assessment of residual life***

An overview of the findings for each management unit is provided below although more detail can be found in the *Defence Condition Survey* report (HR Wallingford, 2003c).

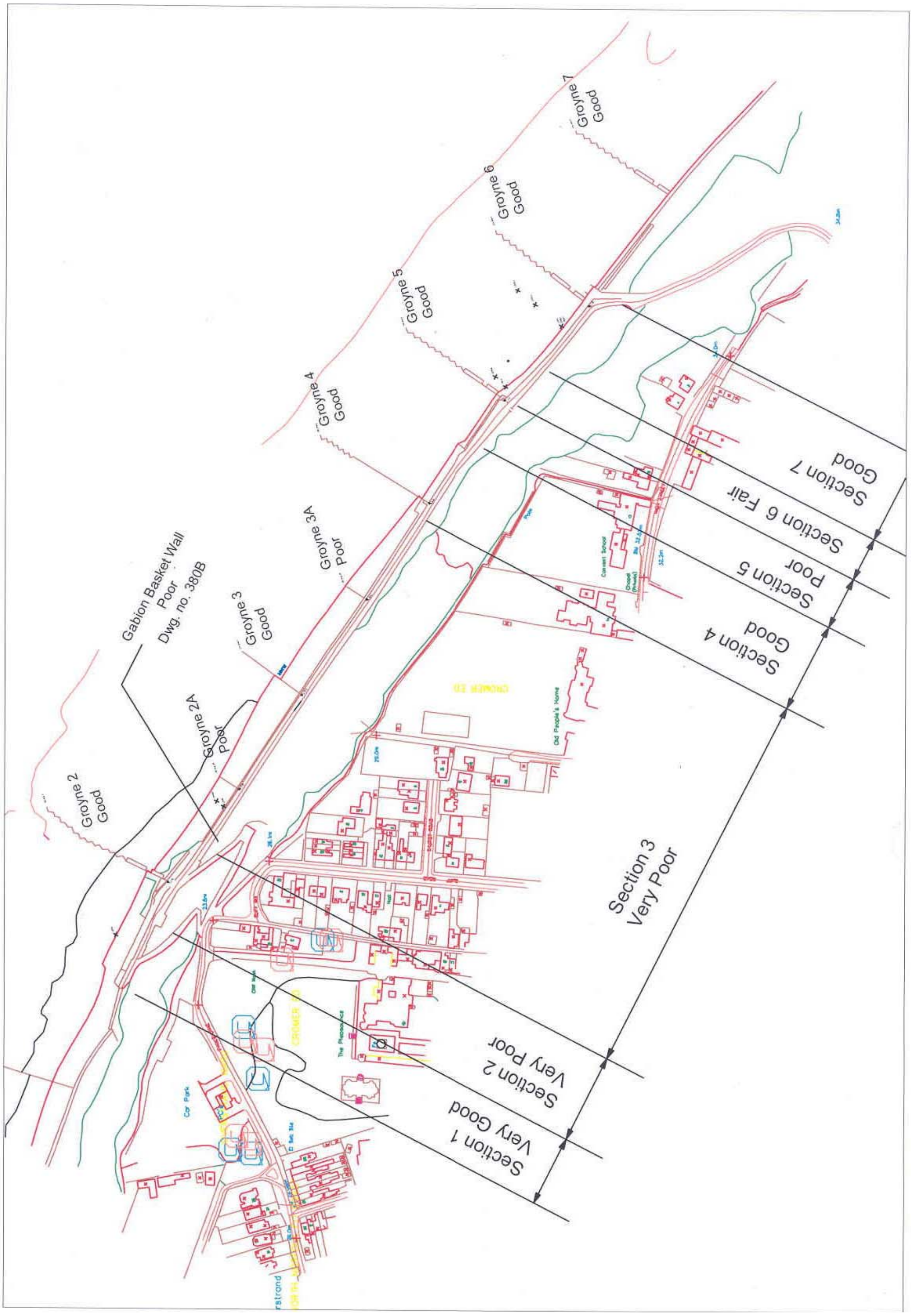

Figure 22 Example of defence length assessment condition rating

5.1 OVERSTRAND

The concrete seawalls at Overstrand are entirely dependent on the stability of the aprons and piles fronting them for their stability. For more than half of the frontage, the steel piles are very badly corroded and at the end of their useful life. Failure of these piles through buckling could lead to seawall failure by overturning. Also, few of the weep holes in the walls are functioning, and most joints in the concrete have lost their sealant or packing. This could affect the integrity of the walls and has been taken into account in the assessment of the defence condition rating. While the main groynes were found to be in good condition with few defects, the two shorter groynes have badly corroded steel components.

Figure 23 Failure of the apron and steel pile toe in 1997 at Overstrand

5.2 SIDESTRAND

This frontage is one of the few stretches of coast in the study area that has never been protected with coastal defences. At its western flank, on the outskirts of Overstrand, the cliffs are protected by a timber revetment which is in poor condition. The eastern flank sees the beginning of the Trimingham defences with a concrete sea wall and timber revetment. The predominately sandy beach is backed by cliffs rising up to fifty metres in height. These cliffs, which are part of a SSSI, are subject to very large failures and slumping.

Figure 24 Wooden revetment with boards missing between Overstrand and Trimingham

5.3 TRIMINGHAM

The toe of the cliff fronting Trimingham is partially protected by a timber revetment, part of which was built on a concrete seawall. The revetment was built in stages between 1972 and 1975. The periodic failures of the cliffs continue to severely damage the timber revetment (which is in poor to very poor condition). The talus from cliff failures is, in places, placing considerable weight against the timber revetment. This will, in turn, cause further revetment failures. A 160m length of timber revetment was reconstructed in July 2003 using rock armour. The groynes on this frontage are typically permeable timber groynes in good condition. However, many of the seaward ends have failed and are in very poor condition. The beach is predominantly sandy but volatile.

Figure 25 Badly damaged revetment and piles

Figure 26 Failure of seaward end of a groyne

5.4 MUNDESLEY

The oldest sections of seawall are now in poor condition. While visual inspections indicate that the newer section is in good condition, its design provides poor resistance to sliding under serviceability limit loads. Thus, a defence condition rating of poor has been assigned to these. Despite their age the rest of the seawalls are in good to very good condition. The groynes are of mixed construction and are generally in fair to good condition with the seaward ends requiring attention. All promenades are in good condition. The retaining walls are also generally in good condition, with some exceptions.

Figure 27 Poor condition of part of old seawall at Mundesley

5.5 BACTON

Timber revetments and timber groynes protect the western end of the Bacton frontage, while the remainder is protected by a seawall extending from Bacton to Ostend (again with timber groynes). The timber revetment in the west, contiguous with the Mundesley defences, primarily protects the economically significant Bacton Gas Site. The gas site is located on a cliff top that reduces in height towards the village of Bacton. The timber revetment was built in the 1960's and is in fair condition. The groynes are permeable, typically of timber construction, and are all in good condition. There are also a number of outfalls serving the gas site which tend to act as groynes. The beach is predominantly sandy in nature but volatile. At times of low beach levels, the temporary works structures associated with gas pipelines can often be seen. The concrete seawall with steel pile toe is generally in good condition. The steel piles have been assessed to be in good condition although there is a minor concern regarding the manner in which they have been anchored to the concrete apron in that there do not appear to be any tie bars. Almost all of the joints in the concrete wall require attention. The promenade formed by the apron varies in condition and is good where repairs have taken place, but otherwise poor. The groynes are typically of timber, permeable construction and are in good condition. The wall protects a mixed community of residential and tourism-related property.

Figure 28 Seawall and steel sheet pile toe at Bacton – note low beach level

5.6 WALCOTT

The entire Walcott frontage is protected by a seawall that is contiguous with that fronting Bacton and Ostend. The concrete seawall with steel pile toe is generally in good condition. However, small sections of the wall exhibit spalling of the concrete, where maintenance works are required. The steel piles have been assessed to be in good condition although there is a minor concern regarding the manner in which they have been anchored to the concrete apron in that there do not appear to be any tie bars. Almost all of the joints in the concrete wall require attention. The promenade formed by the apron varies in condition and is good where repairs have taken place, otherwise poor. The groynes are typically of timber permeable construction and are in good condition. The wall protects a mixed community of tourism related and residential property as well as part of the coast road that runs immediately behind the wall for a distance of approximately 500m. This section is susceptible to overtopping.

Figure 29 Spalling damage to seawall at Walcott

5.7 OSTEND

The village of Ostend is protected in part by a seawall (contiguous with that fronting Bacton and Walcott) and in other sections by a timber revetment. The concrete seawall with steel pile toe is generally in good condition. The steel piles have been assessed to be in good condition although there is a minor concern regarding the manner in which they have been anchored to the concrete apron, in that there do not appear to be any tie bars. Almost all of the joints in the concrete wall require attention. The promenade formed by the apron is generally in poor condition, apart from repaired sections, which are in good condition. The groynes are typically of permeable timber construction and are in good condition. The wall protects a mixed community of tourism related and residential property. A timber revetment built in the early 1990’s protects the eastern part of the Ostend frontage. The revetment is in good condition, having recently been subjected to extensive maintenance works. A particular problem with this particular revetment is the narrow plank spacing that tends to trap mobile flints and cobbles. This in turn causes the revetment to act as a solid wall rather than a permeable structure - causing increased loading on the structure.

Figure 30 Ostend seawall showing exposed steel sheet toe, low beach level, and washed out jointing

6. Overview of consultees concerns and aspirations

Consultation has been fundamental to the development of the strategies. Thus, throughout the duration of the project, efforts were made to ensure that interested parties were able to contact members of the client or project team as necessary. A summary of these activities is provided below.

6.1 OBJECTIVES

The main objectives of the consultation exercise were:

1. To ensure that all people or organisations with an interest in the long-term development strategy for the study area have the opportunity to express their views and aspirations for consideration during the development process.
2. To collect relevant and up to date information relating to processes and practices within the study area.

However, the approach also recognised the context within which the study was undertaken - in particular the extensive consultation carried out during the preparation of the existing Shoreline Management Plan (Halcrow, 1996) to help ensure questions and debate were taken forward rather than repeated, and associated with the various coastal defence and other types of planning and development initiatives.

6.2 CONSULTEES

There are many diverse human and natural environment interests within the study area and the consultation process aimed to consult and involve representatives of as many interest groups as possible. Those parties with potential interests were identified through a range of investigations including the following:

- National, regional, and local organisations such as the Environment Agency, English Nature, and North Norfolk District Council.
- Organisations identified during the preparation of the SMP.

As well as statutory consultees, those representing the following organisations were invited to participate in the consultation process:

- Countryside Agency
- Norfolk County Council
- North Norfolk District Council
- Kings Lynn and West Norfolk Borough Council
- Norfolk Wildlife Trust
- National Trust
- Royal Society for the Protection of Birds
- English Nature
- Environment Agency
- Country Landowners Association
- National Farmers Union
- East of England Tourist Board
- Defra

- Local representative for Sports and Recreation
- East of England Development Agency
- Five elected representatives from the 69 parish councils within the AONB
- An officer from Great Yarmouth Borough Council
- Any other funding partner or group considered appropriate

6.3 MEETINGS, QUESTIONNAIRES AND DISCUSSIONS

Presentations were also made to the Parish Councils of Overstrand and Mundesley-on-Sea on the 6th and 18th of March 2002 respectively.

Presentations of the strategy study were made to the Parish Councils. Chairmen, vice chairmen, councillors, district councillors, and members of the public attended the meetings. An overview of the strategy process was presented followed by the details of the study to date. The opportunity was taken to encourage those present, and others, to contribute to the consultation process. Following the presentations there was a period of open discussion to allow all interested parties to express their views.

A survey was conducted involving discussion groups and questionnaires during the Strategy Study for the Norfolk Coast AONB (1997/98) called ‘The Land and Life Initiative’. The aim was to find out about the views of local people in order to help develop strategy plans. University College London produced a report on this initiative, the summary of which was circulated to parish councils in the AONB for their comments.

Summaries pertinent to this study include;

[1.3.21] In Land and Life meetings, people often found it difficult to understand “*who had overall responsibility for the coast*”. People can feel that they are being “*sent from one organisation and authority to another*” when they try to find out who is responsible for what. *“Gaining the co-operation of all the different people involved*” is felt to be difficult. Decision-making is not seen as transparent, and communication between the many authorities and local people is regarded as less than satisfactory.

[1.3.28] Through living with the sea, local people recognise that “*the power of nature is too great*” for us to expect to be able to maintain the coastline as it is, and that “*solving a problem at one place just pushes it somewhere else*”.

6.4 CONCERNS AND ASPIRATIONS

The main comments made reflected the keen interest of the Councils to maintain and enhance the recreational and tourism attributes of their seafronts. Concerns expressed included the maintenance and repair of existing defences, groundwater in the cliffs, risk of erosion, the need for the appearance of any works to complement local character, and surface water run-off.

In addition to the open forum sessions, those attending were invited to make further comments by post at a later date. However, no new issues were identified using this feedback process.

Other issues and concerns raised by stakeholders included:

- Impact of schemes / designs on landscape and local character

- Works affecting tourism and recreation
- General impacts on designated sites (SSSIs, AONB)
- Impact of strategy on County Wildlife Sites (Mundesley cliffs and Overstrand cliffs)
- Maintenance and improvement of public access
- Allowing natural evolution of the coast
- Requirement for further consultation to inform strategic planning
- Protection of archaeological sites, remains and historic buildings and gardens
- Consideration of the sustainability of defences
- Cliff stability
- Loss of beach material
- Impacts on commerce in the region
- Restriction of new development
- Public conveniences
- Rising sea levels
- Public boat launching facilities
- Private defences
- Implications for adjacent coastlines
- Groyne markers and the need to take account of the navigational requirements of mariners, sailors and jet skiers during any works
- Too many defences – return to a naturally functioning coast
- UK BAP targets for soft cliffs
- Consideration of the European Union's recommendations for Integrated Coastal Zone Management and its concept
- Outflanking of defences
- Cliff top habitats
- Information and communication (of studies, plans, consultations etc.)

The full list of concerns raised and records of public meetings attended are given in the *Consultation (Issues and Concerns)* report (HR Wallingford 2004d).

7. Overview of the economic setting – assets and their value

The section summarises the economic setting, the assets within the study area and their value. For more detail the reader is referred to the interim report on *Economic Valuations* (HR Wallingford, 2004a)

7.1 ASSET VALUES

7.1.1 Residential property

With over 650 residential properties sited within 100m of the cliff top, the potential damage to property from coastal erosion and cliff slides is significant.

A valuation of residential properties, hotels, restaurants, and tourist attractions was undertaken by a local Estate Agent to provide a risk-free market value (base date 2003). Their findings are summarised below.

Table 4 Value of property potentially at risk from erosion (totals by town)[1]

Location	**Total Property Value (£)***
Overstrand	34,529,000
Trimingham	9,174,000
Mundesley	46,732,000
Bacton	13,072,000
Walcott	14,165,000
Total	117,672,000

* Within the area potentially at risk from erosion or flooding

7.1.2 Transport infrastructure

The discrete coastal towns are linked by the single main coastal road, the old B1159 (now reclassified as a "c" route). The potential economic value of this route is a function of its usage and the difficulty in diverting traffic. Through Bacton and Walcott the road is potentially influencing by flooding and hence an economic valuation based on its temporary diversion was considered. Through Trimingham and Mundesley however the road is at risk from erosion and an economic valuation based on a permanent diversion (replacement) has been considered.

7.1.3 Outfalls and pumping stations

In the event of continued erosion, Anglian Water's treated effluent outfall at Mundesley could be lost, together with its supporting infrastructure. The clifftop location of the pumping station at Mundesley is dictated by the layout of the existing sewerage network and given that within the existing network all flows are routed towards the current point of discharge, the pumping and outfall facilities can not simply be reconstructed inland if the present site behind a seawall were to be lost. The capital replacement cost has been

[1] Tables 4 & 7 may appear approximate in general although they are fundamentally different in that table 4 table gives values per <u>town</u> whereas table 7 is for each management <u>unit</u>. Also table 4 figures are residential properties only but table 7 includes all losses.

estimated at £1,428,681 (including two intermediate and one terminal pumping station) and used as a proxy for the economic value of the Mundesley pumping station.

Similarly, the terminal pumping station at Overstrand will be lost if the seawall fails followed by the inevitable cliff failure. Again, the pumping station itself cannot simply be relocated given the layout of the sewerage system in Overstrand. Replacement of these pumping stations would involve the building of new sewers and taking effluent inland rather than towards the sea. In addition, for Overstrand, a new intermediate pumping station with a rising main and a new terminal pumping station on the existing main would need to be built to carry the effluent to Cromer for treatment at an estimated capital cost of £1,654,714 (including a new intermediate pumping station and raising main together with a new terminal pumping station and sewerage sump). Again, this figure has been used as a proxy for the economic value of the Overstrand pumping station.

7.1.4 Commercial activities

The Bacton Gas Site is the United Kingdom's principal processing site for natural gas extracted from the North Sea. The site, operated by three international petroleum companies, represents a multi-million pound investment in the national economy, generating millions of pounds in revenue. In addition, the Interconnector pipeline, used for the movement of gas between the UK and mainland Europe, has its landfall at this site. This pipeline will become increasingly important as the gas reserves of the North Sea become depleted and more gas is imported from Eastern Europe. The site is also the location of a major TRANSCO facility that acts as the wholesale distributor of gas for the UK gas industry.

It is estimated that just one of the three facilities produces gas worth, to the nation, at least £390,000 per day. Extrapolating this to the three sites produces a revenue stream of £1,170,000 per day (based on an estimated £1,300/million standard ft^3).

The Bacton Gas Site is a unique infrastructure facility, of enormous economic importance, serving the UK as a whole. It is the landfall for most of the gas production of the North Sea and there is no immediate viable alternative to the facility.

In such a circumstance the Defra publication FCDPAG3 states:

"A transfer payment occurs when a change simply affects either who gets the consumption or who provides the resources, but there is no change in the national total of either all consumption or all the resources required to generate that consumption."

If the production of the Bacton gas site were to be lost, there would be a dramatic change to consumption of the resource, natural gas, and a consequent impact to the nation's economy. Hence, a loss of production at the Bacton Gas Site is not a transfer payment, and the economic value of the facility is the annual use of the infrastructure (i.e. the revenue stream generated by the site).

The replacement value of the Bacton Gas site facility as a whole is hundreds of millions of pounds. If the coast erodes it is likely that the components under threat would be relocated rather than the whole plant reconstructed, at least initially.

For economic valuation purposes a pragmatic approach has been taken whereby a reconstruction cost of the risers has been used. It has been assumed that when the shoreline is predicted to reach any one of the fifteen risers the interconnector landfall and riser must be rebuilt. The estimated cost of relocating a single riser, excluding any loss of revenue resulting from temporarily shutting down that pipeline is £4,875,000 (March 2003).

7.1.5 Recreation and tourism

The study area has high amenity value in terms of its tourist attractions and accommodation, cliffs, beaches and promenades. Overstrand, Trimingham and Mundesley still depend on tourism for a substantial part of their income – the character of towns like Cromer, depends upon their seafront. When part time and seasonal jobs are considered, the tourism industry supports an estimated 5,690 actual jobs within the North Norfolk District as a whole.

Tourists are primarily attracted to the sandy beaches in the area and loss of this amenity would jeopardise an annual benefit of £3.18 million from day visitors and £1.53 million from staying visitors (£4.71 million pa). Discounted over one hundred years, this annual recreational benefit would yield a Present Value benefit of £32 million. However, without a scheme specific Contingent Valuation Survey it is difficult to attribute these benefits to particular areas or to determine the loss potentially associated with a particular defence failure. In addition, 100 year discounted benefits are difficult to extrapolate from present values when considering beach losses over the long term.

Other assets taken into consideration in the economic analysis were the value of the land occupied by The Royal Cromer Golf Course, playing fields and recreational areas, the costs of relocating caravan parks and replacing chalets. Agricultural land values were based on the average risk-market value – assumed to be £6,769/ha (2002) for the whole of the study area.

Trimingham has two large cliff top caravan / chalet parks, backed and interspersed by residential properties, all at risk from coastal erosion. These caravan parks are recognised as very important to the economy of the area. Access to the beach is provided at Vale Road – the only access point for approximately 6km south of Overstrand. Due to the isolated nature of this access point it is deemed important to maintain it for both public use and for maintenance access to coastal defences.

7.1.6 Historic assets

Listed buildings, scheduled ancient monuments and archaeological features were also identified and valued where appropriate for the purpose of the study. The principal assets exposed to potential erosion over the next 100 years are summarised in Table 5.

Table 5 Listed buildings, scheduled ancient monuments and archaeological features in the study area thought likely to be lost to erosion over the next 100 years under the 'do-nothing' scenario

Name	Location	Listed building grade	First erosion impact (Year)	Value (£000s) (not discounted)
The Pleasance gardens and structures	Overstrand	2	50 –100	1,500
Methodist Chapel	Overstrand	2	100 +	75
Sea Marge Hotel	Overstrand	2	50 – 100	700
Church of St Michael	Sidestrand	2	100	300
WWII Underground HQ	Mundesley	'Historic Site' - Not graded	30+	100 (est)
Church of All Saints	Mundesley	2	50	300 (est)
14 The Dell	Mundesley	2	50	150

Note: £1,500K for the Pleasance gardens is assumed to include the value of all the associated structures such as the Gazebo, Covered Walk and Clock Tower. The value for the Church of All Saints is also an estimated figure and the World War II bunker is attributed a value of 100K as the site, although of historic interest, is not a listed building).

8. Overview of environmental setting

The study area and includes designated areas such as Special Areas of Conservation (SACs), Sites of Special Scientific Interest (SSSIs) and Areas of Outstanding Natural Beauty (AONBs) (see HR Wallingford, 2003e).

Sections of cliff at Overstrand, Trimingham and Mundesley have been designated as SSSIs and the Overstrand cliffs also as a SAC. These designations largely reflect the interesting ecology and geology of the cliffs – largely glacial till. They are recognised as exposures of one of the best pre-glacial stratigraphic sequences in England.

The Sidestrand to Trimingham cliffs SSSI is also designated as a Geological Conservation Review (GCR) site by virtue of features including the Pleistocene deposits of East Anglia, vertebrate palaeontology, and mass movement processes. Furthermore the chalk exposed in the foreshore and cliffs represents the youngest Mesozoic rock in the British Isles and this is the only significant outcrop of chalk of this age in Britain.

The cliffs are subject to frequent cliff falls and slumping: this creates a mosaic of habitats from bare clay and sand to ruderal communities and semi-stabilised grassland with occasional seepage lines that support an outstanding assemblage of invertebrates. With an impressive history of rotational slumping, the cliffs are known as the finest site of slumping unconsolidated sediments in Britain.

The Joint Nature Conservation Committee (1991) describes the principles of conservation for this site as follows:

'The scientific interest of the Trimingham site is the fact that the cliffs exhibit slumping and landslipping. Any constructions that stop or limit this movement therefore detract from the science. However, it would appear that as previous defences have been destroyed, a complex and expensive series of defences would be required to slow down the rate of erosion. This may not be feasible, especially as slippage would still occur as it is seepage induced.'

To the west of Mundesley, the cliffs provide some of the best and nationally important sections in the Pleistocene Cromer Forest-bed Formation, especially in Cromerian marine and freshwater deposits, and freshwater sediments of the early Anglian Cold Stage.

The geological site documentation / management brief (English Nature 1998) states that Mundesley cliffs are of low/medium sensitivity. The document states that any coastal defence works or slope stability measures 'could have very serious and irreversible effect on the geological interest of the site over large areas.'

Hence the nature conservation value attributed to these cliffs is 'Very High'. The study area also includes three County Wildlife sites at Cromer, Overstrand and Mundesley and reflects the interesting flora and fauna living on foreshore, cliff and cliff-top land.

Much of the coastline and immediate hinterland stretching from Mundesley to Heacham forms the major part of the Norfolk Coast AONB. However Cromer, Overstrand and Mundesley themselves are not part of the designation and thus the AONB objectives and policies need not be applied to the management of their sections of coastline and defences. The preservation and enhancement of the coastline and land between the towns however is of importance.

Considerable efforts have been made over the last 200 years to stabilise the cliffs, allowing the building of commercial and residential properties on the cliff top and reducing the threat to existing structures. In urban areas, there is a natural desire to maintain these assets, and this is reflected in the coastal defence policy as set out in the Shoreline Management Plan (Halcrow 1996). This plan envisages 'holding the line' of the present coastal defences at Overstrand, Trimingham, Mundesley, Bacton, and Walcott. ('Hold the line' equates to keeping the defences approximately at their present location and hence, in combination with drainage and other slope stabilisation measures, maintaining the position of the cliff-top.)

These 'Hold the line' policies have reduced the amount of sediment supplied to the beaches by the cliffs along the frontage. Estimates of sediment yield from the North Norfolk cliffs are presented and discussed in the accompanying reports on Cliff Processes and Littoral Sediment Processes (HR Wallingford, 2003a and 2003b).

Recognising that the geological (and biological) attributes of the cliffs along the seafront have been greatly degraded by the development of the coastal towns, English Nature is not opposed to the adopted coastal defence policy. However, this strategy of preserving the cliffs in their present position does conflict with the nature conservation objectives in the study area, which are defined in the North Norfolk Natural Area Profile (English Nature, 1997) as:

'…to allow the natural processes of erosion, sediment transport and cliff mobility to operate. This would enable the following to be achieved:

- *To maintain or restore good exposures of the geological deposits*
- *To allow the movement of sediment along the coast to take place without interference*
- *To allow those cliffs which are unstable to continue to remain mobile*
- *Retain habitat and species diversity*

To attain these objectives it would be necessary to:

- *Resist the addition of new coastal defences, particularly in relation to SSSIs*
- *Resist attempts to stabilise cliffs*
- *Encourage the removal of existing defences'*

These objectives must be considered when evaluating any changes to the extent and type of coastal defences. Particular care will need to be taken to minimise any adverse effects of new defences on the Overstrand Cliffs SSSI / SAC, Sidestrand to Trimingham Cliffs SSSI, and Mundesley Cliffs SSSI.

The sea cliffs are partly vegetated, the nature of which depends on the cliff geology, erosion, geographical location and the degree of exposure to wind and sea spray. Many cliff sites support a number of rare or uncommon plant species. In some exposed areas the vegetation on the cliff-tops grades into maritime heathland, grassland, and scrub that form an integral part of the cliff habitat.

The Sidestrand to Trimingham Cliffs have yielded interesting mammalian fauna, and is known to be the best soft rock cliff site for invertebrates in East Anglia with modern records of rare Coleoptera including *Nebria livida*. Cliff top flora includes a large colony of purple broomrape (*Orobanch purpurea*) a Red Data Book species, which grows inland close to the cliff.

Along the main Overstrand, Trimingham, and Mundesley frontages, however, the long-established seawalls and drains have very largely stabilised the cliff faces, with the result that these are almost completely covered with vegetation. This ranges from close-cut grass sward through to shrubs and small trees. The flora is partly natural and partly introduced species, presumably originating from parks and gardens along the cliff tops. While providing habitats for small mammals and numerous species of bird, both resident and migratory, no particularly important flora, fauna, or associated conservation issues have been identified.

Similarly, much of the cliff-top land around Overstrand, Trimingham, and Mundesley has been developed and covered with residential or commercial properties. There is unlikely to be any significant biological conservation interest in these areas. On the remainder of the cliff-tops, the land is predominantly used for arable farming, and there is generally only a narrow strip of grassland between the tilled land and the cliff edge. It is likely that this habitat, and its species, has developed despite the erosion of the cliff and will continue to survive as the cliff top retreats.

9. Overview of management options

The aim of the Strategy Study is identify the preferred strategic approach to management of the shoreline in the medium to long term. This includes addressing key questions such as whether to hold the existing line of defences or retreat. It also needs to consider possible management options, i.e. are groynes a useful management tool, can seawalls be maintained into the future? This section sets out the strategic options considered and how their implementation costs have been derived.

9.1 OPTION APPRAISAL IN CONTEXT

The strategic option appraisal included in this report is a key stage in the development of the preferred management approach. The aims and objectives of the strategic economic appraisal may be summarised as follows:

- **To ensure best use of public money**
  Demands for public funding always exceed the money available. It is therefore necessary to aim for economic efficiency in the investments that are made. This can only be done by maximising benefit relative to the resource used to achieve that benefit. Using guidance published by Defra (PAG 3) the economic worthiness of any particular intervention is established. To do this an assessment of the flood or erosion damage that may be expected once the scheme is implemented is made and compared to the damage that maybe expected assuming the adoption of a *do nothing* approach. The damage avoided by the scheme is the so-called scheme benefit. The scheme benefits are then compared with the cost of implementation enabling calculation of the Benefit Cost Ratio (BCR).

- **To ensure economic sustainability**
  Sustainability is a key issue in any decision making process. To ensure economic sustainability the decision making process must be mindful of the needs of future generations and should not commit them to unnecessarily expensive solutions or tie in excessive maintenance requirements.

- **To demonstrate accountability**
  A formal process of project appraisal (engineering, environmental and economic) can demonstrate that a wide range of different alternatives has been considered. Economic appraisal is the most auditable of these appraisals and provides the most effective audit trail for the decision making process.

- **Appraisal period and accounting for inflation**
  Options are assessed over a time span of 100 years, with option costs being discounted to a common date (for this study this has been assumed as 2004) using the Test Discount Rate, which was set by the Treasury at 3.5% pa in years 0 – 30, 3.0% pa in years 31 – 75 and 2.5% pa in years 76 - 100. The Test Discount Rate represents the assumed difference between inflation and the likely returns from an investment on the open market and therefore inflation is implicitly included within the discounting process. Once scheme benefits and costs have been discounted to the common base date they are then referred to as Present Values (PVs).

9.2 APPRAISAL ASSUMPTIONS

The performance of strategic management options has been considered in the context the Defra guidance published in 'FCDPAG3 – Flood and Coastal Defence Project Appraisal Guidance – Economic Appraisal' (MAFF 1999) and subsequent amendments, and the following key assumptions:

- A base reference date of March 2003
- An appraisal period of 100 years
- During the appraisal period climate change occurs and sea levels rise
- The boundary conditions in terms of the inflow of sediments from the north west remain unaltered
- No further cliff top development takes place

9.3 STRATEGIC POLICY OPTIONS

A wide range of future strategic management scenarios have been considered and modelled (Table 6). These were used to explore the implications of structure failure, removal, maintenance and improvement and different rates of sea-level rise. Groyne removal, damage and improvement was represented within the model by varying the sediment transport rate, e.g. 20% model groyne damage was represented by a 20% decrease in its effect on the sediment transport rate. The rate of sea-level rise post-2002 assumed for all scenarios, except where noted to the contrary, was 6 mm/a.

For each strategic option a probabilistic estimate of cliff top position has been estimated through a combination of cliffSCAPE modelling and expert judgement.

An example of the type of output is provided in Figure 31 that show the recession of the cliff top at Mundesley assuming a do nothing scenario (Option No. 2 in Table 6) in years 0, 50 and 100.

9.4 STRATEGIC ENGINEERING OPTIONS

Different engineering options exist to achieve the policy options of do nothing or hold the line with different associated costs. Therefore for each policy option a range of engineering options have been considered covering a range of investment levels. These engineering options have been developed based on one of the following generic option types:

- **Do nothing**

- **Monitor shoreline and maintain public safety standards** - this is the basic minimum shoreline management option, involving no attempt to maintain or improve standards of flood or erosion defence, but possibly involving emergency works.

- **Maintain existing standards** - carry out works to maintain existing standards of defence along the existing defence alignment, possibly including upgrading in response to future changes in sea conditions. This option does not include any measure designed to sustain or improve the overall response to the assets in place.

- **Sustain existing standards** - carry out works to sustain the standards of defence, maintaining the approximate alignment of the existing defence (e.g. includes beach renourishment that moves the high water line seaward, or set back walls added at the landward edge of a promenade). Taking steps to ensure that the defences in place at least cause no deterioration in processes or the environment.

- **Improve existing standards -** carry out works to sustain the standards of defence, maintaining the approximate alignment of the existing defence (e.g. includes beach renourishment that moves the high water line seaward, or set back walls added at the landward edge of a promenade). Taking steps to improve coastal processes and the environment.

The details of the above cannot be considered at a strategic level. Therefore, only an appropriate detail is provided on each option to determine the preferred approach at any given location. Further study during the scheme appraisal stage will be required to consider the details of option performance and design.

Details of the options and the costing methods (including an allowance of optimism bias) associated with each engineering option at each location can be found in HR Wallingford, 2004e.

Table 6 Summary of scenarios

No.	Management scenario	Description
1	Open Coast	Remove all seawalls and groynes in January 2003
2	Do Nothing	Structures removed at the mean estimate of residual life
3	SMP policy options	SMP policy option, groynes and seawalls held in present alignment and condition
4	Revised SMP policy options	As scenario 3 but with a Do Nothing policy through Trimingham
5	SMP policy options with groyne modification	20 % increase in groyne efficiency at: • Cromer • Overstrand • Trimingham • Mundesley • Bacton
SMP policy sensitivity to groyne efficiency		
5a	SMP policy options with groyne modification	20% ***increase*** in groyne efficiency at: • Cromer • Overstrand • Mundesley • Bacton
5b	SMP policy options with groyne modification	20% ***increase*** in groyne efficiency at: • Cromer • Mundesley • Bacton
5c	SMP policy options with groyne modification	20% ***increase*** in groyne efficiency at: • Cromer • Bacton
5d	SMP policy options with groyne modification	20% ***increase*** in groyne efficiency at: • Cromer
5e	SMP policy options with groyne modification	20% ***decrease*** in groyne efficiency at: • Overstrand • Trimingham • Mundesley • Bacton With a 20% ***increase*** in efficiency at: • Cromer

Table 6 Summary of scenarios (continued)

No.	Management scenario	Description
5f	SMP policy options with groyne modification	20% ***decrease*** in groyne efficiency at: • Cromer
5g	SMP policy options with groyne modification	20% ***increase*** in groyne efficiency at: • Overstrand • Trimingham • Mundesley • Bacton With a 40% ***increase*** in efficiency at: • Cromer
5h	SMP policy options with groyne modification	20% ***increase*** in groyne efficiency at: • Overstrand • Mundesley With a 40% ***increase*** in efficiency at: • Cromer
Option sensitivity to climate change		
6a	Do nothing	4 mm/A Sea-level rise
6b	SMP policy options	4 mm/A Sea-level rise
6c	Do nothing	2 mm/A Sea-level rise
6d	SMP policy options	2 mm/A Sea-level rise
Option sensitivity to estimated residual life of defences		
7a	Do nothing	Minimum residual life estimate
7c	Do nothing	Maximum residual life estimate

N.B. Unless otherwise stated climate changed assumed at 5mm/yr and groyne efficiency based on calibrated cliffSCAPE model.

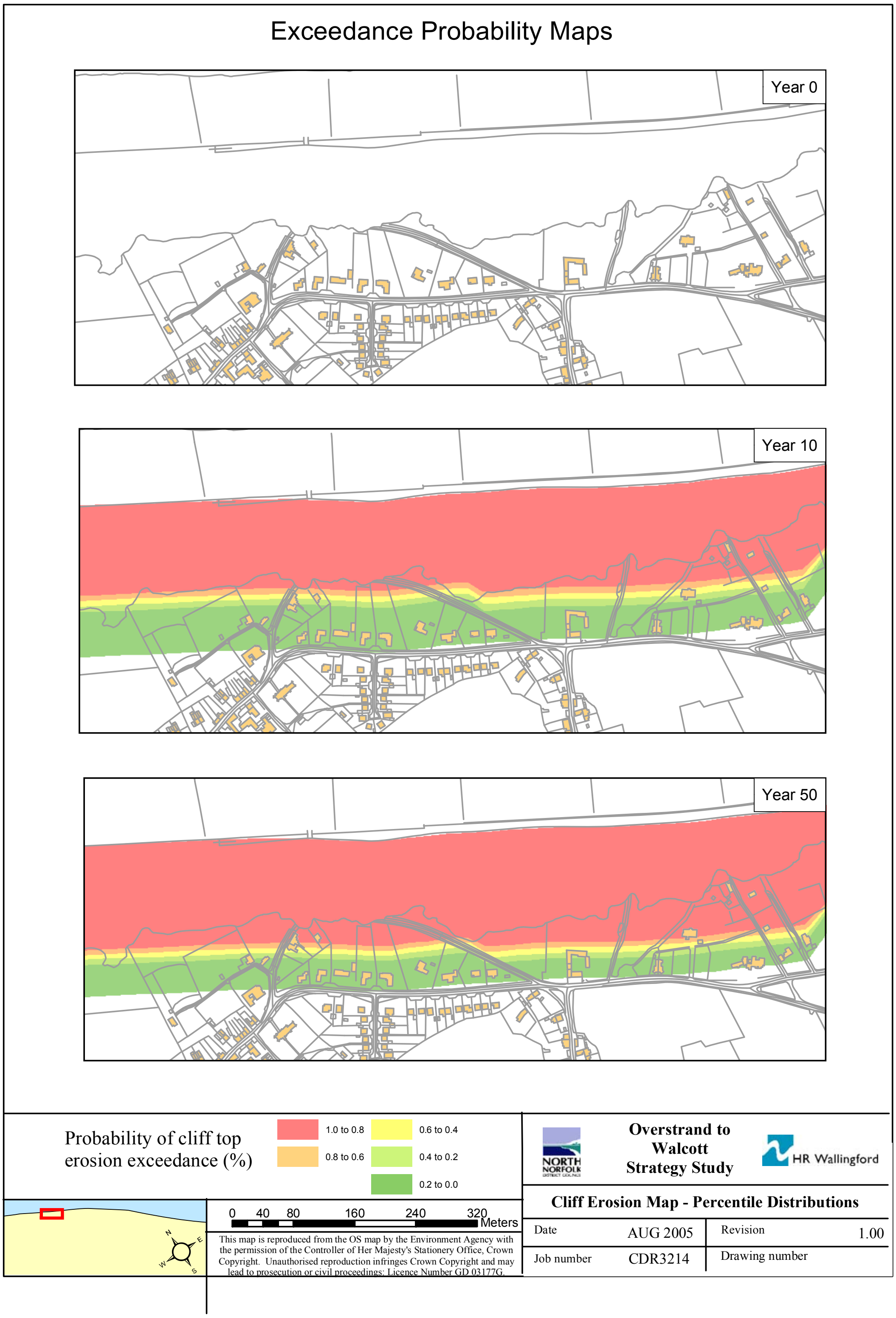

Figure 31 Typical estimate of future cliff top position from the predictive modelling

10. Evaluating the 'do nothing' scenario

To assess the benefits of actively intervening on the coastline with a view to mitigating the risk of coastal erosion and flooding, it is necessary to quantify, and value where possible, the associated losses under the so-called 'Do Nothing' scenario. The 'do-nothing' scenario assumes that the coast is left unmanaged. A summary of the predicted impacts is provided below. More detail can be found in HR Wallingford, 2004b & 2004c.

10.1 DO NOTHING – EROSION LOSSES

In the 'Do Nothing' scenario defence structures are assumed to collapse and have no more effect at the end of their residual life. The residual life of most of the structures is much shorter than 50 years and if not maintained or replaced would leave physical processes to return to their 'natural' state.

Using the analysis described in earlier sections the estimated economic losses assuming a do nothing policy have been estimated to have a total Present Value of approx. £100 million. These losses are broken down by year and management unit in Table 7 and by asset type in Table 8.

Figures 32 to 41 show the estimated (50% percentile) position of the cliff top in years 1, 10, 20, 30, 40, 50 and 100.

Table 7 Valuation of predicted erosion losses by Management Unit

Losses by Management Unit (£k)	**Total PV (£k)**	**Losses (non discounted) (£k)**					
		Year 10	***Year 20***	***Year 30***	***Year 40***	***Year 50***	***Year 100***
TRI1	329	306	309	321	348	382	446
TRI2	8396	1793	2671	3843	5395	17000	34032
TRI3	173	91	100	105	119	138	642
TRI4	2820	0	363	513	689	7231	12848
TRI5	507	0	0	0	119	949	2756
TRI6	13230	3448	3836	9826	13051	24625	46841
BAC1	393	24	24	24	25	381	2399
BAC2	72250	2261	3698	4044	4727	243116	290893
Total Loss (£k)	**98098**	**7921**	**11000**	**18676**	**24472**	**293821**	**390857**

Table 8 Valuation of predicted erosion losses by asset type

Losses by asset type (£k)	**Total PV (£k)**	**Losses (non discounted)**					
		Year 10	***Year 20***	***Year 30***	***Year 40***	***Year 50***	***Year 100***
Properties	87920	3036	6086	12475	18230	275075	358497
Transportation	2398	1283	1283	2552	2552	4955	4955
Commercial	7307	3182	3199	3199	3199	13225	26688
Recreation & Tourism	329	306	309	321	348	382	446
Heritage Sites	0	0	0	0	0	0	0
MOD	0	0	0	0	0	0	0
Agricultural	144	115	124	129	144	184	270
Total Loss (£k)	**98098**	**7921**	**11000**	**18676**	**24472**	**293821**	**390857**

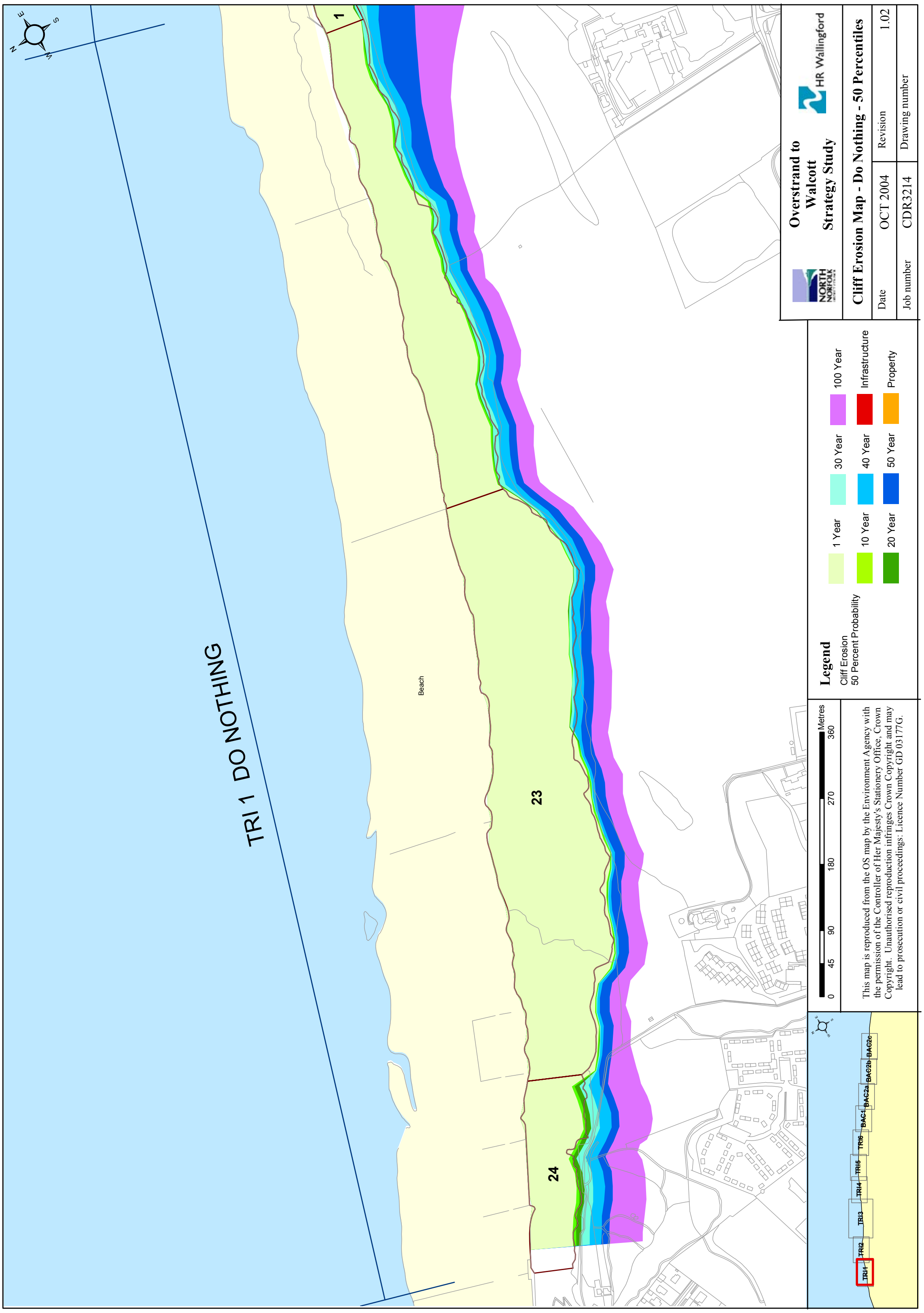

Figure 32 Do nothing – Predicted cliff top recession – TRI 1

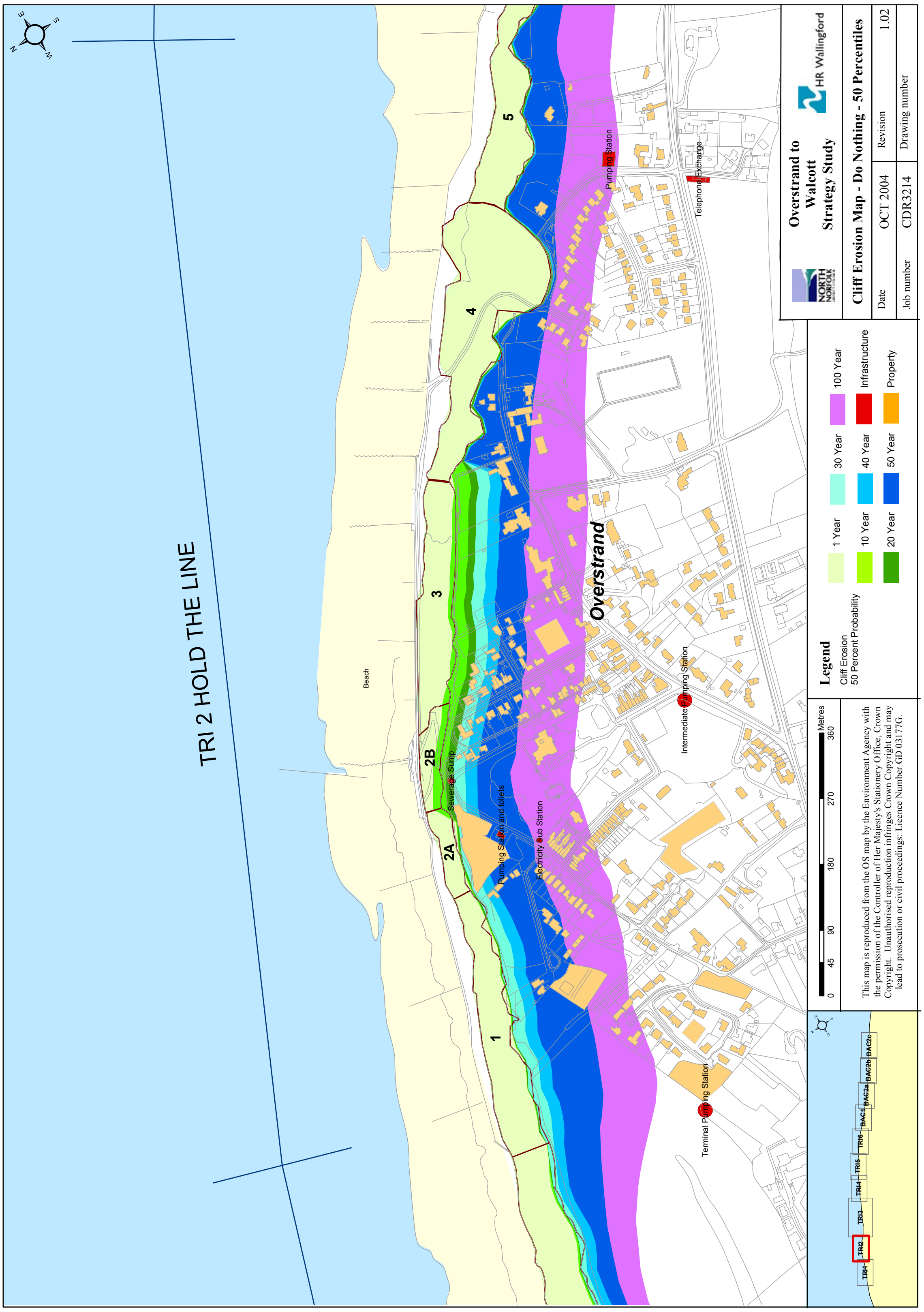

Figure 33 Do nothing – Predicted cliff top recession – TRI 2

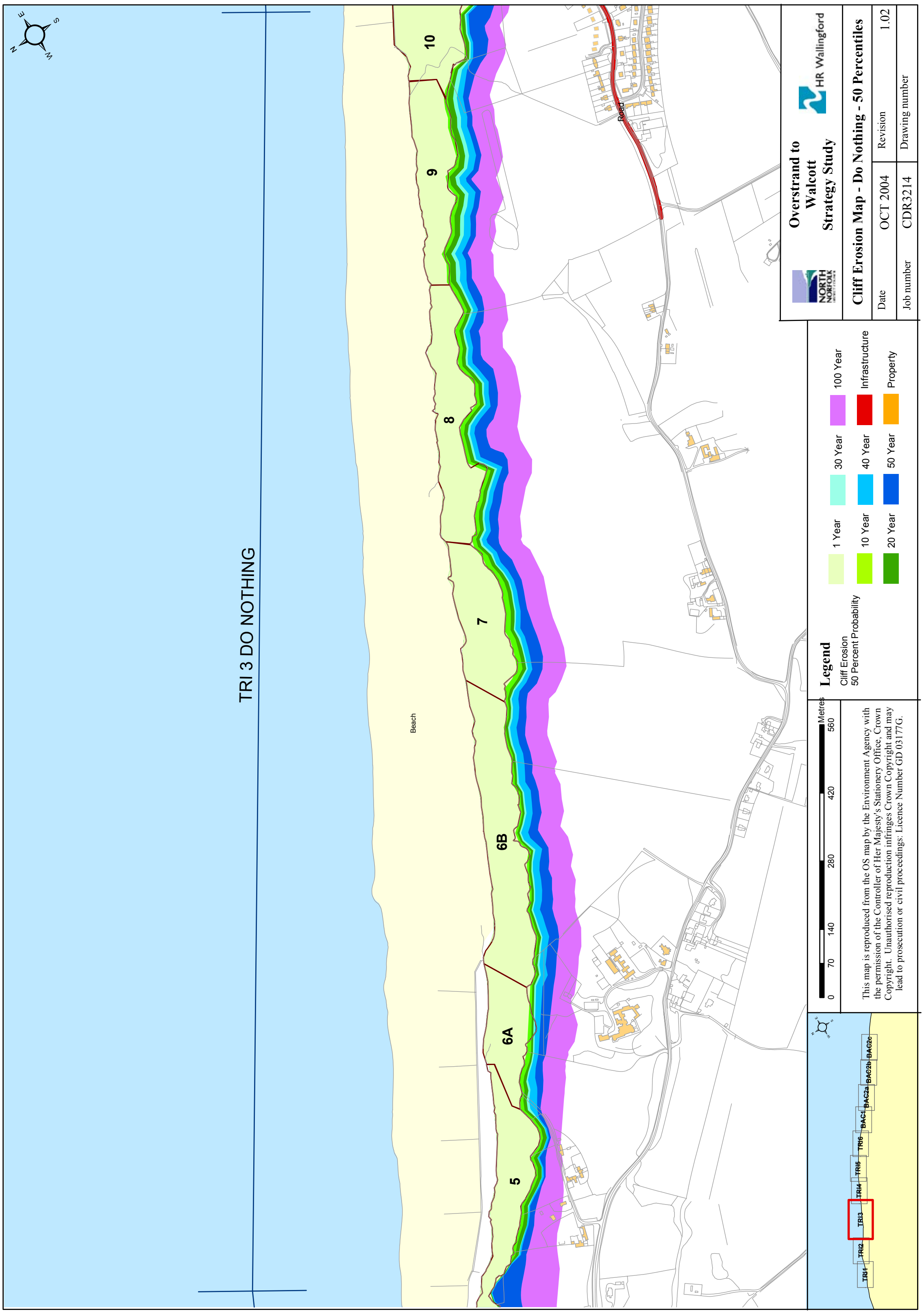

Figure 34 Do nothing – Predicted cliff top recession – TRI 3

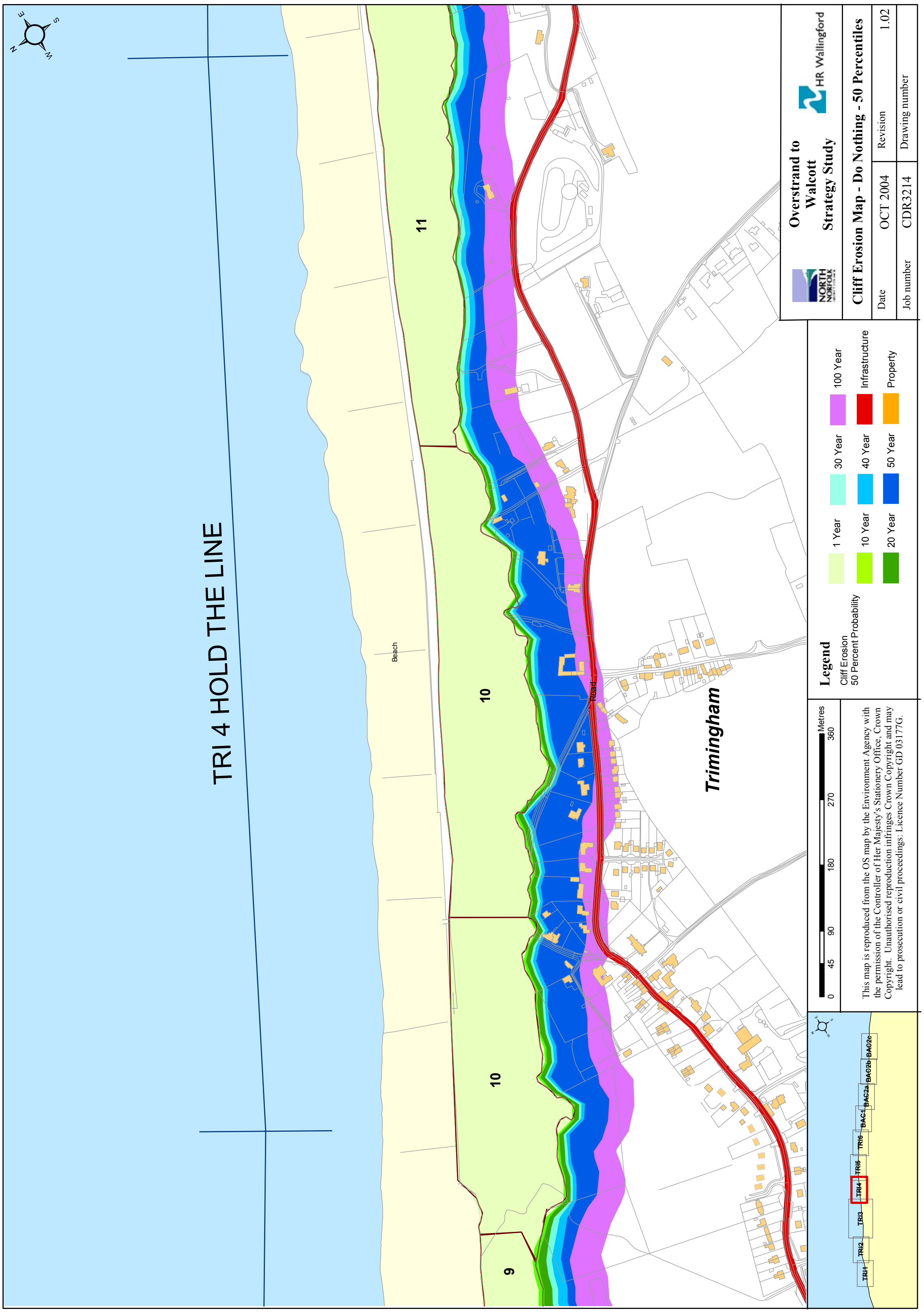

Figure 35 Do nothing – Predicted cliff top recession – TRI 4

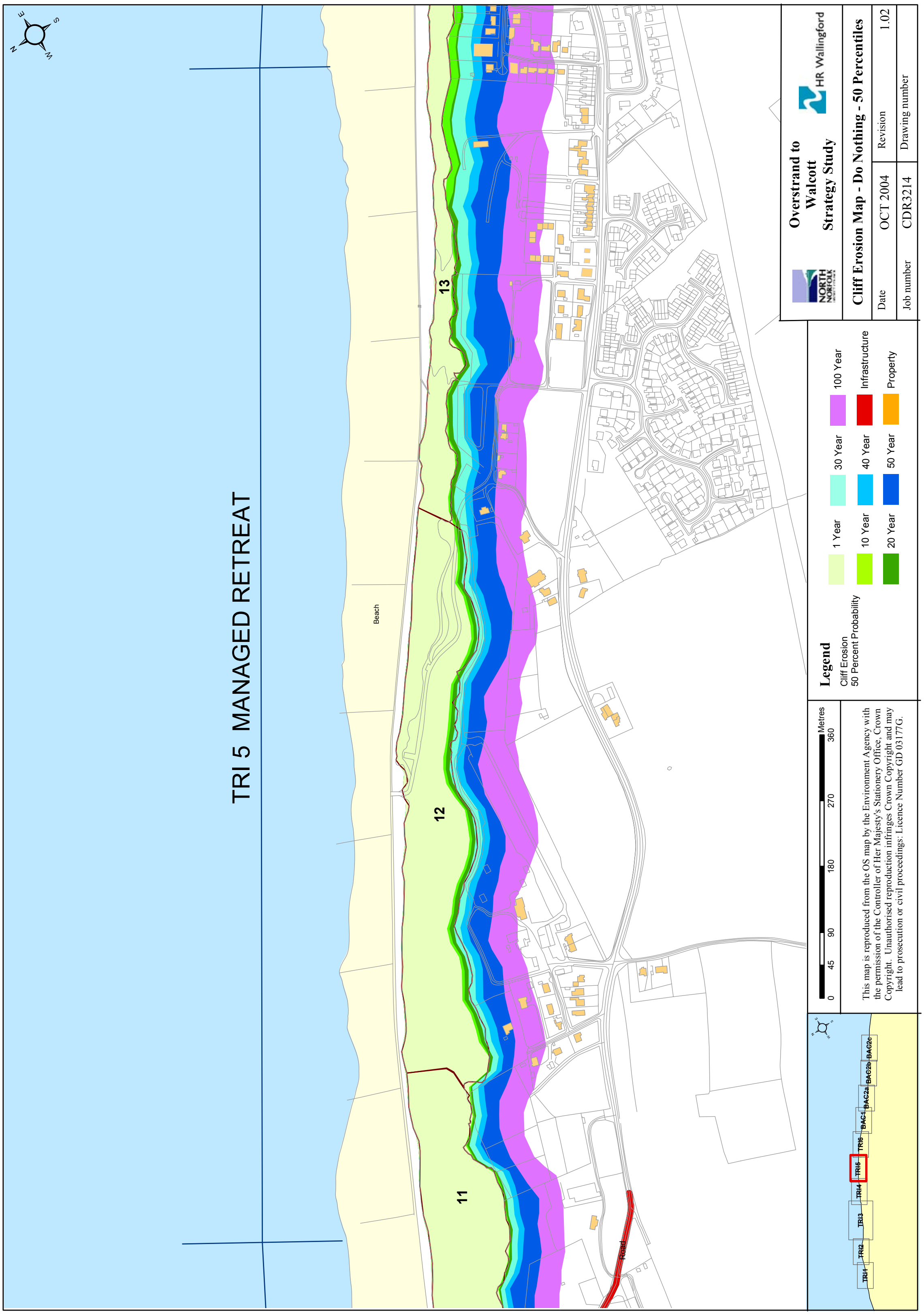

Figure 36 Do nothing – Predicted cliff top recession – TRI 5

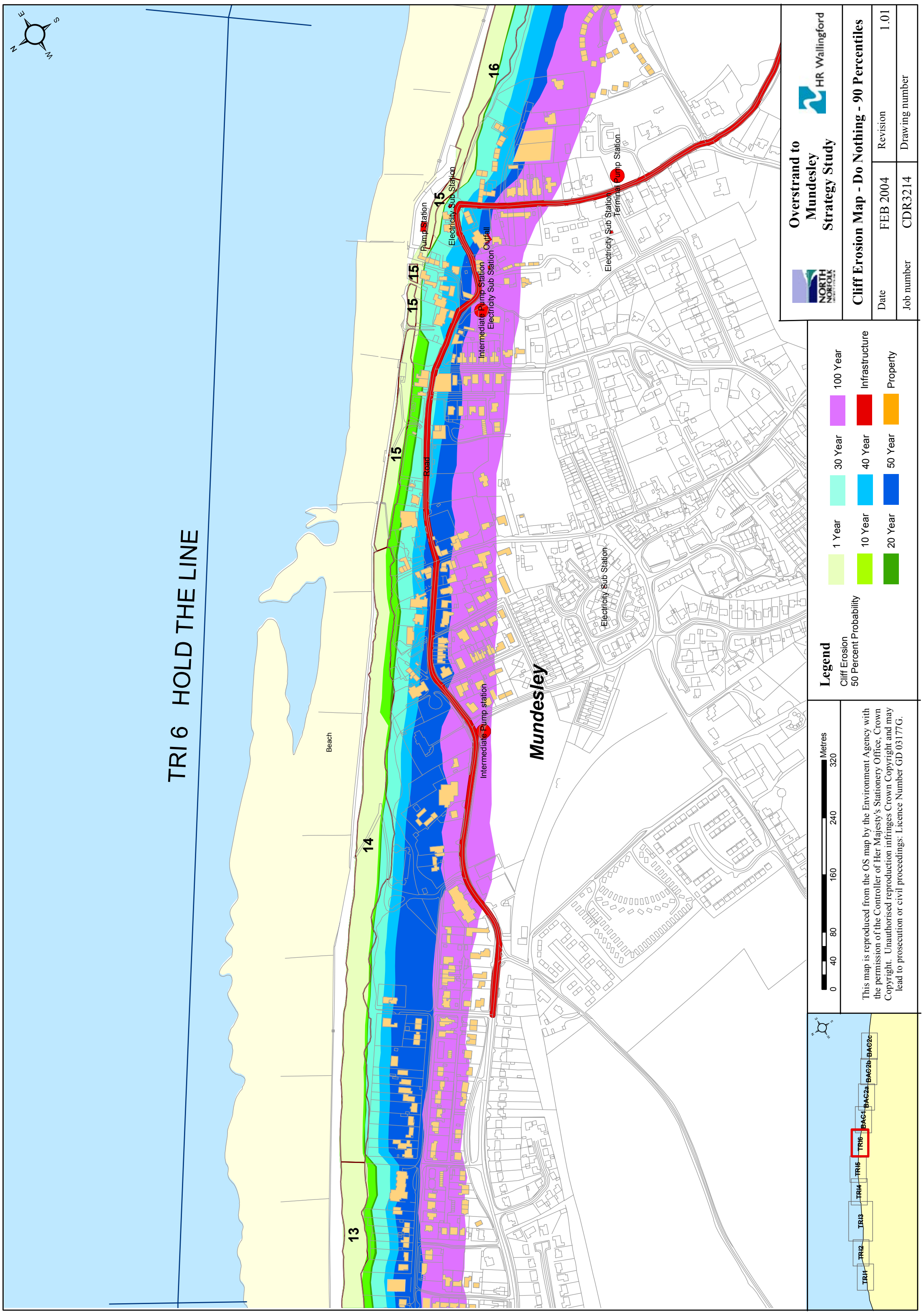

Figure 37 Do nothing – Predicted cliff top recession – TRI 6

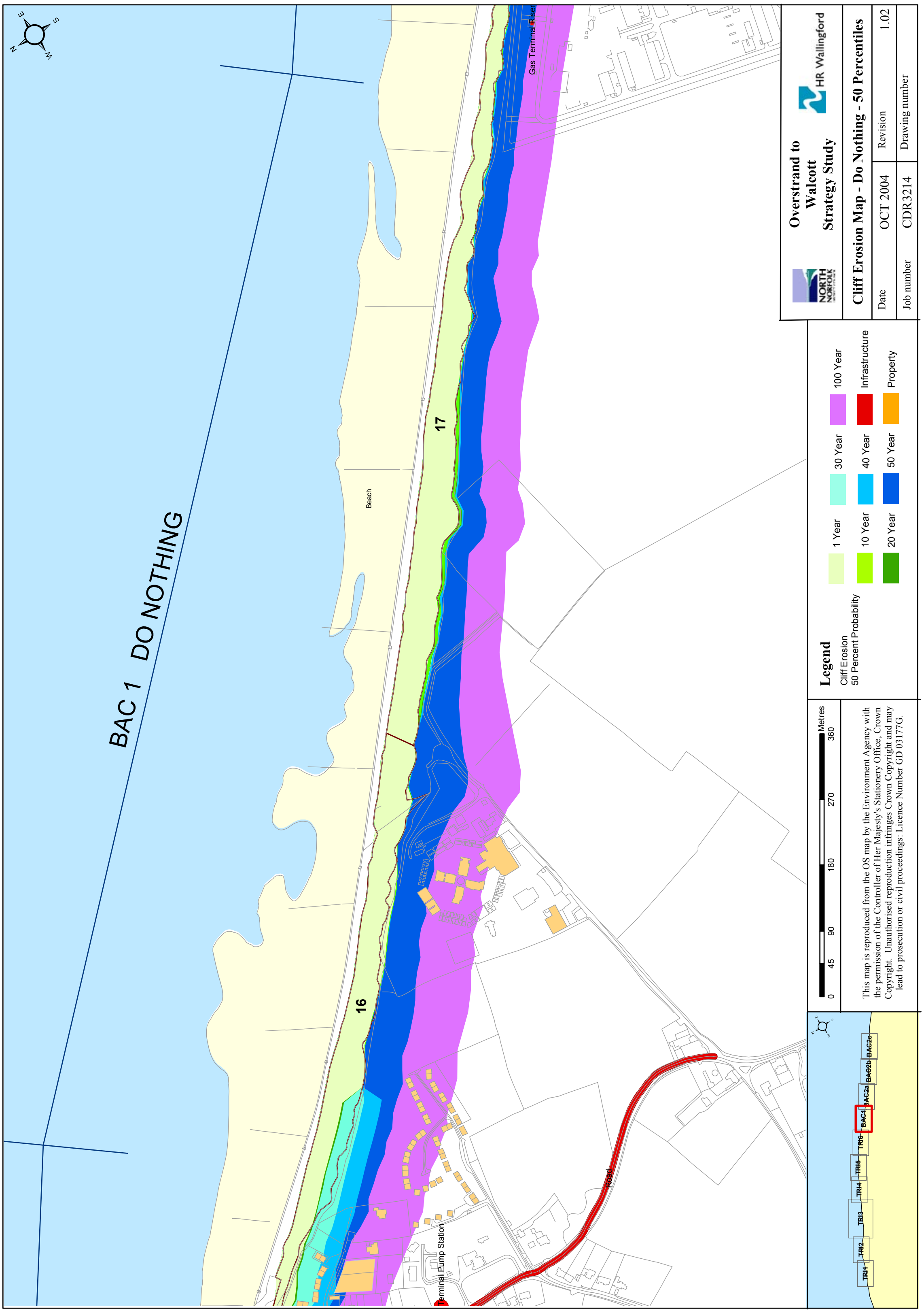

Figure 38 Do nothing – Predicted cliff top recession – BAC 1

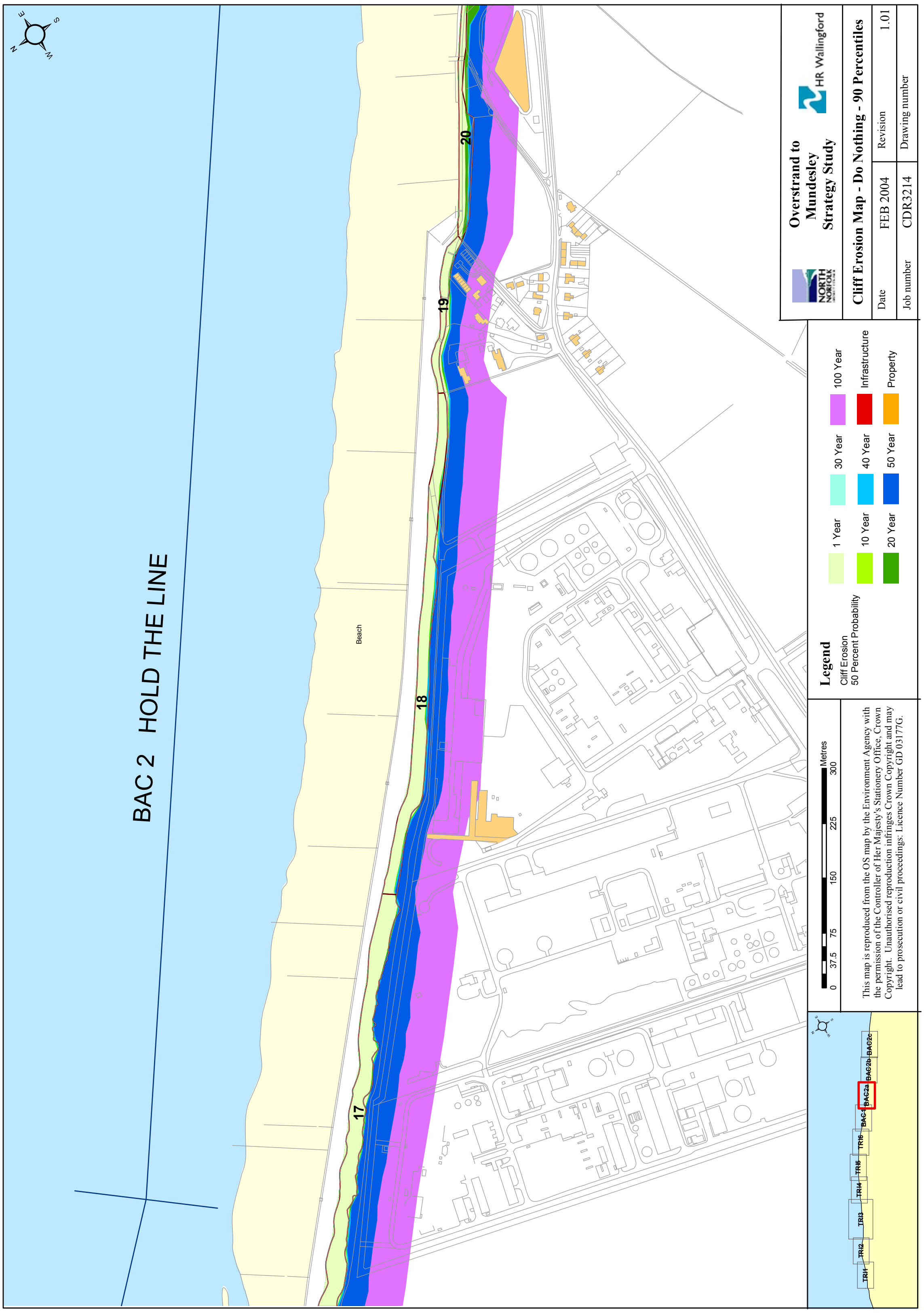

Figure 39 Do nothing – Predicted cliff top recession – BAC 2a

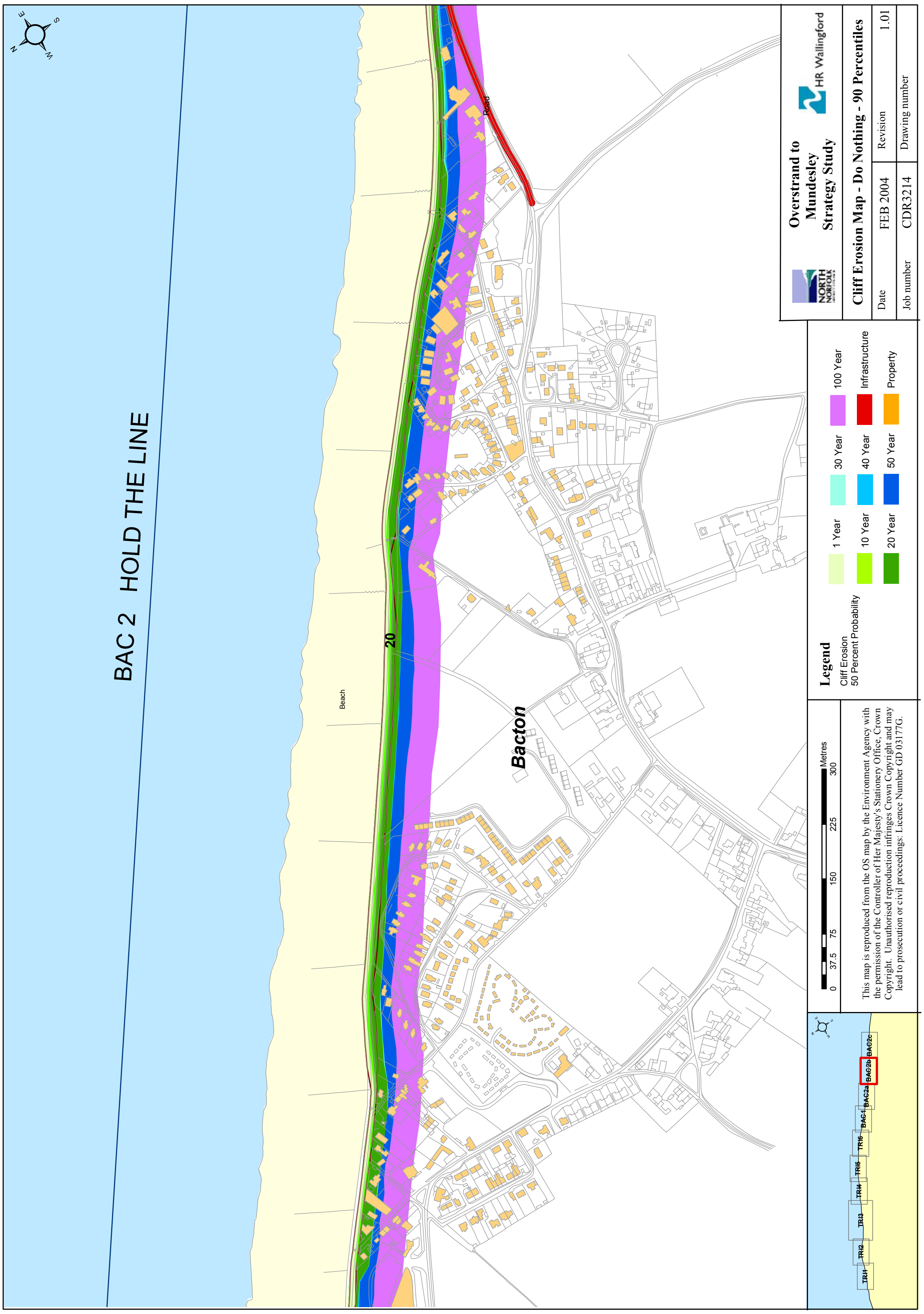

Figure 40 Do nothing – Predicted cliff top recession – BAC 2b

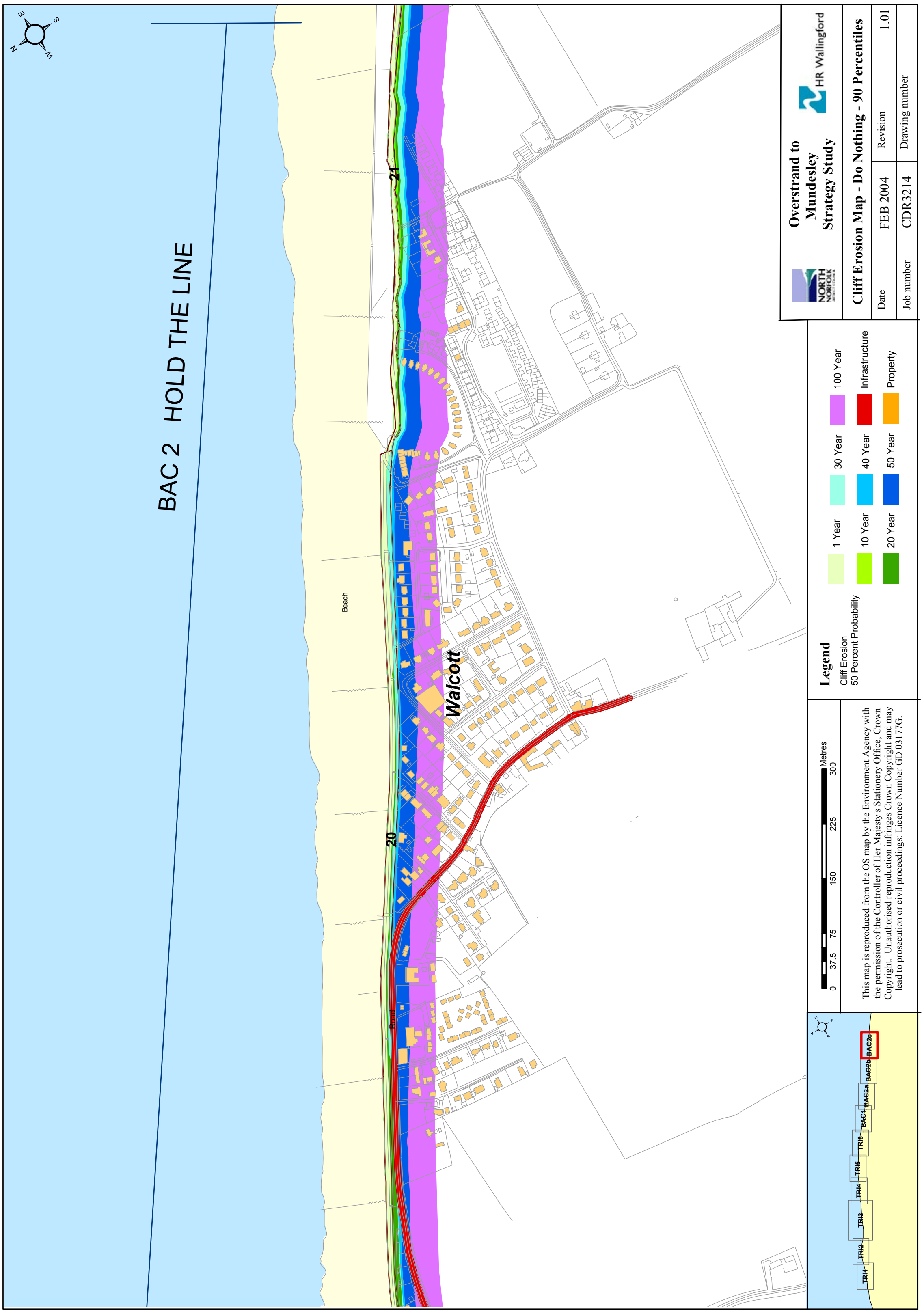

Figure 41 Do nothing – Predicted cliff top recession – BAC 2c

10.2 DO NOTHING – FLOOD LOSSES (WALCOTT)

The Environment Agency's flood map indicates that coastal flooding is an issue of concern in the vicinity of Walcott. Flood risk was therefore investigated through an evaluation of overtopping rates and breach potential. The estimated overtopping rates under both do nothing and maintain existing beach and seawall conditions were then used to drive a LISFLOOD-FP flood spreading model (based on a digital terrain model constructed from LiDAR data). LISFLOOD-FP was used to estimate the flood extent and depth across the study area for several potential storm events and management scenarios (see Table 9). Example results (assuming a 1:100 year storm condition and reduced beach levels associated with the do nothing scenario) are shown in Figure 42.

Table 9 Flood scenarios considered

Management Scenario	Existing defence condition	'Do nothing' residual defence life of 5-10 yrs, coastline receding at Walcott at 0.5m/yr	Sustain Sea level increase of 6mm/yr – present seawall and beach geometry maintained
Return Period (yr) 1 10 100 1000	Based on mean discharge	Based on mean discharge rate Years 0 to 100 (10yr increments)	Based on mean discharge rate Years 0 to 100 (10yr increments)

For each event economic damages were calculated through a depth-damage relationship as given in the Multi-Coloured Manual published by Middlesex University's Flood Hazard Research Centre. The Present Value of the total recurrent flood damages over the 100 years appraisal period under the do nothing scenario (and including climate change) would exceed the write off value of the affected assets and therefore was capped at £5,025k.

Figure 42 *Example of flood mapping at Walcott – 1:100 storm event – Do nothing scenario*

10.3 OVERVIEW OF ENVIRONMENTAL IMPACTS – DO NOTHING SCENARIO

Any works carried out along the seafront at Overstrand will almost certainly affect the SAC at Overstrand and would be likely to influence the Sidestrand to Trimingham site too. Works at Mundesley would potentially affect the Mundesley Cliffs SSSI but they are less likely to have any significant impact on the sites to the west.

Consideration should also be given to the geomorphological consequences of coastal defence schemes. The present policy at Overstrand, Trimingham, Mundesley, Bacton, and Walcott is 'Hold the Line,' but the coastline on either side is allowed to retreat. (Specific policies are 'Managed Retreat' along the management unit between Trimingham and Mundesley and 'Do Nothing' along the units between Cromer and Overstrand, Overstrand and Trimingham, and Mundesley and Bacton.) Over a long period, this will result in the Overstrand, Trimingham, and Mundesley seafronts forming promontories. This will disrupt the natural longshore transport of beach sediment, either retaining it on the up-drift side of the defences (presently to the west) or causing it to be lost offshore. A disruption to the drift regime in this area may eventually adversely affect the beaches in front of low-lying areas between Eccles and Great Yarmouth.

Many of the cliffs along the coastline of Norfolk form important habitats for wildlife, particularly between Cromer and Mundesley and several areas have been notified as SSSIs[2] partly or predominantly because of their flora and fauna, and Overstrand Cliffs is now a SAC. This means that the Overstrand Cliffs designated area contains habitat types and/or species that are rare or threatened within a European context. The Sidestrand to Trimingham Cliffs SSSI, although notified for its geological interest, also has considerable biological interests as well (rare invertebrates and plant communities).

Thus although there are physical losses of land associated with cliff erosion and land-slipping, if anything, there is an environmental <u>gain</u> in <u>not</u> preventing erosion processes from acting by a) providing a particular habitat (probably un-recreatable) for rare species of flora and fauna, and b) maintaining the geological interest of the cliffs.

[2] One objective of the EU SSSI designation is that (subject to natural change) the site should be *maintained in favourable condition. (*Maintenance implies restoration if the feature is not currently in favourable condition).

11. Evaluating alternative strategic options

The Shoreline Management Plan (1996)[3] identified high level management policies for each Management Unit within the study area as shown in Figure 43. Within the SMP (1996) the policies of 'do nothing', 'managed retreat' and 'hold the line' are described below:

- **Do nothing** Allow natural processes to act with no intervention (the consequences of this option are used to assess the benefits arising from the other options).

- **Managed retreat** Allow the natural processes to realign the shoreline to a more swash aligned profile that is more environmentally, technically and economically acceptable. There should be some active intervention, such as transitional works, to control the rate of realignment.

- **Hold the line** Maintain or improve the existing shoreline defences.

Within each Management Unit this strategy has identified a series of defence lengths. For each defence length a variety of engineering options have been identified to achieve the stated policy goal. These options have been costed and assessed in terms of their whole life performance including maintenance requirements.

Each policy and associated engineering option has been assessed against economic, engineering and environmental performance criteria using the framework outlined below.

- **Economic appraisal**
  The economic assessment evaluates whether the options are worthwhile investments for the UK tax-payer. To do so, the flood or erosion damage that may be expected once the scheme is implemented is compared to the damage that may be accepted assuming the adoption of a *do nothing* approach. The damage avoided by the scheme is the so-called scheme benefit. The cost of implementing the option can then me compared with the option benefits to derive a Benefit Cost Ratio (BCR). As long as this ratio is greater than one, the option can be considered to be economically justifiable and the higher the BCR the better.

- **Engineering/technical feasibility**
  This considers the issues involved with constructing, maintaining, and if relevant, demolishing an option. In particular if technically feasible, can it be built and maintained safely?

- **Environmental appraisal**
  The environmental assessment evaluates the impact of an option in a number of different areas.
  - Property
  - Environment

[3] The SMP from 1996 is currently being updated in parallel with the development of the Strategy.

- Amenity
- Health & Safety
- Commerce
- Heritage
- Coastal processes

For each a classification of either beneficial, acceptable, no impact, likely to be unacceptable or unacceptable was then made together with an assessment as to whether the defence standard is maintained, sustained in the face of climate change or improves the standard of protection.

11.1 DESCRIPTION OF ALTERNATIVE OPTIONS

The most significant source of damage in the “do nothing” scenario arises from coastal erosion with only limited flood risk. Therefore all the options considered, other than “do nothing” and “demolish defences”, will at least maintain the defences on their current alignment and prevent the erosion of the shoreline. Therefore, the benefit associated with each of these options is equivalent to the damages incurred under the “do nothing” case.

The option appraisal process involves selecting both the preferred policy and the preferred engineering option for achieving that policy.

The preferred policy options

Through the analysis of the future regional evolution of the cliff the possible policy options have been reviewed. For all but TRI 4 (Trimingham) and TRI 5 (between Trimingham and Mundesley) the policy options within the SMP (Halcrow, 1996) have been shown to be appropriate. However, revised policy options of “do nothing” have been identified for TRI 4 and TRI 5.

The preferred implementation options (on technical and environmental grounds)

For each Management Unit a range of engineering options have been considered in order to achieve either the existing or proposed revision of the SMP policy options. From the engineering options considered a technically preferred option has been identified (see Table 10). However, to inform the selection of the overall preferred option this has been compared against the least cost engineering option for achieving a given management policy.

Figure 43 Management units and existing Shoreline Management Plan (1996) policies

Table 10 Description of preferred Engineering and Environmental options

Management Unit	Defence Length	Preferred Engineering and Environmental Options	Pv Cost (£K)	Annual Monitoring (£K)
TRI 1	1.01 & 1.02	Do Nothing - monitor	0	128
TRI 2	2.01 & 2.02	Hold the Line. Demolish existing timber revetments and replace with rock revetment and monitor	1,526	45
	2.03	Hold the Line. Add scour protection to existing sea wall and enhance groynes making them impermeable and monitor	4,917	57
	2.04 & 2.05	Hold the Line. Demolish existing timber revetments and replace with rock revetment and monitor	1,539	39
TRI 3	3.01	Do Nothing – monitor	0	71
TRI 4	4.01 & 4.02	Do Nothing – monitor	0	148
TRI 5	5.01 & 5.02	Do Nothing – monitor	0	153
TRI 6	6.01 & 6.02	Hold the Line. Demolish existing timber revetments and replace with rock revetment and monitor	3,115	102
	6.03	Hold the Line. Maintain existing seawall and enhance groynes making them impermeable and monitor	1,481	52
	6.04	Hold the Line. Repair timber revetment and monitor	490	16
BAC 1	1.01	Do Nothing	0	138
BAC 2	2.01 & 2.02	Hold the Line. Demolish existing timber revetments and replace with rock revetment and monitor	3,703	137
	2.03 to 2.05	Hold the Line Maintain existing seawall and enhance groynes making them impermeable and monitor	13,987	299
	2.06	Hold the Line. Demolish existing timber revetments and replace with rock revetment and monitor	1,472	51
		Total	32,230	1,436

The preferred combination of policy and implementation options (overall)

In arriving at a recommendation for the coastal defence strategy a combination of policy options and engineering options (least cost and technically preferred) have been considered. An initial summary of the economic performance of the possible combinations of options is summarised in Table 11 assuming policies and options maintained for the whole of the 100 year appraisal period.

Table 11 Summary BCRs for least cost and preferred implementation options for the existing and revised policy options

Management Unit	Existing SMP Policy Options	Revised Policy Options	BCR **Least Cost** Option: Existing SMP Policy Options	BCR **Least Cost** Option: Revised Policy Options	BCR **Preferred Option**: Revised Policy Options
TRI 1	Do Nothing	n/c	-	-	-
TRI 2	Hold the Line	n/c	1.1	1.1	1.0
TRI 3	Do Nothing	n/c	-	-	-
TRI 4	Hold the Line	Do Nothing	0.4	-	-
TRI 5	Managed Retreat	Do Nothing	-	-	-
TRI 6	Hold the Line	n/c	2.7	2.7	2.5
BAC 1	Do Nothing	n/c	-	-	-
BAC 2	Hold the Line	n/c	4.0	4.0	3.7
		BCR for whole frontage	2.6	3.0	2.8

n/c = no change to SMP Policy.

From Table 11 the following initial conclusions can be drawn:

- TRI 1, 3 and BAC 1 – The do nothing policy is appropriate in the longer term.
- TRI 2, 6 and BAC 2 – Through Overstrand (TRI 2), Mundesley (TRI 6) and Bacton to Walcott (BAC 2) the policy of Hold the line is appropriate – at least in the medium term.
- TRI 4 – Trimingham - Implementation of even the least engineering option to achieve the existing SMP policy of Hold the line would fail to achieve a benefit to cost ratio in excess of 1. This implies that the costs of intervention significantly outweigh the benefits and hence the policy must be revised from Hold the line to do nothing at some point in the future.
- TRI 5 – between Trimingham and Mundesley – Erosion of the shoreline in this area causes limited economic damage. Therefore, in the absence of potential benefit it is appropriate to revise the SMP policy from Managed Retreat to Do Nothing at some point in the future.

To determine the preferred strategy the optimum transition period from one policy option to another and the associated preferred implementation option must be considered. In recognition of this for an implementation timeframe Tables 12 and 13 consider the performance of the least cost implementation options assuming first the existing SMP policies remain and secondly revised policies assuming, in turn, no active intervention beyond year 20, 30, 40, 50 and 100. Table 14 considers the same but for the preferred implementation options and the revised policy options.

From Tables 12, 13 and 14 it can be seen that:

- TRI 1, 3 and BAC 1 – The existing do nothing policy is appropriate in the longer term.
- TRI 2 – A policy of hold the line would need to be sustained for at least a period of 50 years in order to achieve a positive return on investment (i.e. a BCR of approx 1) assuming implementation of the least cost approach. Adopting the preferred technical / environmental option would increase costs and demand maintenance of the shoreline for 100 years before achieving a break even benefit to cost ratio.
- TRI 3 – The existing do nothing policy is appropriate in the longer term.
- TRI 4 – Trimingham – Even in the short term the least cost action to hold the line can not be justified (see Table 12).
- TRI 5 – between Trimingham and Mundesley – Proposed change of policy from managed retreat to do nothing.
- TRI 6 – Through Mundesley (TRI 6) a policy of hold the line provides a benefit cost ratio in excess of 1.0 assuming implementation of either the least cost or preferred implementation option; the BCR increasing to a maximum of 2.7 assuming the line is held for the whole of the 100 year appraisal period.
- BAC 1 – The existing do nothing policy is appropriate in the longer term.
- BAC 2 – Holding the line through Bacton to Walcott (BAC 2) is the most robustly justified of actions within the study area, achieving a BCR in excess of 4 assuming the current shoreline is held in the long term.

Table 12 Implementation of least cost options in support of existing SMP Policies

No active intervention beyond Year 20

LMU	SMP Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	65	-	-
TRI 2	Hold the Line	3,878	6,805	72	0.6	0.6
TRI 3	Do Nothing	-	-	36	-	-
TRI 4	Hold the Line	1,282	6,364	75	0.2	0.2
TRI 5	Managed Retreat	-	-	78	-	-
TRI 6	Hold the Line	6,030	4,121	86	1.5	1.4
BAC 1	Do Nothing	-	-	70	-	-
BAC 2	Hold the Line	32,625	11,486	248	2.8	2.8
	Total	43,815	28,776	731	1.5	1.5

No active intervention beyond Year 30

LMU	SMP Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	83	-	-
TRI 2	Hold the Line	4,837	6,889	92	0.7	0.7
TRI 3	Do Nothing	-	-	46	-	-
TRI 4	Hold the Line	1,572	6,430	96	0.2	0.2
TRI 5	Managed Retreat	-	-	100	-	-
TRI 6	Hold the Line	7,659	4,218	110	1.8	1.8
BAC 1	Do Nothing	-	-	89	-	-
BAC 2	Hold the Line	37,592	12,249	316	3.1	3.0
	Total	51,660	29,787	932	1.7	1.7

No active intervention beyond Year 50

LMU	SMP Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	106	-	-
TRI 2	Hold the Line	6,483	7,063	117	0.9	0.9
TRI 3	Do Nothing	-	-	59	-	-
TRI 4	Hold the Line	2,107	6,521	122	0.3	0.3
TRI 5	Managed Retreat	-	-	127	-	-
TRI 6	Hold the Line	10,147	4,662	140	2.2	2.1
BAC 1	Do Nothing	-	-	114	-	-
BAC 2	Hold the Line	48,833	15,680	403	3.1	3.0
	Total	67,570	33,926	1,187	2.0	1.9

No active intervention beyond Year 100

LMU	SMP Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	128	-	-
TRI 2	Hold the Line	8,396	7,261	141	1.2	1.1
TRI 3	Do Nothing	-	-	71	-	-
TRI 4	Hold the Line	2,820	6,610	148	0.4	0.4
TRI 5	Managed Retreat	-	-	153	-	-
TRI 6	Hold the Line	13,230	4,773	169	2.8	2.7
BAC 1	Do Nothing	-	-	138	-	-
BAC 2	Hold the Line	72,250	17,447	487	4.1	4.0
	Total	96,696	36,091	1,435	2.7	2.6

AM = Annual Monitoring

Table 13 Implementation of least cost options in support of revised policies

No active intervention beyond Year 20

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	65	-	-
TRI 2	Hold the Line	3,878	6,805	72	0.6	0.6
TRI 3	Do Nothing	-	-	36	-	-
TRI 4	Do Nothing	-	-	75	-	-
TRI 5	Do Nothing	-	-	78	-	-
TRI 6	Hold the Line	6,030	4,121	86	1.5	1.4
BAC 1	Do Nothing	-	-	70	-	-
BAC 2	Hold the Line	32,625	11,486	248	2.8	2.8
	Total	42,533	22,412	731	1.9	1.8

No active intervention beyond Year 30

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	83	-	-
TRI 2	Hold the Line	4,837	6,889	92	0.7	0.7
TRI 3	Do Nothing	-	-	46	-	-
TRI 4	Do Nothing	-	-	96	-	-
TRI 5	Do Nothing	-	-	100	-	-
TRI 6	Hold the Line	7,659	4,218	110	1.8	1.8
BAC 1	Do Nothing	-	-	89	-	-
BAC 2	Hold the Line	37,592	12,249	316	3.1	3.0
	Total	50,088	23,357	932	2.1	2.1

No active intervention beyond Year 50

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	106	-	-
TRI 2	Hold the Line	6,483	7,063	117	0.9	0.9
TRI 3	Do Nothing	-	-	59	-	-
TRI 4	Do Nothing	-	-	122	-	-
TRI 5	Do Nothing	-	-	127	-	-
TRI 6	Hold the Line	10,147	4,662	140	2.2	2.1
BAC 1	Do Nothing	-	-	114	-	-
BAC 2	Hold the Line	48,833	15,680	403	3.1	3.0
	Total	65,463	27,405	1,187	2.4	2.3

No active intervention beyond Year 100

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	128	0	0
TRI 2	Hold the Line	8,396	7,261	141	1.2	1.1
TRI 3	Do Nothing	-	-	71	0	0
TRI 4	Do Nothing	-	-	148	0	0
TRI 5	Do Nothing	-	-	153	0	0
TRI 6	Hold the Line	13,230	4,773	169	2.8	2.7
BAC 1	Do Nothing	-	-	138	0	0
BAC 2	Hold the Line	72,250	17,447	487	4.1	4.0
	Total	93,876	29,481	1,435	3.2	3.0

Table 14 Implementation of preferred options, in support of revised policies

No active intervention beyond Year 20

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	65	-	-
TRI 2	Hold the Line	3,878	7,582	72	0.5	0.5
TRI 3	Do Nothing	-	-	36	-	-
TRI 4	Do Nothing	-	-	75	-	-
TRI 5	Do Nothing	-	-	78	-	-
TRI 6	Hold the Line	6,030	4,435	86	1.4	1.3
BAC 1	Do Nothing	-	-	70	-	-
BAC 2	Hold the Line	32,625	13,039	248	2.5	2.5
	Total	42,533	25,055	731	1.7	1.6

No active intervention beyond Year 30

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	83	-	-
TRI 2	Hold the Line	4,837	7,685	92	0.6	0.6
TRI 3	Do Nothing	-	-	46	-	-
TRI 4	Do Nothing	-	-	96	-	-
TRI 5	Do Nothing	-	-	100	-	-
TRI 6	Hold the Line	7,659	4,532	110	1.7	1.6
BAC 1	Do Nothing	-	-	89	-	-
BAC 2	Hold the Line	37,592	13,848	316	2.7	2.7
	Total	50,088	26,065	932	1.9	1.9

No active intervention beyond Year 50

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	106	-	-
TRI 2	Hold the Line	6,483	7,834	117	0.8	0.8
TRI 3	Do Nothing	-	-	59	-	-
TRI 4	Do Nothing	-	-	122	-	-
TRI 5	Do Nothing	-	-	127	-	-
TRI 6	Hold the Line	10,147	4,976	140	2.0	2.0
BAC 1	Do Nothing	-	-	114	-	-
BAC 2	Hold the Line	48,833	17,338	403	2.8	2.8
	Total	65,463	30,148	1,187	2.2	2.1

No active intervention beyond Year 100

LMU	Revised Policy Option	Benefits (£k)	Cost (£k)	Annual Monitoring (£k)	BCR	BCR (inc. AM)
TRI 1	Do Nothing	-	-	128	-	-
TRI 2	Hold the Line	8,396	7,982	141	1.1	1.0
TRI 3	Do Nothing	-	-	71	-	-
TRI 4	Do Nothing	-	-	148	-	-
TRI 5	Do Nothing	-	-	153	-	-
TRI 6	Hold the Line	13,230	5,087	169	2.6	2.5
BAC 1	Do Nothing	-	-	138	-	-
BAC 2	Hold the Line	72,250	19,162	487	3.8	3.7
	Total	93,876	32,230	1,435	2.9	2.8

12. Strategy recommendations

12.1 PREFERRED MANAGEMENT POLICIES AND IMPLEMENTATION ACTIONS

The Strategy study has reinforced the need to manage this stretch of coast at a regional scale. It is not possible to consider the discrete Management Units in isolation due to the strong process interactions between one area and the next. It is also clear that in the long term it is not in the national interest (based on current priorities) to attempt to hold the existing cliff line. This conclusion is reached on both economic grounds (the engineering cost would outweigh the benefits) and on process and environmental grounds (the North Norfolk cliffs are both an important sediment source - that if stopped would lead to a rapid reduction in beach volumes locally and further field - and geological exposure). Ultimately, therefore, the shoreline will retreat and the cliff top communities will need to progressively, over an extended but finite time period, relocate.

For the short to medium term the preferred strategic approach is summarised in Figure 44 and described below for each Management Unit. However, it should be noted that given the critical nature of the recommendations in terms of local livelihoods, they will need careful monitoring and periodic review.

TRI 1 Cromer Coastguard Lookout (622740E 41900N) to Overstrand Beach Close

The open coast between Cromer and Overstrand continues to recede and has formed a marginal bay between the "hard points" of Cromer and Overstrand. Given the absence of cliff top assets (other than farmland) and the progressive nature of the recession of the high cliffs (over 70m) the present policy of do nothing remains an appropriate approach into the future. The existing defences will need to be selectively removed as they become dangerous, and a policy of managed retreat may become appropriate in the future.

Preferred strategic policy: Do nothing moving to managed retreat in the medium term (as the remaining defences become dangerous and unsightly).

Preferred intervention: No active intervention – but continued beach and cliff monitoring.

TRI 2 Overstrand – Overstrand Beach Close (624370E 341180N) to Overstrand South

Significant losses would be incurred under a do nothing option. However, limited intervention is unlikely to be effective and hence the cost of a scheme to protect Overstrand is significant (at £7-8M). The scheme would need to be designed to offer protection to Overstrand, both the main frontage and outflanking, for at least 50 years in order to secure significant benefit. A more limited - shorter term – solution is unlikely to be economically worthwhile. Significant effort will need to be devoted through planning to facilitate the transition of a change of policy from hold the line to managed retreat to (ultimately) do nothing.

Preferred strategic policy: Hold the line in the short to medium term (up to 50 years) with a transition to managed retreat by Year 50 and then do nothing.

Preferred intervention: A combination of seawall and groyne repair together with rock protection. By Year 50 the policy transition to managed retreat/do nothing will be complete with no further active intervention.

TRI 3 – Sidestrand – Overstrand South (625520E 340410N) to Trimingham North

This frontage is one of the few stretches of coast in the study area that has never been protected with coastal defences. The predominately sandy beach is backed by cliffs rising up to fifty metres in height. These cliffs, which are part of a SSSI, are subject to very large and frequent failures and slumping. The present policy of Do nothing remains appropriate in the medium to long term and will continue to supply sediment to the downdrift coast and sustain the geological exposures. As the cliffs recede the cliff top communities will become increasingly under threat and in the longer term unsustainable. The difficulties associated with management of the relocation / abandonment of these communities will be significant and will demand the strengthening of existing local planning policy.

Preferred strategic policy: Do nothing

Preferred intervention: No active intervention

TRI 4 – Trimingham – Trimingham North (627800E 338970N) to Trimingham Beacon Hill

The Trimingham defences cannot be maintained in their present form. The coastline is trying to retreat and the existing defences are inadequate to prevent this over the medium term. Holding the present coastline would require significant investment and cannot be justified in economic terms. Progressive retreat of this frontage will also improve the sediment supply to the downdrift coast. However, managed retreat does not come free and a policy of do nothing would leave the beach unattractive and potentially dangerous as the existing structures deteriorate. Therefore, it is proposed that the existing infrastructure is removed in the medium term, when required, to maintain an attractive and safe beach. It is recommended that the need for action is reviewed at least 5-yearly and in light of evidence from the on-going monitoring activities. The difficulties associated with management of the relocation / abandonment of this community will be significant and will demand the strengthening of existing local planning policy.

Preferred strategic policy: A change of policy from Hold the line to Managed Retreat in the medium term (< 20 years) and then ultimately Do nothing.

Preferred intervention: A combination of monitoring in the medium term to maintain safety, with active intervention to remove existing infrastructure when required.

TRI 5 – Trimingham Beacon Hill (629060E 338260N) – Mundesley Seaview Road

Erosion of the shoreline in this area causes limited economic damage. Therefore, in the absence of potential benefit it is appropriate to revise the SMP policy from Managed Retreat to Do Nothing at some point in the future.

Preferred strategic policy: Managed Retreat (ultimately Do nothing).

Preferred intervention: A combination of monitoring in the medium term to maintain safety, with active intervention to remove existing infrastructure when required.

TRI 6 – Mundesley – Mundesley Seaview Road (630430E 337490N) to Mundesley East Cliff

There is a strong economic case for continued protection with a BCR of just under 3 over a 100 year appraisal period. This reflects the significant assets located immediately landward of the present cliff-top and the more moderate cost associated with maintaining and improving the current defences when compared to either Overstrand or Trimingham. A policy of Hold the Line in the long term provides a BCR of 2.7.

Preferred strategic policy: Continue with the present policy of Hold the line into the long term (up to 100 years)

Preferred intervention: A combination of actions will be required through Mundesley including demolition of the existing timber revetments and replacing them with rock together with maintenance of the existing seawall and enhancement of the groynes and timber revetment.

BAC 1 – Mundesley East Cliff (631780E 336350N) to Bacton Gas Terminal

A policy of do nothing continues to be justified through this Management Unit to maintain natural processes and supply to the downdrift coast (whilst conserving geological interests). The predicted recession of the cliff top through BAC 1 is more limited that elsewhere in the short term, however in the medium to longer term action maybe required at the north-western end of the frontage to protect the developments on the edge of Mundesley. However, this can not be justified at present.

Preferred strategic policy: The do nothing policy remains appropriate in the medium term (20 years), although will require review in the longer term to explore the appropriateness of selective action at the north-western end.

Preferred intervention: Monitoring but no active intervention

BAC 2 Bacton Gas Terminal to Walcott Ostend Cottages (636900E 332250N)

The economic case for active intervention to protect the cliffs in front of Bacton is very strong. This is specifically strengthened by the inclusion of Bacton Gas Terminal in the management unit, which accounts for a significant proportion of the benefits. Although the cost of maintaining the defences in this management unit is significantly more than the work required in any other management unit, the maximum BCR that can be achieved after active intervention for just 20 years is just below 3. This rises to just over 4 for active intervention for the whole 100 years of the strategy.

Preferred strategic policy: Hold the line (if Bacton Gas Terminal were to be decommissioned / relocated this policy would need to be reviewed).

Preferred intervention: A combination of actions including demolition of existing timber revetments and replacement with rock, together with maintenance of the existing seawall and enhancement of the groynes.

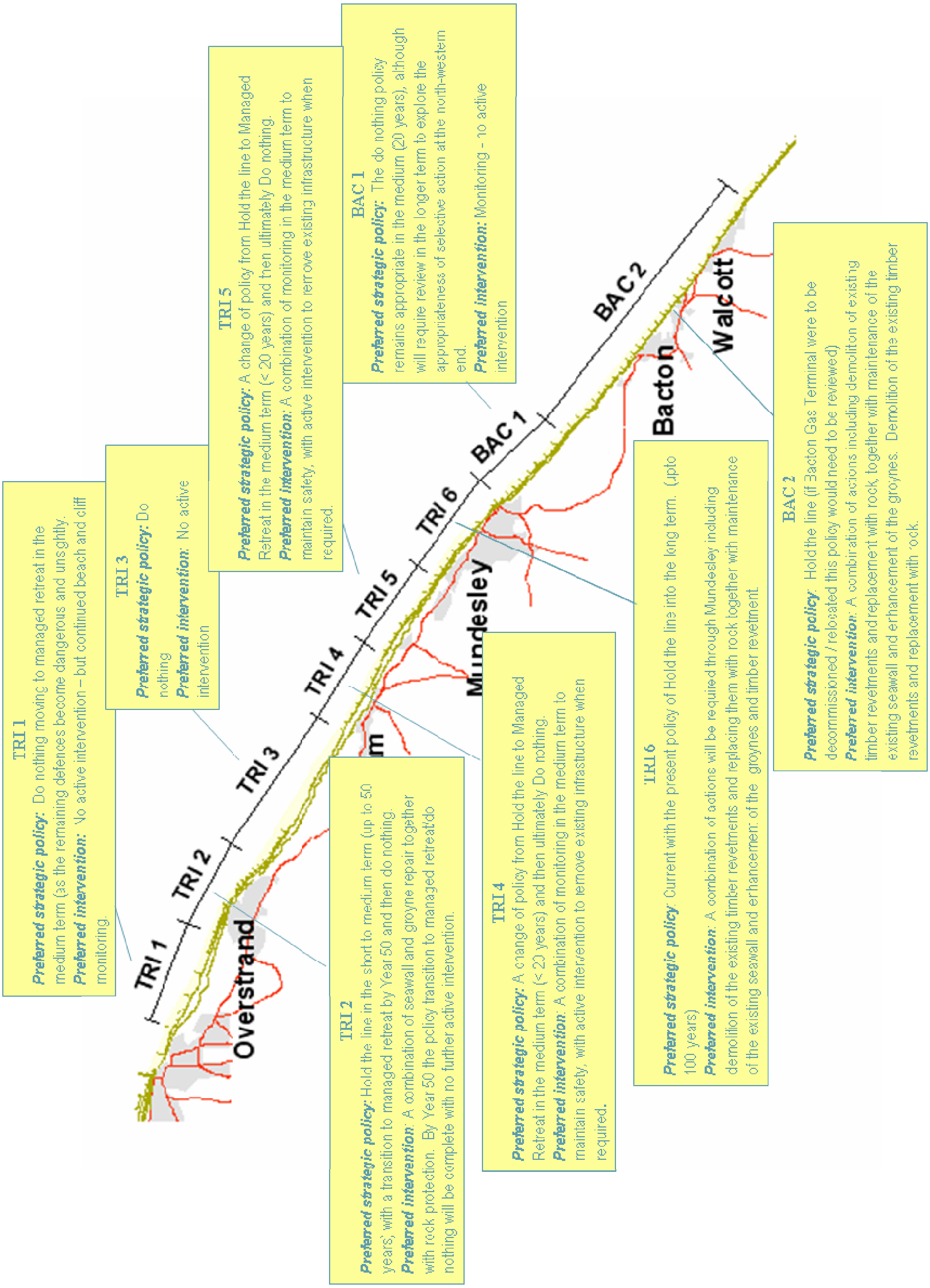

Figure 44 Summary of Strategic Options and Interventions

12.2 RECOMMENDED MONITORING

The coastal processes within the study area are extraordinarily dynamic. The preferred policies and actions hinge on how the cliffs are predicted to behave in the future and the performance of the existing defences. Therefore it is recommended that the existing monitoring activities should be formalised through a regional monitoring programme and supporting database infrastructure. This would include as a minimum:

Environmental monitoring

The levels of vegetation on the cliff face and any evidence of damage or change are a primary indicator of cliff stability. As such the cliff face should be subject to visual surveys every four years. More detailed advice on environmental monitoring is provided by English Nature (1994a and 1994b). This should be used to establish action points for the North Norfolk coastal SSSIs.

Beach monitoring

The health of the beach is crucial to maintaining the cliff line and hence the existing beach surveys should be continued and supplemented. Annual quantitative surveys should include:

- ***Aerial photography of the coast position*** – with the identification and documentation of cliff slips, size and position.
- ***Beach profiles*** – with “short profiles” (at intervals of 1km or less) and “long profiles” (at intervals of 5km or less). These should be held in a spatial temporal database and used to annually update the sediment budget model established as part of the Strategy.
- ***Local beach / cliff topographic surveys*** - at Cromer, Overstrand, Vale Road beach access, Trimingham, Mundesley and Walcott.

Monitoring of Defence infrastructure

Through the strategy study estimates of present and future defence performance have been made. These need to be updated to determine the optimum time for intervention and to inform future scheme design where identified as appropriate. It is recommended that NNDC develop a data base consistent with the National Flood and Coastal Defence Database to record routine and periodic defence inspections. As a minimum these inspections should include:

- An annual visual walkover survey – including cliff slopes, promenades, seawalls and groynes
- Periodic quantitative survey of geometry – 5 yearly – including cliff and seawall cross-section.
- Periodic qualitative survey – as required based on visual evidence.

The information recorded to the NNDC database should then be uploaded to NFCDD using the emerging national protocols.

12.3 FURTHER STUDIES

Supporting a community in transition

This Strategy recommends a number of significant changes to current policy. In particular the Strategy recognises the unsustainable nature of the shoreline position through Trimingham and in the longer term Overstrand. The significance of this change for those affected can not be under-estimated and the transition will need to include a combination of progressive planning, consultation and monitoring. For example as the cliff recedes defence assets will become unsightly and potentially unsafe, cliff top assets and municipal infrastructure such as pipelines and sewerage systems will become exposed and unsafe. The communities will need to be engaged so that when active intervention to hold the line stops the communities are prepared. This process will need to be actively managed. How to do so in practice remains unclear. It is recommended that a policy transition plan is developed and implemented.

Development of models to support on-going management decision

North Norfolk DC already have a forward programme to further develop the use of GIS to support coastal management and planning discussions. This provides an opportunity to maximise the value from the on-going monitoring programme outlined above and the approaches developed in this Strategy. In addition to the periodic updates of the Strategy two further studies should be developed:

Establishment of a regional sediment budget tool – Understanding the sediment budget and variations to it are fundamental in understanding how the cliff top is likely to recede in the short term (i.e <5 years). The sediment budgeting process developed in this Strategy should be used to provide a rapid assessment of the changing sediment budget based on the data gathered through the monitoring programme. This would enable changes in beach volume to be easily identified.

Establishment of a regional predictive tool – The regional cliffSCAPE model developed as part of the strategy could be developed to provide an on-going decision testing tool to be used by engineers from NNDC to support future updates of the Strategy and explore options as evidence is gathered from the on-going monitoring process to confirm the conclusions drawn within this report. It is recommended that the model is established and then transferred for use by NNDC as a routinely used tool.

Defence reliability trigger levels – The defence fragility curves developed within the Strategy could be used to identify those defence assets with an increased risk of failure/collapse. Coupled with the monitoring data a regional asset reliability tool would provide a useful management aid. This would be allied with the developement of a NFCDD compatible database.

13. Strategy revisions and updates

This strategy should be subject to periodic review (in line with the Government is Flood and Coastal Defence Project Appraisal Guidance) in order to reflect changes in the area, improvement in understanding of the processes involved, the results of monitoring and any other lessons learnt from scheme implementation. There is a vital link in the feedback chain which should ensure that the benefit of expertise and knowledge gained is actively used in the development of future strategy planning including reviews of large-scale plans (e.g. SMPs and CFMPs).

Each review should follow the procedures for strategy development. Where there are any significant developments or changes, all major assumptions that are likely to affect the future direction of the strategy should be critically re-examined to determine whether there is a need for any change in strategic direction.

Normally a maximum period of five years between reviews is appropriate but this may be adjusted if there is a need to take account of particular external factors or the time scales of specific changes are particularly short. The strategy should normally be extended at the time of the review to maintain its time frame (e.g. a further 100 years from the review date for a 100-year strategy).

Due to the highly active and dynamic nature of this coastline it is suggested that a 'preliminary review assessment' be held annually to determine whether strategy revisions or updates need to be made. In any case a full strategic review should be made within five years. In particular the review should cover progress towards a change of policy in those Management units identified within this strategy Study as in transition from *hold the line* to *managed retreat* to *do nothing*.

14. References

Cambers, G. (1976). Temporal scales in coastal erosion systems. Trans. Inst. Brit. Geogrs. 1, 246-256

Clayton, K.M. and Coventry, F. (1986). A report on the effectiveness of revetments along the Norfolk cliffed coast. NCC Report HF3-03-316.

English Nature (1994a). Geological Site Documentation / Management Brief: Mundesley Cliffs SSSI, (EC), Norfolk. S Graham, Earth Science Branch, March.

English Nature (1994b). Geological Site Documentation / Management Brief: Overstrand Cliffs SSSI, (EC), Norfolk. S Graham, Earth Science Branch, March.

English Nature. (1997) The North Norfolk Natural Area Profile.

English Nature. (1998). A vision for nature conservation in the Norfolk coast Area of Outstanding Natural Beauty (AONB) 1997-2022, April.

Halcrow (1996). Sheringham to Lowestoft Shoreline Management Plan, Sediment Sub-cell 3B. Phase 2 – Shoreline Management Plan Strategy Document. North Norfolk District Council, Great Yarmouth Borough Council, Waveney District Council and the National Rivers Authority, May, 1996.

HR Wallingford (2001). Coastal Defence Vulnerability 2075. Report SR 590.

HR Wallingford (2002). Hydrodynamics. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2003a). Littoral Sediment Transport Processes. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2003b). Cliff Processes. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2003c). Defence Condition Survey. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2003d). CliffSCAPE Modelling and Recession Analysis. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2003e). Environmental Value. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2004a). Economic Valuations. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2004b). 'Do Nothing' – Erosion Probability and Erosion Losses. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2004c). 'Do Nothing' – Flood Probability and Flood Losses. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2004d). Consultation (Issues and Concerns). Interim Technical Report supporting EX4692 – Part II.

HR Wallingford (2004e). Option Identification and Appraisal. Interim Technical Report supporting EX4692 – Part II.

HR Wallingford, (2005). Sustainable Flood and Coastal Management web site; http://www.sfcm.org.uk/ [Accessed: 30/08/05].

Joint Nature Conservation Committee 1991. Sidestrand and Trimingham Cliffs, North Norfolk, (N 11, 3 SILS). GBNCRS Site Report No. 23E. Prepared for English Nature by R Cottle. August 1991.

MAFF, (1997). Interim Guidance for the Strategic Management of Coastal Defences.

MAFF, (2001). Flood and Coastal Defence Policy Appraisal Guidance, FCDPAG 2 Strategic Planning and Appraisal, April 2001

MAFF, (1999). Flood and Coastal Defence Policy Appraisal Guidance, FCDPAG 3 Economic Appraisal, December 1999. Pub. PB4650

MAFF, (2000). Flood and Coastal Defence Policy Appraisal Guidance, FCDPAG 5 Environmental Appraisal, March 2000

MAFF / Welsh Office (1993). Strategy for flood and coastal defence in England and Wales, Pub. PB 1471, September 1993.

North Norfolk Coastal Partnership (1998). Norfolk Coast Area of Outstanding Natural Beauty Strategy Study.

Penning –Rowsell, E., Johnson, C., Tunstall, S., Tapsell, S., Morris, J., Chatterton, J., Coker, A. and Green, C. (2003). The Benefits of Flood and Coastal Defence: Techniques and Data for 2003. Flood Hazard Research Centre, Middlesex University.

Silverman, B.W. (1986) Density Estimation for Statistics and Data Analysis. Chapman and Hall, New York.

Walkden, M.J., Hall, J.W. and Lee, E.M. (2002). A modelling tool for predicting coastal cliff recession and analysing cliff management options. Proc: *Instability Planning and Management.* Ventnor, Isle of Wight, May 20-23, edited by R.G. McInnes and J. Jakeways. London: Thomas Telford, pp.415-422.