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EX 4985

Kelling to Cromer Strategy Study

Report EX 4985
December 2006

Option appraisal and strategy recommendations

“Do nothing” - erosion probability and erosion losses

Consultation (Issues and Concerns)

Environmental Review

Hydrodynamics

Littoral sediment processes

Cliff processes

Defence condition survey

Economic evaluation

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Summary

Kelling to Cromer Strategy Study

Option appraisal and strategy recommendations

Report EX 4985
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Introduction

Shoreline Management Plans covering the Kelling to Cromer coastal frontage were adopted by North Norfolk District Council (NNDC) in 1996. Following completion of the SMPs, NNDC have been committed to the continued development of a programme of coastal defence works through the undertaking of strategy studies based upon the adopted recommendations of the SMPs. This summary outlines the scope and findings of the Kelling to Cromer Strategy Study. The study frontage, and relevant demarcations, is depicted in the attached plans, Figures 1.1 – 1.3.

The context and purpose of the Strategy Study

The Strategy Study constitutes an important link in the necessary planning process. In broad terms, the stages of development of a coastal management scheme can be summed up according to the generic order, as follows:

1. Shoreline Management Plan (SMP)
2. Strategy Study
3. Project Appraisal Report (PAR)
4. Scheme design (i.e. detailed analysis, reporting, preparation of construction drawings, etc.)
5. Scheme implementation (i.e. tendering procedures, contract administration, construction and/or management)
6. Scheme operation (i.e. maintenance, monitoring)

It follows that the Strategy Study is a high level initiative, being on the next tier of development to the most fundamental plan, the SMP.

The SMP sets the future coastal defence policy for long lengths of coast. In this case, the study area was covered by two SMPs extending in total from Snettisham to Lowestoft, with Sheringham forming the boundary between the two. To facilitate the planning process, the coast is divided into a number of smaller but still sizeable lengths called Management Units. The Strategy Study considers the comparatively short length of coast from Kelling to Cromer, comprising just three of the SMP defined Management Units. For the strategic frontage considered here, the relevant units were defined as:

- MU1/CU1 extending from Kelling to the west of Sheringham;
- RUN 1, Sheringham Town;
- RUN 2 extending from the east of Sheringham to the west of Cromer.

The middle Management Unit, RUN 1, is characteristically different from those on either side, being the urban part of Sheringham town, whilst the adjacent units are largely rural with isolated properties, caravan and leisure parks. Other than the town area, the only significant concentrations of infrastructure are in the most easterly unit, RUN 2, which contains two engineered access points to the beach.

The SMP sets out the broad defence policy for each Management Unit based on environmental, technical and economic criteria. These policies are expressed in very generic terms which, for the relevant Management Units just mentioned, are:

- MU1/CU1: Do Nothing (allow natural process to act without intervention);
- RUN 1: Hold the Line (keep the line of coastal defence where it is, and continue to provide protection);
- RUN 2: Snettisham to Cromer: Managed Retreat (staged and/or selective withdrawal of defence).

The draft of a second generation of SMPs was produced in 2005; as with the first generation SMP the second version also indicates that the urban frontage of Sheringham will need to be defended into the foreseeable future (100 years).

The Strategy Study examines the three Management Units in greater detail than was required for the SMP. To facilitate this higher level of definition, the coast is divided into smaller sub-units called “defence lengths” (also, referred to as RUNs in some contexts). Thus, MU1/CU1 is divided into two defence lengths (CU1.1 and CU1.2), RUN 1 into eight defence lengths (1.01 to 1.08), and RUN 2 in five defence lengths (2.01 to 2.05). Whilst working within the broad policy option categorisations (e.g. Hold the Line), the Strategy goes on to define a level of protection (e.g. Sustain, Improve, etc. – these terms are explained later) and a typical means by which they can be achieved (e.g. by strengthening the seawall, reconstructing the groynes, etc.).

In most cases the Strategy Study confirms the adopted policy option. In other cases, the higher level of definition highlights the more vulnerable parts of the SMP policy recommendations, thus pointing to alternative policy options that would deliver a better economic return.

The Strategy Study is by no means the last stage in the process for planning and developing coastal defence. The next stage, the preparation of Project Appraisal Reports, is concerned with smaller lengths of coast. The PAR usually deals with a scheme specific length of coast which might be within a single defence length or a cluster of defence lengths. Generally, the PAR is the precursor to development of a scheme (items 4 to 6 in the list above) and, as such, is conducted nearer to the time that the particular scheme needs to be acted on.

Strategy method

As with the SMP, the Strategy aims to achieve the three tenets for good coastal defence: the strategic solutions must be technically sound, economically viable and environmentally acceptable. To achieve these objectives it is necessary to take a strategic approach to option identification and evaluation. This means taking a broad view of the overall defence performance both geographically, i.e. having cognisance of potentially far reaching effects, and in time, i.e. taking the long term view (i.e. 100 years).

The work was initiated by a consultation exercise to assess the issues and concerns of those with an interest in coastal defence of the study area. The initial consultation was carried out in May 2004. Consultation on the developed Strategy Study is to be integrated with that required for other planning initiatives from NNDC.

In order to meet the study objectives, and be in a position to provide informed response to the consultation process, a series of detailed studies were undertaken. The studies are reported in separate volumes which collectively form the Strategy Study Report (HR Wallingford, 4985, December 2006). The complete set of report titles that constitute the Strategy is as follows:

1. Consultation – The discrete coastal communities that are characteristic of this coastline are well aware they occupy an eroding coastline. The strategy study consultations ran in parallel with on-going consultations by NNDC and the review of the Shoreline Management Plan.
2. Environmental Value – Reviews of the environmental, geological and aesthetic value of the study area.
3. Hydrodynamics – Review of waves, surges and tides along the study coastline.
4. Littoral Sediment Processes – Review of beach processes, longshore and cross shore sediment transport at the study coastline.
5. 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 and quantification of cliff retreat.
6. Defence Condition Survey – Review of the condition of the existing defence structures including estimates of residual life.
7. Economic Evaluation – Assessment of the present value of both natural and man-made assets using data provided by local estate agents and the council's valuation office.
8. The Do Nothing Scenario - An assessment of the consequences and monetary damages incurred if no further management of the shoreline was undertaken. This case provides a baseline against which to assess the benefits of various possible future interventions
9. Options Appraisal and Strategy Recommendations - 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 options; this volume provides the overall conclusions and recommendations regarding strategic shoreline management.

The principal purpose of this summary is to outline the findings from the Strategy Study and, in this respect, it draws mainly from the "Option Appraisal and Strategy Recommendations". However, it is useful to recap the main findings of the background research, as indicated by the titles listed above, and this is done in the next section.

The background

Land Use

Land use is predominately recreational and agricultural in nature, but includes the town of Sheringham. With over 1,100 properties sited within 200m of the cliff top, the potential damage to property from coastal erosion and cliff slides is large. The RNLI maintain an inshore lifeboat station at the western end of the promenade at Sheringham. The facilities there include a launch ramp, tractor shed, and a lifeboat shed with associated facilities.

The tourist industry is extremely important to the economy of North Norfolk. There are approximately 1140 mobile homes located within the study area. Sheringham golf course is located in the western portion of the study area, to the west of Sheringham. This has significant local importance, attracting tourists and employing staff.

Both full time and part time inshore fishing boats operate from the beaches of Weybourne, Sheringham, West Runton and East Runton.

The RAF maintains a small site at Weybourne, once used as a radar station but now used primarily as a camp for RAF cadets. The secure site is also the location of some very sensitive air quality monitoring equipment owned and maintained by the University of East Anglia.

Natural Environment

The coast consists of soft cliffs, primarily composed of sand and gravel. The study area is particularly rich in natural assets as evidenced by its several conservation designations:

- Weybourne Cliffs SSSI
- Beeston Cliffs SSSI
- West Runton Cliffs SSSI
- East Runton Cliffs SSSI
- Kelling County Wildlife site
- Weybourne County Wildlife Site
- East Runton to Overstrand County Wildlife Site (Cliff and beach between East Runton SSSI and Overstrand Cliffs SSSI).

With the exception of Sheringham, the study area is also part of an Area of Outstanding Natural Beauty.

Heritage

The study area contains many Listed Buildings, Scheduled Ancient Monuments and archaeological features. For many of these features, there is a statutory duty to protect them.

Coastal Defence

The coastal defences are concentrated at the centre of population, Sheringham (RUN 1), with isolated defences also being present at the concrete ramps which provide access to the sea for small boats through the cliffs at West Runton and East Runton (RUN 2).

There has been a long history of sea defence construction at Sheringham with the earliest records dating from the 19^{th} century. Initially these were instigated by landowners striving to protect their own property. Later, defences were also built to protect hotels as tourism increased. There is a continuous record of recurrent building, maintenance and extension of all the defences. The defences at Sheringham consist of concrete seawalls with the addition of timber and rock groynes. The town defences were substantially improved in 1995. Where the walls are most exposed to wave action, rock armour was added.

Despite the major overhaul of Sheringham's defences in 1995 and a programme of continuous maintenance, none of the defences have an expected residual life in excess of 25 years and some sections at the eastern end of the frontage have already collapsed or are nearing exhaustion.

Coastal processes

To the west of Sheringham, the unprotected cliffs are fronted by a relatively healthy shingle beach which is underlain by a chalk platform, itself an important source of beach material.

At Sheringham, containment of the cliffs and prevention of land erosion by the construction of seawalls has reduced the supply of sediments to the beach regime. Further to this, extensive groyne construction has reduced the natural drift of sediment along the shore to adjacent beaches.

A significant feature of the Strategy frontage is that it has been defended for such a long time (more than 100 years) that it now forms an artificial divide between the beaches to the west and those to the east. In broad terms, the effect of this “divide” is to encourage the natural drift of beach sediments west of the town to go westwards, whilst those to the east go eastwards. As a result, the beaches of Sheringham are depleted compared to former times, and the outlook is for continued lowering.

The coastal cliffs, where exposed, provide an important source of beach building sediments in the form of sand and gravel. The cliffs have quite variable properties, ranging in height between 10m to 40m. The cliff erosion rates also vary, with historic rates ranging approximately between 0.1 and 0.5 metres per year. For the purposes of the study, future erosion rates were postulated taking due account of climate change and other changing circumstances.

Economic Setting

In order to evaluate the economic benefit of providing coastal defence, a necessary first step is to evaluate the economic losses that would occur if defence was not provided or was discontinued. This (often notional) case is called the “Do Nothing” scenario. In the Do Nothing scenario, defence structures are assumed to become ineffective at the end of their residual life.

The economic impacts of damage are calculated on the basis the value of assets that would be lost through coastal erosion. The analysis takes account of the timing of losses through a process called discounting, whereby future losses are reduced by a compounded annual percentage, called the Test Discount Rate - a rate set by the Treasury (see notes below the Table). Through this process, losses occurring in the future have less impact in terms of present values than losses occurring now. The total discounted damages in the Do Nothing case amount to some £23.4 million. This figure is made up as shown in the Table below:

Summary of Total Losses in 100 years – Do nothing scenario

Management Unit	Do Nothing Damages (£)
MU1/CU1	838,657
RUN 1	19,647,180
RUN 2	2,927,329
TOTAL	23,413,166

Note: Test Discount Rate = 3.5% for years 0-30; 3% for years 31-75; and 2.5% thereafter.

The losses are dominated by damages within RUN 1, i.e. Sheringham. Within RUN 1, some £2.12 million of damages are predicted to occur with the next five years. Of this figure, some £1.58 million are seaward of the present cliff-line, comprising promenade infrastructure and the lifeboat station. As such, they constitute the most imminent potential losses in the case of no intervention.

Strategy Conclusions

Management Unit MU1/CU1, Kelling to Sheringham

The two defence lengths that constitute the Kelling to Sheringham Management Unit are considered as one for the purpose of the Strategy Study. This length of coast is currently undefended. The SMP policy option, as noted above, is Do Nothing. The preferred Strategy option for the coastal defence of this length of coast is also Do Nothing, with the proviso of continued monitoring.

Management Unit RUN 1, Sheringham

This length of coast is currently defended with seawalls and groynes of various types and vintages. The SMP policy option, as noted above, is to Hold the Line. The eight defence lengths (RUNs 1.01 to 1.08) are considered separately and in combination in respect of the strategic approach.

To comply with the intent of the SMP, it is implicit that the defence line can be held for 100 years. Simply maintaining the defences though routine or piecemeal measures would not be tenable as none of the structures have a residual life better than 25 years. Undermining and/or geotechnical instability through beach lowering are limiting factors in the longevity of many of the coastal structures.

All options to Hold the Line therefore entail reconstruction of the defences, seawalls and groynes, on a periodic basis. In strategic terms these options can either “sustain” the present standard of defence (i.e. continuing the same level of risk) or “improve” it (i.e. reduce risk).

The defence lengths that comprise the inner part of the frontage (RUNs 1.02 to 1.05) contain the highest density of assets at risk from coastal erosion. Consequently, defence of these sections represents good value for money, yielding benefit/cost ratios generally in excess of 1.00 (RUN 1.03, the exception, has a b/c ratio of 0.93).

In defence lengths RUN 1.01, and RUNs 1.06 to 1.08, the benefit/cost ratios are all significantly below 1.00 for Hold the Line options. The low levels of benefits are due to there being few assets at risk (RUNs 1.01 and 1.08), and because significant damages (in the case of no intervention) do not occur for several tens of years into the strategy life (RUNs 1.06 and 1.07). Hence, the early provision of defences does not deliver good economic value.

In the case of RUNs 1.01 and 1.06 there is some considerable residual life left in the defences (16 years and 20 years respectively); hence, there is time to give these cases more timely consideration, benefiting from the many years of valuable monitoring data gathered in the interim.

In the case of RUNs 1.07 and 1.08, the very short (or now exhausted) residual lives means that urgent action is needed to address the problems both at a strategic level and, in the case of RUN 1.08, to translate the agreed policy into action on site.

If coastal defence of the entire length of RUN 1 were to be continued into the foreseeable future (i.e. Hold the Line for 100 years) then the ratio of the overall benefits to overall costs is just 1.09 (i.e. effectively neutral).

This approach, however, complies with the policy set out in the SMP. As an alternative to this, if the non-compliant policy of Managed Retreat was to be adopted for the uneconomic defence lengths 1.01, and 1.06 to 1.08, then the benefit to cost ratio increases to 1.44. This alternative supposes that these defence lengths would be maintained until the ends of their respective residual lives which, in the case of RUNs 1.01 and 1.06 is considerable. Only defence lengths 1.07 and 1.08 require urgent attention, the latter in particular as it has already suffered substantial collapse.

Management Unit RUN 2, Sheringham to Cromer

This length of coast is currently defended with a derelict timber revetment in the first defence length (RUN 2.01) and by short concrete defences in each of the two units that contain the beach access ramps, RUN 2.02 and RUN 2.04. The SMP policy option, as noted above, is Managed

Retreat. There is little interaction between the five defence lengths which can be considered separately.

Urgent action is required in respect of RUN 2.01 where the derelict timber revetment and toe structure presents a significant safety hazard and negative impact in respect of beach amenity. Removal of the defence structure is therefore recommended for RUN 2.01. The slightly increased rate of cliff erosion following removal of the structure will benefit downdrift areas by way of improved sediment supply.

For the remaining defence lengths in RUN 2 the outlook is comparatively straightforward. Logically, defence of these sections can be categorised into Do Nothing (RUNs 2.03 and 2.05), and Sustain (2.02 and 2.04); in the latter cases, the economic motivation is derived from the beach access ramps plus the associated infrastructure and social value.

Strategy recommendations

The Strategy has identified a number of issues requiring early or immediate action over the next five years. The recommendations relating to these actions are listed below:

Monitoring of the beaches and coastal structures is currently underway. This monitoring campaign should be continued, and the results collated periodically to facilitate utilisation in future appraisal, strategy and SMP updates.

The study has identified the need to carry out early works to remedy the derelict defences in the adjoining defence lengths RUN 1.08 and RUN 2.01. In view of the extent of works involved (both removal and/or reinstatement) and the fundamental issues relating thereto, the schemes should be preceded by the preparation of a Project Appraisal study, and possibly an EIA. Given that there are similar issues pertaining to adjoining defence lengths RUNs 1.06 and 1.07, in particular regarding the question of sustainability, these should be included in the study, albeit no major works are required in 1.06 for at least 16 years.

Pending the outcome of the study mentioned above, there is likely to be a need to undertake imminent design, tender and contact administration in respect of site works in RUNs 1.08 and 2.01, and possibly 1.07.

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1. Introduction

1.1 BACKGROUND

This report, Option Appraisal and Strategy Recommendations, concludes the suite of reports that, collectively, constitute the Kelling to Cromer Strategy Study; a major study of coastal defence commissioned by North Norfolk District Council.

The three tenets for good coastal defence are that it must be technically sound, economically viable and environmentally acceptable. To achieve these objectives it is necessary to take a strategic approach to option identification and evaluation. This means taking a broad view of the overall defence performance both geographically, i.e. having cognisance of far reaching (downdrift) effects, and in time, i.e. taking the long term view (e.g. 100 years).

The study examines the coastline from Kelling Quag eastwards to the outskirts of Cromer and encompasses the Management Units: MU1/CU1 Muckleburgh and Weybourne, RUN1 Sheringham and RUN2 West Runton to Cromer. The study area consists of sand and gravel cliffs and, with the exception of the town of Sheringham, is predominantly undefended. Recreational and agricultural land uses dominate, although there are some built up areas including Sheringham, Weybourne and West and East Runton. Figures 1.1 to 1.3 illustrate the management units in more details.

The complete set of report titles that constitute the Strategy is as follows:

- Consultation Process
- Environmental Review
- Hydrodynamics
- Cliff Processes
- Littoral Sediment Processes
- Defence Condition Survey
- Economic Evaluation
- The Do Nothing Scenario
- Option Appraisal and Strategy Recommendations

The earlier volumes describe the physical environment, in particular with reference to its interaction with the coastal processes. The assets at risk due to coastal erosion or flooding are identified and valued, and the capacity of the present defences to protect those assets into the future is assessed. Thus, the first eight reports provide the baseline of information from which to consider the future requirements for coastal defence.

This report describes the options considered and details both the approach and the preferred options.

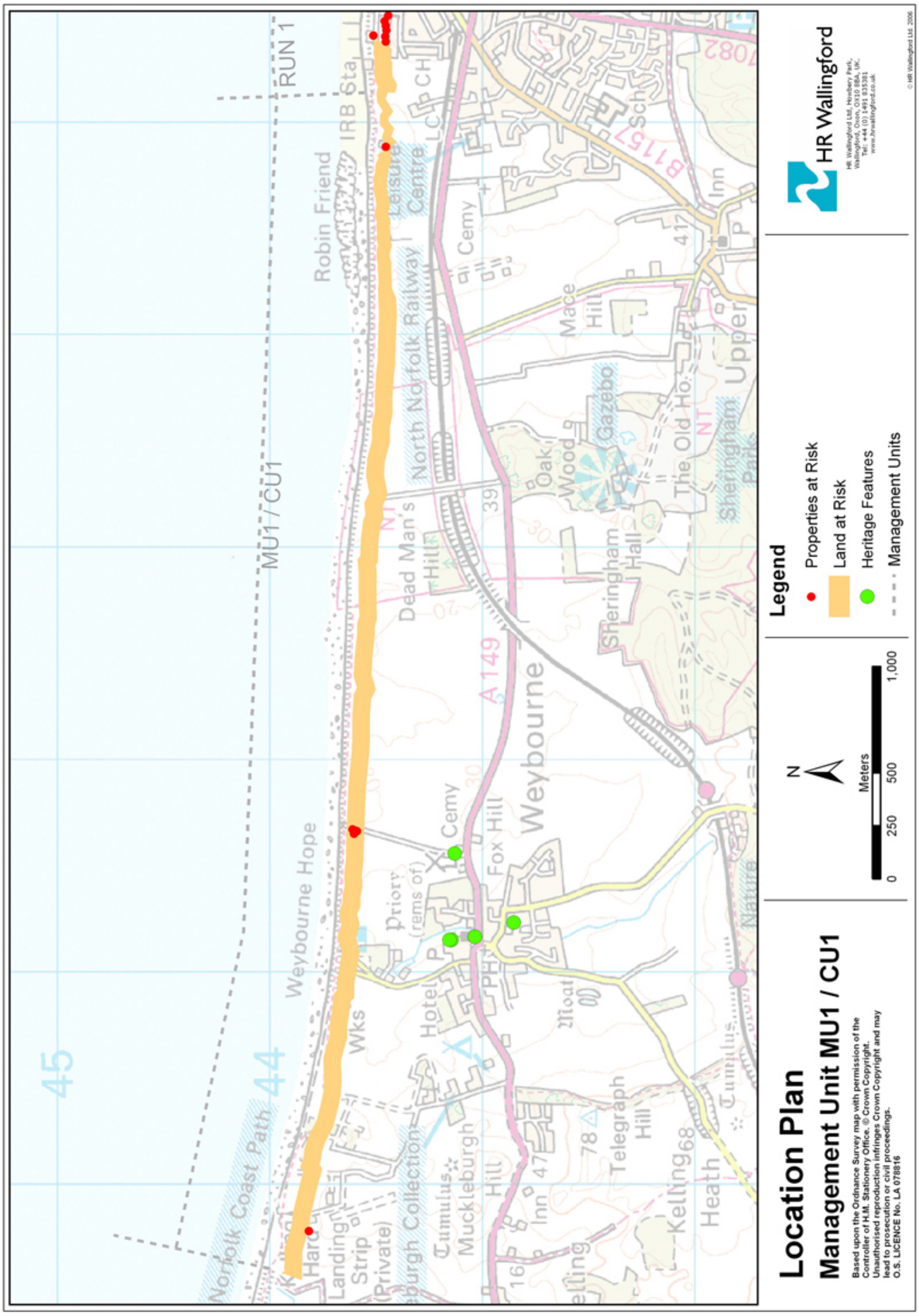

Figure 1.1 Location Management Unit MU1 CU1

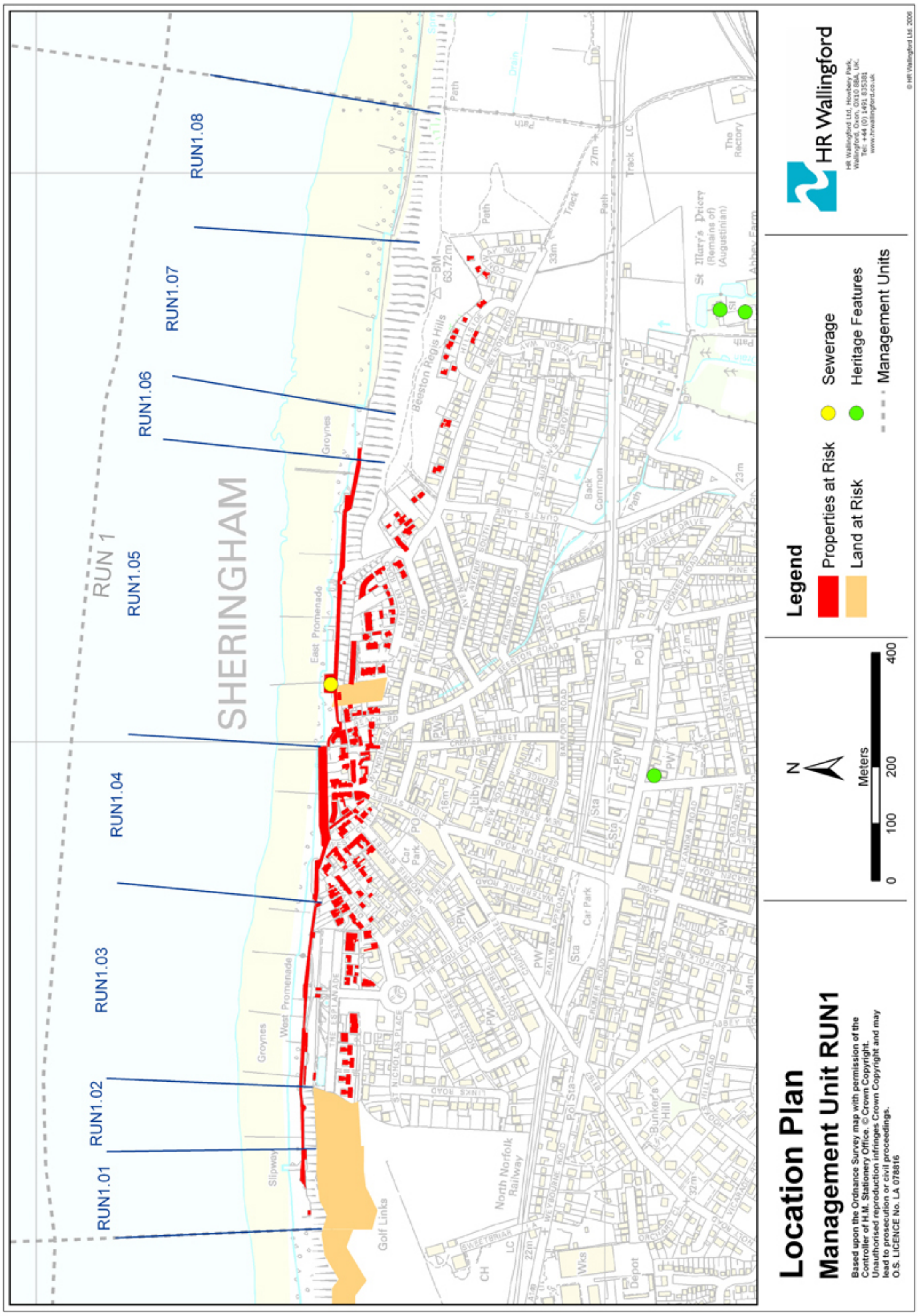

Figure 1.2 Location Management Unit RUN1

Figure 1.3 Location Management Unit RUN2

2. Identification of strategic coastal defence options

It is recognised that the option identification, evaluation and selection process is an iterative process of exploring the problem, generating options and selecting the preferred approach. The first stage of this process has been completed as part of the Shoreline Management Plans.

It is worthwhile recalling the policy options recommended by the adopted Shoreline Management Plans for this area SMP1 ((Sub-cell 3a) Mouchel 1996, (Sub-cell 3b) Halcrow, 1996.) and the draft recommendations of the second generation shoreline management plan, SMP2 (Halcrow, 2005).

In SMP1, the coastline between Kelling and Cromer is sub-divided into three "Management Units", with the recommendation being to adopt a given coastal defence policy within each (see Figures 1.1 – 1.3). Briefly they are as follows:

Management Unit MU 1/CU 1	Muckleburgh and Weybourne	Do nothing
Management Unit RUN 1	Sheringham	Hold the line
Management Unit RUN 2	West Runton to Cromer	Do nothing

In the SMP2, the coastline between Kelling and Cromer is sub-divided into three "Policy Units", with the recommendation being to adopt a given coastal defence policy within each. The Policy Units correspond approximately to the Management Units. The recommended policy options for the area are as follows:

Policy Unit 3b01	Kelling Hard to Sheringham	No active intervention
Policy Unit 3b02	Sheringham	Hold the existing line
Policy Unit 3b03	Sheringham to Cromer	No active intervention

Both the adopted policies of SMP1 and the recommended policies of SMP2 indicate that the urban frontage of Sheringham (RUN1/3b02) will need to be defended into the foreseeable future (for the next 100 years or more). By contrast, the adjacent sections (MU1/CU1/3b01 and RUN 2/3b03) are mainly rural frontages and it is assumed that they will remain so.

For the purposes of this report, it is proposed to continue to identify the discrete lengths of coast by the use of the management unit identifiers referred to in SMP1.

2.1 GENERIC OPTION TYPES

There are various engineering and coastal management options available to achieve the SMP policy options with different associated investment costs and consequent benefits. For each policy option several technical options have been considered; these have been developed, based on the following generic option types:

1. **Do nothing -** Allow natural processes to act without intervention. The prediction of the likely consequences (of Do Nothing) is used to assess and evaluate the resulting damages, and hence the benefits arising from intervention options. This option does not preclude the undertaking of essential safety measures (which are not costed).

2. **Monitor shoreline** - this is the basic minimum “do-something” option, involving no measures to actually maintain, sustain or improve the coastal defence. This option does not preclude the undertaking of essential safety measures (not costed). Apart from this case, monitoring is implicit in every intervention option.
3. **Maintain defences** – likely to be the minimum “do-something” option which does entail intervention with the defences; this option implies only routine maintenance to preserve an existing defence. This option does not necessarily sustain the present standard of defence and certainly does not improve it; nor does it imply that a defence structure can be maintained for the scheme life (100 years). Thus, replacement of a defence structure, or such works as might constitute a capital scheme, do not form part of this option. This option is, therefore, likely to be associated with a declining standard of defence and/or a reduced scheme life.
4. **Sustain Standard of Defence** – this option is targeted generically at the standard(s) of defence afforded by a given defence structure or management system. As its name implies, the option aims to sustain the present standard of defence for the intended scheme life of 100 years (e.g. by keeping pace with or pre-empting sea level rise). This generic option can include maintenance and the construction of new defences.
5. **Improve Standard of Defence** - this option is targeted generically at the standard(s) of defence afforded by a given defence structure or management system. As its name implies, the option aims to improve the present standard of defence for the intended scheme life of 100 years (i.e. so that even at the end of the scheme life the standard is higher than at present). This generic option can include maintenance and the construction of new defences; it is likely to include new construction at the start of the project in order to raise present standards.

The Kelling to Cromer frontage is divided into three Management Units, each divided into smaller units. For example, in the case of Sheringham (RUN 1) the frontage is divided into eight smaller defence lengths designated RUNs 1.01 to 1.08, representing differences in the types of defence. These smaller defence lengths have varying properties including different residual lives. It follows that the strategy will have to adapt to these variations which will include defence replacement at different times, and so forth. In line with strategic thinking, therefore, we can include within the “improvement” class of measures, works and management systems applied to a defence length which effect an overall improvement to the Management Unit (or beyond) whilst, as a minimum, sustaining standards within their particular defence length.

The term “Standard of Defence” (SoD) is more readily applied to flood protection where the SoD is expressed simply as the return period of the threshold of tolerable flooding. In the case of coastal erosion the term can be used in an equivalent sense in terms of the probability (expressed as a return period) of failure of the defence structure, from which point erosion ensues. For the strategic level of consideration adopted for this study, however, structural failures are identified in deterministic terms rather than probabilistically. We cannot, therefore, quantify degrees of improvement but we can identify whether or not a given option reduces the threat in the given defence length or elsewhere; this is the basis for distinguishing improvement options from sustain options.

The details of the above cannot be examined at a strategic level in isolation from consideration of the means of achieving the desired intent, as different defence methods can have significantly different consequences. An appropriate level of detail is, therefore, provided on each option to determine the preferred approach at any given location. Further study during subsequent scheme appraisal will be required to consider more specific details of option performance and design.

2.2 OPTION COSTING

A key element of the engineering assessment is to establish a reliable cost for each option. Given the number of defence lengths considered and the variable number of options available per defence length, a recipe system of valuing the options has been developed (i.e. using typical local rates per metre run of defence length). The rates used are based on unit rates collated from a number of sources supplemented using published pricing data. This level of resolution is considered adequate at this strategic level of study; more bespoke valuations would be warranted at a detailed appraisal stage.

The whole life cost for each and every option has been determined for the full 100 years of the strategy. In the case of Maintain options, the incurred costs terminate at the end of the defences' residual lives, at which point the defence practice effectively switches to one of Do Nothing.

In respect of major replacements or renewals, it has been assumed that these will be implemented at the end of the estimated residual life for existing defences. The following items have also been included in the estimates.

- Annual maintenance
- Cyclic refurbishment
- Annual inspection
- Routine coastal monitoring
- In-house staff costs and other Professional fees.

The base date for all costs is July 2006. The present value of each option has been determined using the procedures referred to in DEFRA FCDPAG3 "Flood and Coastal Defence Project Appraisal Guidance – Economic Appraisal" as modified by the supplementary note to operating authorities issued by DEFRA in March 2003. Hence, a test discount rate of 3.5% has been used for years 0 – 30, 3.0% for years 31 – 75, and 2.5% thereafter.

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).

The estimated costs of the options do not include bespoke contingency or risk allowances but Optimism Bias is included in line with DEFRA guidance (i.e. +60%).

2.3 DEFENCE LENGTH OPTIONS

Within the strategic study area, the two principal threats to the coastal defences, and what they protect, may be summarised as:

- Beach lowering – prospect of undermining of existing defences; also increasing water depth can allow more severe wave attack to penetrate to the defences, leading to increased wear and tear, and overtopping.

- Geotechnical failure due to cliff slippage – risk of collapse of cliff faces including damage to the environment, the infrastructure and coastal structures themselves.

Several defence options have been examined for each defence length. These options include, as appropriate, the more generic categorisations of: do nothing, maintenance of the defences, and options which sustain or improve the standard of defence. Apart from the Do Nothing case, defences are monitored throughout their residual and extended lives. However, where Do Nothing is the preferred defence option it is assumed and recommended that shoreline monitoring is, in any case, continued.

More specific types of coastal defence mitigation are outlined below. A range of appropriate mitigation measures are covered. A major coastal improvement scheme involving the restoration of groynes and strengthening of seawall structures was carried out in 1995-1997. As this scheme included the planning and installation of groynes, alternative major beach control structures are not considered to be necessary or appropriate for the frontage now, and do not feature in the schemes described herein. An appropriate range of defence options has been considered for each defence length drawn from the following generalised cases:

- General maintenance and repair: this includes measures such as repairs to cracks, grouting, replacement of dislodged capping, promenade resurfacing, cosmetic measures, and so forth, but does not include any major rebuilds, new or replacement construction.
- Repair seawall toe piles: the repair of damaged or corroded toe piles; this might be combined with the encasing of the sea walls and the renewal of the toe apron.
- Renew seawall toe piles: the replacement of derelict toe piles; this might be combined with the encasing of the sea walls and the renewal of the toe apron.
- Rock scour protection: with this option, the derelict piles are effectively ignored and protection is, instead, afforded by a rock revetment at the toe of the wall.
- Rock revetment: a timber revetment is replaced with a rock revetment at the foot of the cliff or along the line of the existing defences
- Rock sill: A continuous rock sill is built shore parallel in front of the existing defences. The purpose here is to hold the toe of the beach and to minimise the loss of beach material due to offshore transport.
- Part new sea wall: The older and poorer sections of seawall are replaced with a new wall.
- All new sea wall: A sea wall is built along the entire frontage to replace the existing defences, irrespective of their condition. Where the existing defence is a timber revetment, this is demolished before the sea wall is built along the same line. If there is a sea wall already in existence then a new wall is built directly in front of this.
- Beach recharge: This defence option tends to avoid the need to maintain and renew linear defences. Suitable beach material is deposited on the beach and renewed periodically throughout the study period.
- Rebuild groynes: This option may be used where beach loss is due to adverse longshore drift gradient. The groynes also provide a degree of shelter to the seawall in the manner of a breakwater.

An assessment of the impact of each of these options on property, environment, amenity, health and safety, commerce, heritage and coastal processes is given with the summary for each defence length.

3. Option performance evaluation

Where the SMP requires "Hold the Line", active intervention is usually required; in the Strategy, however, non-intervention measures are also included for comparison purposes, and to test the appropriateness of the preferred SMP policy options in respect of smaller coastal defence lengths that collectively constitute a management unit.

In areas designated as *Do Nothing* or *Retreat,* active intervention to hold the coastline will generally provide little benefit and could possibly have a detrimental effect on adjoining defence lengths due to interrupting coastal processes. In areas where there are no existing defences, therefore, no new intervention has been considered other than annual monitoring.

The process for determining suitable strategy options relies on satisfying the three tenets: environmentally acceptable; technically possible and workable; and economically viable. The next three sections describe the methods used to assess each of these criteria.

3.1 TECHNICAL PERFORMANCE

The appraisal of technical performance of strategy options includes the following steps:

- establishing a list of possible mitigation measures (options) based on the generic options of Maintain, Sustain and Improve where these are appropriate to the SMP policy option, and based more specifically on the option types outlined in Section 2.3;
- considering the functional performance of each option including mitigation of overtopping, breaching and erosion;
- if appropriate, highlighting safety issues related to given options;
- considering impacts of each option on the environment and in terms of sustainability;
- estimating a broad brush but strategically reliable cost for each option.

3.2 ENVIRONMENTAL PERFORMANCE

To ensure due recognition of environmental concerns within the option selection process, and promote environmental enhancement, each generic option has been assessed based on its impact on four key areas:

- Built environment (Property/Commercial)
- Nature conservation and geological designations (Environment)
- Tourism and leisure (Amenity)
- Archaeology and cultural heritage (Heritage)

Human and natural environmental assets, including nature conservation, landscape and archaeological interests, are considered in the context of the environmental objectives.

3.3 ECONOMIC PERFORMANCE

The appraisal of economic performance is a key stage in the development of the preferred strategic 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 worth of any particular coastal management option is established. The costs and residual damages of each scheme are compared with the damages that might occur in the case of a *Do Nothing* approach. The damage avoided by the scheme is the so-called scheme benefit. The scheme benefits are compared with the scheme cost, thus enabling an evaluation of the so-called Benefit Cost Ratio (b/c).

- **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 or untenable commitments.

- **To demonstrate accountability**
  A formal process of project appraisal (engineering, environmental and economic criteria) 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 of the decision making process.

4. Option evaluation

A range of options is presented for each individual defence length making up the entire study frontage, i.e.:

- Management Unit MU1/CU1: Kelling to Sheringham (comprising two smaller units, treated as one)
- Management Unit RUN1: Sheringham (comprises eight defence lengths designated RUNs 1.01 to 1.08)
- Management Unit RUN2: West Runton to Cromer (comprises five defence lengths designated RUNs 2.01 to 2.05).

4.1 MANAGEMENT UNIT MU/CU1: KELLING TO SHERINGHAM

SMP1 Policy: Do Nothing

Description: This management unit includes the defence lengths MU1/CU1.01 & MU1/CU1.02. It is the most western of the management units within the study area bordering on the low lying Salthouse marsh. The hinterland of defence length CU1.02 consists of agricultural land and Sheringham Golf Club's course. The entire length of CU1.02 is also a SSSI. There are no coastal defences in this management unit

4.1.1 MU1/CU1.01 & CU1.02

Table 4.1 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.1 Options Summary

Management Unit: MU1/CU1.01/.02		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
Monitoring only		160,431	838,657	0	0
Do Nothing		-	838,657	0	0

Option Discussion:

Do Nothing: Losses in this long section of coastline are principally large sections of land. Most of this is agricultural land (or land of equivalent value) but there are also stretches of land owned by the National Trust (Sheringham Park) and the northern fringe of the links golf course. A small number of properties are also lost during the study period. Costs have been included to cover the removal of large caravans situated close to the cliff. The loss of the County Wildlife sites at Kelling and Weybourne has been accounted for as if the sites were recreated elsewhere. Total damages due to coastal erosion over 100 years are evaluated at £838,657.

As CU1.01/.02 is an undefended length of coast, no maintenance works are required. The damages incurred equate to only about £150 per metre run of the frontage and, therefore, would not support any new construction. New construction in this unit would, in any case, be inappropriate given that continued erosion provides valuable material into the sediment budget.

In this case, the preferred option in principle is Do Nothing. This conclusion agrees with the SMP policy option. It is recommended, however, that coastal monitoring is continued; the budget for this is given in the table above.

4.2 MANAGEMENT UNIT RUN1: SHERINGHAM

SMP1 Policy: Hold the line

Description: The coastal defences protect the town of Sheringham. Whilst the coastal defences have protected the town since the late 19th century, the coastline has eroded on either side forming a promontory at Sheringham. If the defences were allowed to fail then the coastline would start to erode rapidly back to a more stable position.

This management unit includes the defence lengths designated Runs 1.01 to 1.08. A section of the cliff within defence length 1.07 is part of the Beeston Cliffs SSSI. The entire cliff within defence length 1.08 is part of the Beeston Cliffs SSSI.

4.2.1 RUN 1.01

Overview: Present defences comprise a reinforced concrete seawall (in fair condition) fronted by a volatile shingle beach (in good condition). The likely failure mechanism is cliff failure and/or sustained loss of beach shingle, leading to structural instability. The defence length is not prone to large slips.

The hinterland is semi-urban cliff top, with golf course and a number of residential properties.

Table 4.2 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.2 Options Summary

Management Unit: RUN 1.01		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
Option 0	Do Nothing	0	77,041	0	-
Option 1	Maintain	164,310	77,041	0	0
Option 2	Sustain	1,182,418	0	77,041	0.065
Option 3	Improve	1,077,750	0	77,041	0.071
	Monitoring only	16,420	77,041	0	0

Option Descriptions:

No Nothing: Certain properties to the north of the cliff face are lost with the sea wall, subsequent to which losses are confined to golf course land only. Total damages due to coastal erosion over 100 years are evaluated at £77,041.

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component within an estimated 16 years; the defences are then abandoned.

Maintenance would entail annual attention to essential safety measures, keeping the defence functional and dealing with cosmetic issues. However, as this option would not provide continued protection for the strategy life of 100 years it does not comply with the policy option of hold the line.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. This means deepening toe structures as necessary to cater for falling beach levels; given the likely rate of beach lowering this is tenable. This defence length abuts the undefended defence length MU1/CU1. In order to mitigate the risk of outflanking, rock armour is provided at the end of the seawall, against the cliff, in year 10.

Option 2 protects property and commercial interests; it has a neutral impact in respect of the natural environment, amenity and health and safety; it provides no advantage in respect of coastal processes, which can expect to worsen in terms of the falling beaches.

Option 3: This option is identical to Option 2 in respect of measures applied to the sea wall. The two groynes in this defence length may have been provided originally to bolster the defence of the RNLI facilities, particularly a launch ramp, at this location. The ramp has been replaced by a very robust structure, capable of sustaining falling beach levels. Thus, the groynes may now be an unnecessary impediment to the natural of movement of flint into the rest of the RUN 1 system. This option includes the removal of the two groynes which, consequently, avoids all associated maintenance and renewal costs.

The increased throughput of sand would benefit other areas downdrift of RUN 1.01. In this respect this option offers an improvement to the Management Unit as a whole, albeit not within the defence length itself.

Option 3 protects property and commercial interests; it has a neutral impact in respect of the natural environment, amenity and health and safety; it provides some advantage in respect of coastal processes, by removing the impedance to sediment transport; there is, however, no net gain to the overall sediment budget.

This option would require further study to confirm the impacts and effectiveness of groyne removal.

Viable Options:
None of the schemes are justified economically. However, Do Nothing would not comply with the SMP policy option and it would incur other non-quantified damages to heritage and amenity.

If it is required to Hold the Line within this management unit, then Option 3 provides the cheapest means of achieving this. However, the adoption of Option 3 depends on the undertaking of more specialised studies. Pending this, the costs for Option 2, which is marginally more expensive, should be allowed for.

Given the very low level of economic benefits derived from the Hold the Line policy, consideration should be given to altering the policy to Managed Retreat. This is feasible as the unit is at the very end of the defended frontage, and does not significantly affect adjacent infrastructure. In the case of Managed Retreat, Option 1 (Maintain) could be a suitable way forward. This option would maintain the status quo for up to 16 years during which time the necessary steps could be taken to plan for the future withdrawal of defence.

Moreover, there is time to check the merits of the chosen option at the time of future strategic reviews.

RUN 1.01 is discussed in more detail in Section 5.3.2.

4.2.2 RUN 1.02

Overview: The present defences comprise a concrete seawall, promenade and retaining wall (in very poor condition) fronted by volatile shingle beach (in good condition). The likely failure mechanism is overturning following a large loss of beach shingle and a drop in beach crest.

The hinterland is semi-urban cliff top with a number of residential properties.

Table 4.3 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.3 Options Summary

Management Unit: RUN 1.02		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	2,605,541	0	-
Option 1	Maintain	47,547	2,605,541	0	0
Option 2	Sustain	2,331,396	0	2,605,541	1.12
Option 3	Improve	1,325,113	0	2,605,541	1.97
Option 4	Sustain	1,411,286	0	2,605,541	1.85
Option 5	Sustain	1,314,418	0	2,605,541	1.98
	Monitoring only	12,860	2,605,541	0	0

Option Descriptions:

Do Nothing: Properties to the north of the cliff face are quickly lost, followed by golf course land throughout the whole study period. The launch ramp is also lost together with the most westerly set of buildings on "The Esplanade". Total damages due to coastal erosion over 100 years are evaluated at £2,605,541.

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component within an estimated 5 years; the defences are then abandoned. Maintenance would entail annual attention to essential safety measures, keeping the defence functional and dealing with cosmetic issues. However, as this option would not provide continued protection for the strategy life of 100 years it does not comply with the policy option of hold the line and is rejected.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. As the seawall here has an extremely short residual life and is in very poor condition, it is replaced by a new seawall with a steel pile toe protection at year 2 say. The depth of this toe would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon.

This option does nothing to mitigate or prevent the continuing erosion of the beach platform or the loss of beach material and the flint backshore. Option 2 protects property and commercial interests; it is of neutral impact in respect of the natural environment, amenity and health and safety; it provides no advantage in respect of coastal processes.

Option 3: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. In addition, the flint at the head of the beach is renourished periodically with similar material thereby sustaining the protection offered by the existing flint backshore. This obviates the need to reconstruct completely the seawall which, instead, is encased at year 2 with the addition of a steel pile toe.

Option 3 protects property and commercial interests; it is of neutral impact in respect of the natural environment, amenity and health and safety; arguably it effects a neutral impact on coastal processes, as beach losses are to a degree compensated by the renourished flint backshore. In view of the potential advantage to the coastal processes, Option 3 is regarded as an improvement option.

Option 4: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. The seawall is encased at year 2 and scour protection is provided by a rock armour revetment instead of steel piles. The volume of material placed would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon.

Option 4 protects property and commercial interests; it is of neutral impact in respect of the natural environment. The use of rock on the shore could be regarded negatively with respect to amenity and health and safety; the option provides no advantage in respect of coastal processes.

Option 5: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. No work is done to renew the seawall. Instead, the principal defence is provided by way of a rock armour revetment. The volume of material placed would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon.

Option 5 protects property and commercial interests; it is of neutral impact in respect of the natural environment. The use of rock on the shore could be regarded negatively (moreso than Option 4) with respect to amenity and health and safety; the option provides no advantage in respect of coastal processes.

Viable Options:
Options 2, 3, 4 and 5 all deliver b/c ratios over 1.00. As Option 2 entails a complete rebuild of the sea wall, whereas the others entail strengthening of one form or another, it

is correspondingly more expensive. Moreover, it offers no real advantage over the other three options and is, therefore, rejected.

Of the remaining options, both Options 4 and 5 include the use of rock which might be regarded negatively in terms of safety and amenity. Option 3 is marginally more expensive than the cheapest option and, given the potential advantage to coastal processes, is taken to be the preferred strategic option for defence length 1.02.

4.2.3 RUN 1.03

Overview: The present defences comprise a very old concrete seawall, promenade and retaining wall (in very poor condition) which rely on a high beach for continuing stability. The shingle beach is volatile but in fair condition. The likely failure mechanism is instability, following beach drawdown.

The hinterland is urban cliff top with predominantly residential housing.

Table 4.4 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.4 Options Summary

Management Unit: RUN 1.03		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	3,861,671	0	-
Option 1	Maintain	150,029	3,861,671	0	0
Option 2	Sustain	7,397,126	0	3,861,671	0.52
Option 3	Improve	4,163,162	0	3,861,671	0.93
Option 4	Sustain	4,526,779	0	3,861,671	0.85
Option 5	Sustain	4,268,687	0	3,861,671	0.90
	Monitoring only	37,432	3,861,671	0	0

Option Descriptions:

Do Nothing: Properties to the north of the cliff face and the main section of the West Promenade are quickly lost followed by the rest of the buildings on "The Esplanade" and the western side of "The Driftway". Total damages due to coastal erosion over 100 years are evaluated at £3,861,671

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component within an estimated 3 years; the defences are then abandoned. Maintenance would entail annual attention to essential safety measures, keeping the defence functional and dealing with cosmetic issues. However, as this option would not provide continued protection for the strategy life of 100 years it does not comply with the policy option of hold the line and is rejected.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. As the seawall here has an extremely short residual life and is in very poor condition, it is replaced by a new seawall with a steel pile toe protection at year 2 say. The depth of this toe would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon.

This option does nothing to mitigate or prevent the continuing erosion of the beach platform or the loss of beach material and the flint backshore.

Option 2 protects property and commercial interests; it is of neutral impact in respect of the natural environment, amenity and health and safety; it provides no advantage in respect of coastal processes.

Option 3: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. In addition, the flint at the head of the beach is renourished with similar material thereby sustaining the protection offered by the existing flint backshore. This obviates the need to reconstruct completely the seawall which is, instead, encased at year 2 with the addition of a steel pile toe.

Option 3 protects property and commercial interests; it is of neutral impact in respect of the natural environment, amenity and health and safety; arguably it has a neutral impact on coastal processes, as beach losses are to a degree compensated by the renourished flint backshore. In view of the potential advantage to the coastal processes, Option 3 is regarded as an improvement option.

Option 4: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. The seawall is encased at year 2 and scour protection is provided by a rock armour revetment instead of steel piles. The volume of material placed would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon.

Option 4 protects property and commercial interests; it is of neutral impact in respect of the natural environment. The use of rock on the shore could be regarded negatively with respect to amenity and health and safety; the option provides no advantage in respect of coastal processes.

Option 5: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. No work is done to renew the seawall. Instead, the principal defence is a rock armour revetment. The volume of material placed would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon.

Option 5 protects property and commercial interests; it is of neutral impact in respect of the natural environment. The use of rock on the shore could be regarded negatively (moreso than Option 4) with respect to amenity and health and safety; the option provides no advantage in respect of coastal processes.

Viable Options:
Options 3, 4 and 5 all deliver b/c ratios just less than 1.00. As Option 2 entails a complete rebuild of the sea wall, whereas the others entail strengthening of one form or another, it is correspondingly more expensive, delivering a b/c ratio of only 0.52. Moreover, it offers no real advantage over the other three options and is, therefore, rejected.

Of the remaining options, both Options 4 and 5 include the use of rock which might be regarded negatively in terms of and amenity and other perspectives. Option 3 is the cheapest option and, given the potential advantage to coastal processes, is taken to be the preferred strategic option for defence length 1.03.

4.2.4 RUN 1.04

Overview: The present defences comprise a reinforced concrete facing to original seawalls together with a new steel pile toe and rock armour stone protection to the toes of walls (in very good condition). The shingle beach is volatile but in good condition. The likely failure mechanism is very severe and sustained beach lowering leading to toe failure.

The hinterland is urban cliff top with both commercial and residential properties in the town centre. The immediate hinterland also contains a sewerage storm tank and pumping station.

Table 4.5 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.5 Options Summary

Management Unit: RUN 1.04		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	4,755,152	0	0
Option 1	Maintain	520,333	4,755,152	0	0
Option 2	Sustain	2,579,779	0	4,755,152	1.84
Option 3	Improve	5,715,592	0	4,755,152	0.83
	Monitoring only	31,117	4,755,152	0	0

Option Descriptions:

Do Nothing: Following the loss of the central promenade and sea wall a large number of properties behind are lost throughout the study period. Total damages due to coastal erosion over 100 years are evaluated at £4,755,152.

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component within an estimated 25 years; the defences are then abandoned. Maintenance would entail annual attention to essential safety measures, keeping the defence functional and dealing with cosmetic issues. However, as this option would not provide continued protection for the strategy life of 100 years it does not comply with the policy option of hold the line and is rejected.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. This option is effectively a continuation of existing practice.

Option 2 protects property and commercial interests; it is of neutral impact in respect of the natural environment, amenity and health and safety; it provides no advantage in respect of coastal processes which can be expected to suffer in the long term due to the likely eventual beach lowering in this area.

Option 3: The beach is nourished with 45,020m^3 of dredged sand to the form and profile recommended in the HR Wallingford report "Sheringham Coast Protection Scheme 902, Stage2: Beach Recharge and Control Structures Physical Model Study, EX3147, May 1995. This follows the improvement of the rock groyne to the profile referred to in that report. The nourishment of the beach obviates the need for maintenance and renewal of the seawall and the existing rock armour scour protection.

Option 3 protects property and commercial interests; it would yield a positive impact in respect of the natural environment, amenity and health and safety; it also, provides an advantage in respect of coastal processes by countering beach lowering. Having due regard to these unquantified benefits, Option 3 is regarded as an improvement option.

Viable Options:
Options 2 and 3 are both technically viable and environmentally acceptable. Option 3 is desirable in so far as it provides certain environmental improvements and is advantageous in respect of the longer term coastal processes. However, the b/c ratio for Option 3 is only 0.83 compared with 1.84 for Option 2. In view of this significant difference, Option 2 should be adopted provisionally and the shoreline monitored over coming years. The existing hard defence has a considerable residual life (25 years) and hence there is sufficient time to gather data and review this provisional decision at the time of future strategic reviews.

4.2.5 RUN 1.05

Overview: The present defences comprise a concrete seawall, promenade and retaining walls. The original wall is protected by a rock revetment (in good condition where wall is combined with a revetment). The shingle beach is narrow and in fair condition. The likely failure mechanism is cliff failure leading to surcharge or overturning.

The hinterland is urban cliff top with predominantly residential properties.

Table 4.6 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.6 Options Summary

Management Unit: RUN 1.05		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
Option 0	Do nothing	0	7,882,587	0	-
Option 1	Maintain	974,707	7,882,587	0	0
Option 2	Sustain	4,701,713	0	7,882,587	1.68
Option 3	Improve	7,684,813	0	7,882,587	1.03
	Monitoring component	60,742	7,882,587	0	0

Option Descriptions:

Do Nothing: Following the loss of the East Promenade and sea wall the adjacent car park is lost together with a large number of properties in the surrounding area. Sheringham pumping station and connecting sewerage infrastructure would be lost with the sea wall together with the east beach access ramp. Total damages due to coastal erosion over 100 years are evaluated at £7,882,587.

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component within an estimated 22 years; the defences are then abandoned. Maintenance would entail annual attention to essential safety measures, keeping the defence functional and dealing with cosmetic issues. However, as this option would not provide continued protection for the strategy life of 100 years it does not comply with the policy option of hold the line and is rejected.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. This option is effectively a continuation of existing practice.

Option 2 protects property and commercial interests; it is of neutral impact in respect of the natural environment, amenity and health and safety; it provides no advantage in respect of coastal processes which can be expected to suffer in the long term due to the likely eventual beach lowering in this area.

Option 3: The beach is nourished with 87,880m^3 of dredged sand to the form and profile recommended in the HR Wallingford report "Sheringham Coast Protection Scheme 902, Stage2: Beach Recharge and Control Structures Physical Model Study, EX3147, May 1995. This follows the improvement of the three rock groynes to the profile referred to in that report. The nourishment of the beach obviates the need for maintenance and renewal of the seawall and the existing rock armour scour protection.

Option 3 protects property and commercial interests; it would yield a positive impact in respect of the natural environment, amenity and health and safety; it also provides an advantage in respect of coastal processes by countering beach lowering. Having due regard to these unquantified benefits, Option 3 is regarded as an improvement option.

Viable Options:
Options 2 and 3 are both technically viable and environmentally acceptable. Option 3 is desirable in so far as it provides certain environmental improvements and is advantageous in respect of the longer term coastal processes. However, the b/c ratio for Option 3 is 1.03 compared with 1.69 for Option 2. In view of this significant difference, Option 2 should be adopted provisionally and the shoreline monitored over coming years. The existing hard defence has a considerable residual life (25 years) and hence there is sufficient time to gather data and review this provisional decision at the time of future strategic reviews. Given that Option 3 is justified economically, albeit marginally, it should be given more detailed consideration, in particular with respect to the geotechnical advantage of holding a higher beach level.

4.2.6 RUN 1.06

Overview: The present defences comprise a concrete seawall set in front of the cliff, with a rock armour revetment placed in 1995. The shingle beach is low and in fair condition. The likely failure mechanism is cliff failure causing overturning or surcharging, resulting in sliding.

The hinterland is urban with a number of residential properties set back from the cliff edge.

Table 4.7 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.7 Options Summary

Management Unit: RUN 1.06		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	46,849	0	-
Option 1	Maintain	131,700	46,849	0	0
Option 2	Sustain	834,654	0	46,849	0.056
	Monitoring only	8,267	46,849	0	0

Option Description:

Do Nothing: A small number of properties on "Nelson Road" are lost right at the end of the study period; hence, the low level of discounted damages due to coastal erosion over 100 years which are evaluated at £46,849.

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component within an estimated 22 years; the defences are then abandoned. Maintenance would entail annual attention to essential safety measures, keeping the defence functional and dealing with cosmetic issues. However, as this option would not provide continued protection for the strategy life of 100 years it does not comply with the policy option of hold the line.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. This option is effectively a continuation of existing practice.

Option 2 protects property and commercial interests, albeit latently; it is of neutral impact in respect of the natural environment, amenity and health and safety; it provides no advantage in respect of coastal processes which can be expected to suffer in the long term due to the continued beach lowering in this area.

Viable Options:
Whilst being the only option that complies with the SMP policy option of Hold the Line, Option 2 is not economically justified.

Given the very low level of economic benefits derived from the Hold the Line policy, consideration should be given to altering the policy to Managed Retreat. This is especially feasible if RUNs 1.07 and 1.08 are considered similarly. Being at the end of the defended frontage these units do not significantly affect the adjacent higher density infrastructure.

In the case of Managed Retreat, Option 1 (Maintain) could be a suitable way forward. This option would maintain the status quo for up to 22 years during which time the necessary steps could be taken to plan for the future withdrawal of defence.

Moreover, there is time to check the merits of the chosen option at the time of future strategic reviews.

4.2.7 RUN 1.07

Overview: The defences comprise a concrete seawall with slightly concave face set forward of the cliff, with apron and steel pile toe. It is badly abraded, with exposed aggregate and rust stains from reinforcement. The shingle beach is low. The likely failure mechanism is cliff failure causing overturning or surcharging, resulting in sliding.

The hinterland is urban with a number of residential properties set back from the cliff edge.

Table 4.8 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.8 Options Summary

Management Unit: RUN 1.07		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	418,338	0	-
Option 1	Maintain	137,892	418,338	0	0
Option 2	Sustain	2,889,561	0	418,338	0.14
Option 3	Sustain	3,329,910	0	418,338	0.13
Option 4	Improve	2,195,843	0	418,338	0.19
	Monitoring only	35,136	418,338	0	0

Option Descriptions:

Do Nothing: In this scenario, properties on “Hillside” and “Conway Road” are lost in the latter half of the study period. Total damages due to coastal erosion over 100 years are evaluated at £418,338. Do Nothing would also result in partial loss of Beeston Hill, a local landmark and part of the Beeston Cliffs SSSI.

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component. The defences are then abandoned. Maintenance would entail annual attention to essential safety measures, keeping the defence functional and dealing with cosmetic issues. This option represents a more or less neutral situation until the defences fail in an estimated six years time. After this time, as with Do Nothing, partial loss of Beeston Hill would ensue.

However, as this option would not provide continued protection for the strategy life of 100 years it does not comply with the policy option of Hold the Line.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. The depth of the toe would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon. This option does not favour coastal processes but in other respects is neutral in so far as it maintains the status quo.

Option 3:
All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. However, instead of renewing the steel pile scour protection to the wall at year 6, rock armour is used as scour protection instead. The volume of material placed would have to be sufficient for the option to be sustainable (subject to subsequent rebuilds) for the 100 year horizon.

The impacts of this are similar to those of Option 2, albeit coastal processes at a local level might be slightly improved (reduced wave reflection from seawall). The use of rock on the shore could be regarded negatively with respect to amenity and health and safety.

Option 4: In this option the seawall and scour protection is not maintained or renewed at year 6. The principal defence is then provided by a rock armour revetment built in front of the moribund seawall.

The impacts of this are similar to those of Option 2, albeit coastal processes at a local level might be slightly improved (reduced wave reflection from seawall). The use of rock on the shore could be regarded negatively with respect to amenity and health and safety.

Viable Options:
None of the intervention schemes are economically justified; i.e. b/c << 1.0. Moreover, they would continue to have a negative impact on coastal processes. The SMP policy option is to Hold the Line; on the basis of this being applied, the best option from those identified is the least cost option, i.e. Option 4.

Given the low level of economic benefits derived from the Hold the Line policy, consideration should be given to altering the policy to Managed Retreat. This is especially feasible if RUN 1.08 is considered similarly. Being at the end of the defended frontage these units do not significantly affect the adjacent higher density infrastructure to the west of RUN 1.06.

In the case of Managed Retreat, Option 1 (Maintain) could be a suitable way forward. In this case, however, the residual life of the existing defence is rather short (six years). In view of this, the future of defence length RUN 1.07 needs to be given early attention by way of a detailed appraisal in which the environmental merits can be examined in greater detail, and a wider range of technical solutions considered.

RUN 1.07 is discussed in more detail in Section 5.3.2.

4.2.8 RUN 1.08

Overview: The defences in Run 1.08 comprise a derelict timber revetment on a badly abraded concrete base. The steel pile toe is very badly abraded. Moreover, it is a health and safety hazard. The shingle beach is very low. The likely failure mechanism is cliff failure causing overturning or surcharging, causing sliding.

The hinterland is urban with a number of residential properties set well back from the cliff edge.

Table 4.9 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.9 Options Summary

Management Unit: RUN 1.08		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	0	0	-
Option 1	Maintain	0	0	0	0
Option 2	Sustain	3,023,650	0	0	0
Option 3	Improve	1,099,237	0	0	0
Option 4	Removal	91,596	0	0	0
	Monitoring only	26,180	0	0	0

Option Descriptions:

Do Nothing: This small section suffers no significant economic losses due to coastal erosion during the strategic life of 100years. Total damages are taken to be zero. Do Nothing would, however, result in partial loss of Beeston Hill, a local landmark and part of the Beeston Cliffs SSSI.

Option 1: By definition, all of the components of the existing defences are maintained until the earliest failure of a principal component; the defences are then abandoned. However, in this case, the defences have already failed and so Option 1, Maintain, has the same meaning as Do Nothing. This option does not comply with the policy of Hold the Line.

Option 2: All of the components of the existing defences are renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. The revetment here is already in a very advanced state of dereliction. Hence, this option begins with the complete reconstruction of the revetment, to its original design.

In the operational phase, this option has effectively a neutral impact on the environment as it is essentially a re-run of passed practice.

Option 3: The principal defence is provided by a rock armour sill built over the line of the moribund revetment. Where practicable, components of the old defence are demolished, removed or incorporated in to the new works.

Coastal processes at a local level might be improved slightly (reduced wave reflection from the seawall). The use of rock on the shore could be regarded negatively with respect to amenity, health and safety.

Option 4: The existing defence is demolished and removed.
Notwithstanding the partial loss of Beeston Hill, potentially, this option would be beneficial to the environment, safety, and coastal processes, with no significant economic loss other than the cost of removal. This option does not comply with the SMP policy of Hold the Line.

Viable Options:
Given that there are no identified economic losses incurred in the Do Nothing scenario, it follows that all the intervention options have a zero benefit-cost ratio.

The SMP policy option is to Hold the Line; on the basis of this being applied, the best option from those identified is the least cost option, i.e. Option 3.

Notwithstanding this being the cheapest option which actually continues to Hold the Line, consideration should be given to Option 4, to demolish the defence, and not replace it. This would improve public safety and coastal processes.

Given that the defence has effectively failed and now constitutes a safety hazard, more detailed plans for the future of Run 1.08 need to be considered as a high priority. A decision to implement this must be preceded by a decision to change the SMP1 policy from Hold the Line to Managed Retreat.

RUN 1.08 is discussed in more detail in Section 5.3.2.

4.3 MANAGEMENT UNIT RUN2: WEST RUNTON TO CROMER

SMP1 Policy: Managed Retreat.

Description: This management unit includes the defence lengths RUN 2.01 to 2.05. Defence length 2.01 is characterised by the presence of the derelict timber revetment over its entire length. Defence lengths RUN 2.02 and 2.04 cover the short, defended, lengths of the West and East Runton ramps/beach access points respectively. Defence lengths RUN 2.03 and 2.05 are undefended stretches of cliff.

The eastern portion of RUN 2.01, RUN 2.02 and the western portion of 2.03 include the West Runton Cliffs SSSI. The eastern half of RUN 2.03, RUN 2.04 and the western half of RUN 2.05 include the East Runton Cliffs SSSI. The West Runton and East Runton SSSI are not continuous within RUN 2.03.

4.3.1 RUN 2.01

Overview: The defences comprise a timber revetment with steel sheet pile toe, in various stages of dereliction. The sill still retains beach material landward of the structure. There is generally a shallow shingle upper/sand lower beach that is in good condition. The defences have already failed.

The hinterland is rural cliff-top land, with residential properties, mobile home sites and agricultural land adjacently.

Table 4.10 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.10 Options Summary

Management Unit: RUN 2.01		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	851,142	0	-
Option 1	Maintain	800,889	851,142	0	0
Option 2	Maintain (to year 50)	4,011,601	185,206*	665,936*	0.17
Option 3	Maintain	1,318,222	851,142	0	0
Option 4	Removal	559,352	851,142	0	0
	Monitoring only	165,690	851,142	0	0

* note: see Option 2 text

Option Descriptions:

Do Nothing: Losses consist of a small number of properties, agricultural land and two caravan park areas containing static chalets and mobile caravans. Total damages due to coastal erosion over 100 years are evaluated at £851,142.

Option 1: The principal component of this option is directed at health and safety measures to mitigate the hazards associated with the remains of the revetment and, in particular, the steel pile toe. The groynes are maintained until they reach their likely residual life. At that time, both the groynes and the revetment are demolished.

This Maintain option complies with the SMP policy option of Managed Retreat. However, because the defences would become ineffective (through removal) at the same time as they would in the Do Nothing case, there is no significant benefit in terms of the avoidance of erosion damages. The principal advantage relates to improved safety. The option has a near neutral environmental impact in the short term as the form of the defences does not change. In the longer term (from 5 years) the removal of the relic defences should represent an improvement in terms of visual impact. Because of their present ineffectiveness the impacts on coastal process, cliff exposure and the natural environment are expected to be slight in the medium to long term. The sill would result in a short term accelerated erosion of the cliff.

Option 2: The steel pile toe to the derelict revetment (as distinct from the superstructure) continues to provide a modest degree of protection in that it is effectively a sill. This option enhances that protection by building a rock armour sill over the existing piles. The added benefit is that the hazard of the existing piles is removed. The groynes are maintained until they reach the end of their residual lives at which time they are demolished. Maintenance of the rock sill ends at year 50.

This Maintain option complies with the SMP policy option of Managed Retreat. In this case, the defences reduce, only slightly, the rate of erosion losses for 50 years. Hence the scheme provides a reduction in the discounted value of damages accrued over the remaining 50 years (of the strategy time horizon). On the basis that erosion was curtailed altogether (an artificial but useful test), the deferred damages amount to £185,206, yielding a benefit of £665,936. This result yields a b/c ration of just 0.17. Given that the true damages would be greater, due to the continued (but slightly alleviated) erosion, then the benefits and the b/c ratio would be correspondingly reduced also. The scheme is, therefore, not economically justified.

The impacts other than the significant improvement in safety, would be modest as the relic defence would effect no greater influence than the present structure (i.e. which is minimal).

Option 3: The hazard presented by the steel pile toe is mitigated by the fixing of timber walings to both faces of the piles thereby masking the exposed pile tops. The groynes are maintained until they reach the end of their residual lives at which time they are demolished along with the derelict revetment.

This Maintain option complies with the SMP policy option of Managed Retreat. However, because the defences would become ineffective (through removal) at the same time as they would in the Do Nothing case there is no significant benefit in terms of the avoidance of erosion damages. The principal advantage relates to improved safety. The option has a near neutral environmental impact in the short term as the form of the defences does not change. In the longer term (from 5 years) the removal of the relic defences should represent an improvement in terms of visual impact. Because of their present ineffectiveness the impacts on coastal process, cliff exposure and the natural environment are expected to be slight.

Option 4: The existing revetment and groynes are demolished at year 0. This option would benefit safety. Other operational environmental impacts would be modest, given the present defences are rather ineffective now.

Viable Options:
There is insufficient justification for holding the defence line for the residual life of the structures or for an extended period of 50 years. Removal of the revetment and groynes now, Option 4, would result in the eventual loss of some property, agricultural land and caravan park, however it is beneficial in respect of conservation, coastal processes and health and safety. The continued defence of Run 2.01 is not sustainable; the preferred solution in this case is, therefore, removal of the defences, Option 4.

RUN 2.01 is discussed in more detail in Section 5.3.3.

4.3.2 RUN 2.02

Overview: The defences comprise a concrete access ramp, protected by concrete walls with steel sheet pile toe on flanks, generally in good condition. The ramp itself has been extended in 2005/06. The likely failure mechanism is beach lowering, resulting in steel pile failure, or cliff failure. Extensive areas of chalk exposure now prevail where once there were expanses of sand that this location was well known for.

The hinterland is mainly rural cliff-top land, with the village of West Runton set back from the cliffs. The defence length contains an access ramp used by tourists and local fishermen alike.

Table 4.11 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.11 Options Summary

Management Unit: RUN 2.02		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing		875,765	0	0
Option 1	Maintain	205,130	875,765	0	0
Option 2	Sustain	917,357	0	875,765	0.95
Option 3	Improve	1,355,887	0	875,765	0.65
	Monitoring only	15,731	875,765	0	0

Option Descriptions:

Do Nothing:
Losses in this small section consist of the launch ramp at West Runton, sewerage infrastructure including West Runton pumping station, a single property and a small amount of agricultural land. Total damages due to coastal erosion over 100 years are evaluated at £875,765

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component. The defences are then abandoned in year 22. This Maintain option complies with the SMP policy option of Managed Retreat.

During the first 22 years the impacts of the scheme would be negligible as it represents a continuation of existing practice. Beyond 22 years the impact would be negative in respect of the loss of the beach access facility and the amenity value that goes with that.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. At year 22, in conjunction with seawall renewal, works to prevent outflanking are implemented.

The environmental impacts of the scheme would be modest, given that it represents a continuation of existing practice. In the longer term, the ramp would tend to become more exposed as the cliff line eroded to either side. This could, additionally, effect a small negative influence on the coastal processes. However, in the longer term, there could be opportunities for setting back the facility at the time of rebuilding; this option being available because of the discrete nature of the installation.

Option 3: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. At year 22, in conjunction with seawall renewal works, works to prevent outflanking are implemented. Rock armour scour protection is provided at year 0 to counter the impact of eroding beach platform levels.

The environmental impacts of the scheme would be modest, given that it represents a continuation of existing practice. The use of rock could be regarded negatively in terms of amenity and visual impact. In the longer term, the ramp would tend to become more exposed as the cliff line eroded to either side. This could, additionally, effect a small negative influence on the coastal processes. However, in the longer term, there could be opportunities for setting back the facility at the time of rebuilding; this option being available because of the discrete nature of the installation.

Viable Options:
Do Nothing or Maintain options would result in the eventual loss of the ramp. Considered in conjunction with other losses that would occur, the case for intervention is fair and results in a near neutral b/c ration for the Sustain case (Option 2 b/c = 0.97). Notwithstanding that the b/c ratio falls just below 1.00, the access ramp is important to both the visiting and resident communities and, in that respect, its continued protection constitutes additional benefits which have not been quantified. The preferred solution for Run 2.02 is the cheapest option that would provide long term protection to the access ramp, Option 2 (Sustain).

4.3.3 RUN 2.03

Overview: There are extensive areas of chalk platform exposed. The beaches are eroding and no longer present the consistent expanses of sand that this location was well known for. The cliffs are undefended and eroding.

The hinterland is predominantly rural cliff-top land, mainly agricultural, but with a few residential properties and mobile home sites. There is a long, sea treated effluent outfall in this area.

Table 4.12 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.12 Options Summary

Management Unit: RUN 2.03		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	55,835	0	-
Option 1	Maintain	0	55,835	0	0
	Monitoring only	41,340	55,835	0	0

Option Description:

Do Nothing: Losses in this section consist of a small number of properties, a large stretch of agricultural (or equivalent) land and the cost of moving large caravans sited along the cliff. Total damages due to coastal erosion over 100 years are evaluated at £55,835.

Option 1: As RUN 2.03 is an undefended length of coast, no maintenance works are required.

Viable Options:
In this case, the preferred option is to continue the existing practice of no active intervention other than monitoring of the coast.

4.3.4 RUN 2.04

Overview: The defences comprise a concrete access ramp and steps, protected by flanking concrete walls and rock armour. The ramp was extended and the flanking defences rehabilitated in 2006. The flat sandy beach is in good condition. The likely failure mechanism is outflanking of the defences.

The hinterland is urban cliff top land, containing both residential and a few commercial properties in East Runton. The area between residential properties and the cliff edge is filled with mobile homes for holiday visitors. The ramp provides access to the beach for fishermen and for amenity use.

Table 4.13 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.13 Options Summary

Management Unit: RUN 2.04		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing		1,094,520	0	-
Option 1	Maintain	94,251	1,094,520	0	0
Option 2	Sustain	171,741	0	1,094,520	6.37
	Monitoring only	13,090	1,094,520	0	0

Option Description:

Do Nothing: This small section gives losses similar to that of RUN2.02; that of the launch ramp at East Runton, East Runton pumping station and sewerage infrastructure and a small number of properties. Total damages due to coastal erosion over 100 years are evaluated at £1,094,520.

Option 1: All of the components of the existing defences are maintained until the earliest failure of a principal component. The defences are then abandoned in year 50. This Maintain option complies with the SMP policy option of Managed Retreat.

During the first 50 years the impacts of the scheme would be negligible as it represents a continuation of existing practice. Beyond 50 years the impact would be negative in respect of the loss of the beach access facility and the amenity value that goes with that.

Option 2: All of the components of the existing defences are maintained and, where necessary, renewed at their respective likely residual lives taking account of the need to sustain the standard of protection. No additional work is necessary as the defences were substantially improved in 2006.

The environmental impacts of the scheme would be modest, given that it represents a continuation of existing practice. In the longer term, the ramp would tend to become more exposed as the cliff line eroded to either side. This could, additionally, effect a small negative influence on the coastal processes. However, in the longer term, there could be opportunities for setting back the facility at the time of rebuilding; this option being available because of the discrete nature of the installation.

Viable Options:
Do Nothing or Maintain options would result in the eventual loss of the ramp. Considered in conjunction with other losses that would occur, the case for intervention is strong and results in a high b/c ratio for the Sustain case (Option 2 b/c = 6.37). The access ramp is important to both the visiting and resident communities and, in that respect, its continued protection constitutes additional benefits which have not been quantified. The preferred solution for Run 2.04 is the cheapest option that would provide long term protection to the access ramp, Option 4 (Sustain).

4.3.5 RUN 2.05

Overview: The cliffs are undefended. The sandy beach with exposed shore platform is always exposed east of Runton Gap.

Hinterland is semi-urban cliff-top land on the western outskirts of Cromer, containing a few residential properties, mobile home sites and public open space. The area between residential properties and the cliff edge is filled with mobile homes for holiday visitors. There is no access to the beach for fishermen and for amenity use.

Table 4.15 outlines the options together with their generic type, the costs (c), residual damages, benefits (b), and the b/c ratios.

Table 4.15 Options Summary

Management Unit: RUN 2.05		Whole life (100 years) Costs + 60% Optimism Bias, Residual Damages, Benefits and Benefit/Cost Ratio			
Options	Category	Costs £ (c)	Residual Damages £	Benefits £ (b)	b/c
	Do Nothing	0	50,077	0	0
	Monitoring only	30,991	50,077	0	0

Option Description:

Do nothing: Losses consist of a small number of properties, the cost of moving large caravans sited along the coast and a stretch of car park. Total damages due to coastal erosion over 100 years are evaluated at £50,077.

Option 1: As RUN 2.05 is an undefended length of coast, no maintenance works are required.

Viable Options:
In this case, the preferred option is to continue the existing practice of no active intervention other than monitoring of the coast.

5. Strategy results

5.1 OVERVIEW OF FINDINGS

The study has examined the strategic coastal defence management of the Kelling to Cromer frontage. A coastal length of some 9.16 km in total, this study area comprises three Management Units (MUs), as defined in accordance with the relevant Shoreline Management Plans:

5.1.1 MU1/CU1: Kelling to Sheringham (5.6 kms)

This Management Unit combines two defence lengths (CU1.01 and CU1.02), considered herein as a single unit. This length is characterised by the absence of man-made defences. The hinterland consists of agricultural land and includes Sheringham Golf Club course. The entire length of the unit is a SSSI.

The coastal defence policy advised by the Shoreline Management Plan is Do Nothing. The strategic assessment has confirmed this approach in respect of coastal intervention. It is, however, advised that monitoring of the coastline is continued.

5.1.2 RUN 1: Sheringham (1.4kms)

This Management Unit comprises eight defence lengths (referred to as RUN 1.01 to RUN 1.08) which are considered independently. This Management Unit is fundamentally different from those on either side as it contains the urban hinterland of Sheringham town. Parts of the cliff line in RUN 1 are designated under the Beeston cliffs SSSI.

The coastal defence policy advised by the Shoreline Management Plan is to Hold the Line. The strategic assessment has confirmed the appropriateness of this approach in several of the RUN units within the interior of the Management Units. However, defence lengths at the ends of the Management Unit fail to justify the Hold the Line policy on economic grounds (RUNs 1.01, 1.06 to 1.08). Where this occurs, the issue is highlighted, and generally the cheapest SMP compliant option is identified, albeit noting that the b/c ratio falls significantly below 1.0. In these cases, Managed Retreat is a viable alternative to the policy compliant option; to illustrate this alternative, the Maintain option is also included in the respective tables and discussion.

Monitoring throughout the unit is recommended.

5.1.3 RUN 2: West Runton to Cromer (2.16 kms)

This Management Unit comprises five defence lengths (referred to as RUN 2.01 to RUN 2.05) and considered independently. The first defence length to the east of Sheringham is characterised by an extensive derelict timber revetment. Two of the units (2.02 and 2.04) contain the protected beach access ramps at West and East Runton. Otherwise, the Management Unit is undefended. The Management Unit contains the East and West Runton Cliffs SSSIs.

The coastal defence policy advised by the Shoreline Management Plan is Managed Retreat. The strategic assessment has concluded on the continued defence of the two short defence lengths containing the access ramps: RUN 2.02 (neutral economic case) and RUN 2.04 (economically justified). The defence of the other units cannot be justified and is concluded to be discontinued, or the present policy of Do Nothing is applied, as the case may be.

Monitoring throughout the unit is recommended.

5.2 DETAILED SUMMARY OF RESULTS WITH DISCUSSION

This section gives a more detailed breakdown of the findings alluded to above, including key data concerning the advised options for each defence length.

5.2.1 Results

Tables 5.1 to 5.14 give summaries of the advised strategy options for each of the defence lengths. In line with economic data given elsewhere, benefits and costs are evaluated for a time horizon of 100 years, discounted to a base date of July 2006.

Table 5.1 MU1 CU1 Summary

Defence Length:	**MU1 / CU1**
Length:	5.6 kms
SMP policy Option:	Do Nothing
Strategy Option:	Do Nothing with Monitoring
Brief Description:	• No active intervention • Monitor shoreline and cliff erosion
Benefit (b):	£ nil
Cost (c):	£ 160,431
b/c ratio:	N/A
Comment:	

Table 5.2 RUN 1.01 Summary

Defence Length:	**RUN 1.01**		
Length:	25 m		
SMP policy Option:	Hold the Line	OR	Managed Retreat
Strategy Option:	Option 2: Sustain		Option 1: Maintain
Brief Description:	• Maintain existing defences • Renew defences at end of residual life and deepen toe structure • Provide end rock protection to avoid outflanking • Monitor shoreline, defence performance and residual cliff erosion		• Maintain existing defences up to end of residual life (16 years) • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 77,041		£ nil
Cost (c):	£ 1,182,418		£ 164,310
b/c ratio:	0.065		0
Comment:	The option is not justified economically, but complies with the SMP policy option. Pending further study there may be scope for removing the groynes from this section, thus alleviating their future maintenance costs, whilst effecting improved drift of beach sediments to downdrift areas.		Non-compliant SMP Option Benefits to coastal processes are not quantified.

Table 5.3 RUN 1.02 Summary

Defence Length:	**RUN 1.02**
Length:	100 m
SMP policy Option:	Hold the Line
Strategy Option:	Option 3: Improve
Brief Description:	• Maintain existing defences • Renew defences at end of residual life • Install a steel pile toe • Renourish flint at the head of the beach periodically • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 2,605,541
Cost (c):	£ 1,325,113
b/c ratio:	1.97
Comment:	Though not the cheapest option (marginally) Option 3 provides additional non-quantified benefits to the coastal process regime.

Table 5.4 RUN 1.03 Summary

Defence Length:	**RUN 1.03**
Length:	330 m
SMP policy Option:	Hold the Line
Strategy Option:	Option 3: Improve
Brief Description:	• Maintain existing defences • Renew defences at end of residual life • Install a steel pile toe • Renourish flint at the head of the beach periodically • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 3,861,671
Cost (c):	£ 4,163,162
b/c ratio:	0.93
Comment:	In this case Option 3 is the cheapest (SMP compliant) option, having a b/c ratio just less than unity.

Table 5.5 RUN 1.04 Summary

Defence Length:	**RUN 1.04**
Length:	170 m
SMP policy Option:	Hold the Line
Strategy Option:	Option 2: Sustain
Brief Description:	• Maintain existing defences • Renew defences at end of residual life • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 4,755,152
Cost (c):	£ 2,579,779
b/c ratio:	1.84
Comment:	The defence has a considerable residual life (25 years). During this period, the selected option, which is effectively a continuation of existing practice, should be checked for continued efficiency and appropriateness. At the present time, beach nourishment, which offers certain environmental advantages, cannot be justified on cost terms, in favour of the cheaper hard defence approach (Option 2).

Table 5.6 RUN 1.05 Summary

Defence Length:	**RUN 1.05**
Length:	115 m
SMP policy Option:	Hold the Line
Strategy Option:	Option 2: Sustain
Brief Description:	• Maintain existing defences • Renew defences at end of residual life • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 7,882,587
Cost (c):	£ 4,701,713
b/c ratio:	1.68
Comment:	The defence has a considerable residual life (25 years). During this period, the selected option, which is effectively a continuation of existing practice, should be checked for continued efficiency and appropriateness. At the present time, beach nourishment, which offers certain environmental advantages, cannot be justified on cost terms, in favour of the cheaper hard defence approach (Option 2).

Table 5.7 RUN 1.06 Summary

Defence Length:	**RUN 1.06**		
Length:	86 m		
SMP policy Option:	Hold the Line		Managed Retreat
Strategy Option:	Option 2: Sustain		Option 1: Maintain
Brief Description:	• Maintain existing defences • Renew defences at end of residual life • Monitor shoreline, defence performance and residual cliff erosion	OR	• Maintain existing defences up to end of residual life (22 years) • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 46,849		£ nil
Cost (c):	£ 834,654		£ 131,700
b/c ratio:	0.056		0
Comment:	The option is not justified economically, but complies with the SMP policy option. The defence has a considerable residual life (20years). During this period, the selected option, which is effectively a continuation of existing practice, should be checked for continued efficiency and appropriateness.		Non-compliant SMP Option. Benefits to coastal processes are not quantified.

Table 5.8 RUN 1.07 Summary

Defence Length:	**RUN 1.07**		
Length:	320 m		
SMP policy Option:	Hold the Line	OR	Managed Retreat
Strategy Option:	Option 4: Improve		Option 1: Maintain
Brief Description:	• Maintain existing defences to year 6 • Construct rock revetment in front of the wall • Monitor shoreline, defence performance and residual cliff erosion		• Maintain existing defences up to end of residual life (6 years) • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 418,338		£ nil
Cost (c):	£ 2,195,843		£ 137,892
b/c ratio:	0.19		0
Comment:	The option is not justified economically, but complies with the SMP policy option. The solution provides protection to a non quantified asset, the local landmark known as Beeston Hill.		Non-compliant SMP Option. Benefits to coastal processes are not quantified.

Table 5.9 RUN 1.08 Summary

Defence Length:	**RUN 1.08**		
Length:	250 m		
SMP policy Option:	Hold the Line	OR	Managed Retreat
Strategy Option:	Option 3: Improve		Option 4: remove defence
Brief Description:	• Provide rock armour over moribund seawall • Monitor shoreline and defence performance and residual cliff erosion		• Remove defence structures • Monitor shoreline and cliff erosion
Benefit (b):	£ nil		£ nil
Cost (c):	£1,099,237		£ 91,596
b/c ratio:	0		0
Comment:	The option is not justified economically, but complies with the SMP policy option. The solution provides protection to a non quantified asset, the local landmark known as Beeston Hill.		Non-compliant SMP option. Benefits to coastal processes are not quantified.

Table 5.10 RUN 2.01 Summary

Defence Length:	**RUN 2.01**
Length:	100 m
SMP policy Option:	Managed Retreat
Strategy Option:	Option 4: Improve (remove defence)
Brief Description:	• Remove defence structures • Monitor shoreline and cliff erosion
Benefit (b):	£ nil
Cost (c):	£ 559,352
b/c ratio:	N/A
Comment:	Continued defence of RUN 2.01 is not sustainable. Immediate removal of those defences therefore provides for the earliest environmental benefits to be reaped at the least cost. The option complies with the Managed Retreat policy

Table 5.11 RUN 2.02 Summary

Defence Length:	**RUN 2.02**
Length:	24 m
SMP policy Option:	Managed Retreat
Strategy Option:	Option 2: Sustain
Brief Description:	• Maintain existing defences • Renew defences at end of residual life • Construct outflanking wall in year 22 • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 875,765
Cost (c):	£ 917,357
b/c ratio:	0.95
Comment:	This defence length contains one of the two access ramps to the beach. Continued defence using the cheapest solution presents a more or less neutral economic case. The discrete nature of the facility means that there would be scope for setting future rebuilds back, or withdrawing from defence altogether if the circumstances and demands for the facility change. Thus, the option complies with the intent of Managed Retreat, albeit with an indefinite timescale for that retreat.

Table 5.12 RUN 2.03 Summary

Defence Length:	**RUN 2.03**
Length:	1464 m
SMP policy Option:	Managed Retreat
Strategy Option:	Do Nothing
Brief Description:	• No active intervention • Monitor shoreline and cliff erosion
Benefit (b):	£ nil
Cost (c):	£ 41,340
b/c ratio:	N/A
Comment:	

Table 5.13 RUN 2.04 Summary

Defence Length:	**RUN 2.04**
Length:	60 m
SMP policy Option:	Managed Retreat
Strategy Option:	Option 2: Sustain
Brief Description:	• Maintain existing defences • Renew defences at end of residual life • Construct outflanking wall in year 22 • Monitor shoreline, defence performance and residual cliff erosion
Benefit (b):	£ 1,094,520
Cost (c):	£ 171,741
b/c ratio:	6.37
Comment:	This defence length contains one of the two access ramps to the beach. Continued defence using the cheapest solution presents a robust economic case. The discrete nature of the facility means that there would be scope for setting future rebuilds back, or withdrawing from defence altogether if the circumstances and demands for the facility change. Thus, the option complies with the intent of Managed Retreat, albeit with an indefinite timescale for that retreat.

Table 5.14 RUN 2.05 Summary

Defence Length:	**RUN 2.05**
Length:	510 m
SMP policy Option:	Managed Retreat
Strategy Option:	Do Nothing
Brief Description:	• No active intervention • Monitor shoreline and cliff erosion
Benefit (b):	£ nil
Cost (c):	£ 30,991
b/c ratio:	N/A
Comment:	

5.3 DISCUSSION

5.3.1 General

Tables 5.1 to 5.14 give the summarised data concerning each of the 14 defence lengths (taking CU1.01 and 1.02 to be a single unit). The tables show the stated SMP policy option for each defence length and conclude on the advised strategy option. The latter can be divided into schemes which are intended to continue protection through intervention, and those that are not (e.g. Do Nothing, and removal of defence). Table 5.15 illustrates this distinction.

Table 5.15 Distinction of Strategy Options

Management Unit	Defence Length	SMP Policy Option	Strategy Option Type	
			Defend through Intervention	Do Nothing or Discontinue defence
MU1 CUI	CU1.01/.02	Do Nothing		Do Nothing
RUN 1	1.01	Hold the Line	Sustain or Maintain*	
RUN 1	1.02	Hold the Line	Improve	
RUN 1	1.03	Hold the Line	Improve	
RUN 1	1.04	Hold the Line	Sustain	
RUN 1	1.05	Hold the Line	Sustain	
RUN 1	1.06	Hold the Line	Sustain or Maintain*	
RUN 1	1.07	Hold the Line	Improve or Maintain*	
RUN 1	1.08	Hold the Line	Improve, or	Discontinue*
RUN 2	2.01	Managed Retreat		Discontinue
RUN 2	2.02	Managed Retreat	Sustain	
RUN 2	2.03	Managed Retreat		Do Nothing
RUN 2	2.04	Managed Retreat	Sustain	
RUN 2	2.05	Managed Retreat		Do Nothing

*Note: These options do not comply with the SMP. Maintenance continues up to the end of residual life only.

Of the defence lengths for which continued defence is indicated, the economic performance varies significantly. Included within this group are schemes with very low b/c ratios, but which are included on the basis of being the cheapest solutions that still comply with the SMP policy option of Hold the Line. To put matters into perspective, if we consider these economic performances, in very broad terms, as being poor (b/c <0.9), neutral (for Strategy purposes taken as 0.9 <b/c <1.1) or good (b/c > 1.1), we get:

Poor performance: RUNs: 1.01; 1.06; 1.07; 1.08
Neutral performance: RUNs: 1.03; 2.02;
Good performance: RUNs: 1.02; 1.04; 1.05; 2.04

The poor performing defence lengths are those at the ends of the defended Sheringham frontage where, by virtue of being in the margins of the urban-rural interface, there are comparatively few assets to be protected.

The consideration of individual defence lengths can be misleading as it does not expose the potential value of the integrated strategic frontage. To test this concept, Table 5.16 lists the costs and benefits of the continuous lengths of Sustained or Improved coastal frontages within RUNs 1 and 2. In doing this, no presumptions are made concerning the actual interdependence of assets within the different defence lengths. Three scenarios are given for RUN 1: (i) Hold the Line throughout RUN 1; (ii) supposes that RUN 1.08 is removed at year 0 (Managed Retreat), otherwise Hold the Line; and (iii) supposes that RUN 1.08 is removed in year 0 and RUNs 1.01, 1.06 and 1.07 are maintained for the remainder of their residual lives only (Managed Retreat), otherwise Hold the Line.

Table 5.16 Combined Cost and Benefits for continuous lengths of defence

Continuous frontage	Total Costs (c)	Total Benefits (b)	b/c
(i) RUN 1.01 to RUN 1.08 (all Hold the Line)	£ 18,081,919	£ 19,647,179	1.09
(ii) RUN 1.01 to RUN 1.08 (as (i), but 1.08 removed)	£ 17,074,278	£ 19,647,179	1.15
(iii) RUN 1.01 to RUN 1.08 (as (ii) but 1.01 and 1.06-1.08 as Managed Retreat))	£ 13,295,265	£ 19,104,951	1.44
RUN 2.02	£ 917,357	£ 875,765	0.95
RUN 2.04	£ 171,741	£ 1,094,520	6.37

The exercise demonstrates that, taken at a strategic level, a continuously held defence line in RUN 1 is more or less neutral in economic terms (b/c = 1.09). As it contributes no significant additional benefit, the early removal of defence in RUN 1.08 improves the economic performance (b/c increases from 1.09 to 1.15). Further to the removal of RUN 1.08, with RUNs 1.01 and 1.06 - 1.07 designated as Managed Retreat (i.e. Maintain for residual life only) then the overall economic performance improves considerably (b/c increases from 1.15 to 1.44).

Defence of the Runton beach access sections, RUNs 2.02 and 2.04, yields economic performances that, according to the above defined terms, can be regarded at strategic level as neutral and good, respectively.

5.3.2 Poor economic cases

On the basis of compliance with the Hold the Line policy, the proposed mitigations for defence lengths RUNs 1.01, 1.06, 1.07 and 1.08 all deliver very poor economic cases, with b/c ratios of 0.065, 0.056, 0.19 and zero respectively. In view of the marked shortfall in the benefit/cost ratio to justify these options economically it is worth recapping and discussing the factors pertaining to each case:

RUN 1.01 (b/c = 0.065)
The assets protected comprise a number of properties and Golf Course land. As the defences have a residual life of some 16 years, losses that would otherwise result from the Do Nothing case would not occur until after that. The few properties lost would include the Lifeboat Station which, being more or less integral with the seawall, would be lost immediately the seawall breached. The assessment indicates that it would be

economically better to relocate the Lifeboat Station rather than continue to protect it; the nature of the installation means that it would always have to be located at the water's edge.

It remains that if the Hold the Line policy is to be upheld then, logically, the cheapest solution (in this case the Option 2) should be applied. Section 4.2 noted that there may be environmental advantages in removing the groynes at this site (Option 3). Moreover, this yields a slightly better economic case. However, it was also noted that this should not be carried out without the undertaking of a more specific study, or Project Appraisal, to consider the advantages and impacts of groyne removal.

On economic grounds, Managed Retreat is preferable to Hold the Line. A Project Appraisal study should also examine, in more detail, the merits of discontinuing defence in RUN 1.01. This would include consideration to any interaction between the assets in this unit and those in the adjacent urban unit RUN 1.02. Given that, subject to normal maintenance, the present defences are not expected to be at risk for at least 16 years, there is no immediate urgency to conduct such an exercise; however, allowing for the possibility that such a study might conclude on withdrawing defence (unless this has since been heralded by future revisions of the SMP) then sufficient time should be allowed to administer the social as well as technical implication of the policy change.

RUN 1.06 (b/c = 0.056)
The assets protected comprise a number of properties on "Nelson Road". The reason for the very low benefits is due to the fact that losses would not occur until the end of the study period, i.e. in 95 to 100 years time. The relatively high cost of providing continuing defence comes about because of the need, under the Hold the Line policy, to continue defence throughout the whole period, even when no significant damages would otherwise occur in the Do Nothing case.

If the Hold the Line policy is to be upheld then, logically, the cheapest solution (in this case the Option 2) should be applied.

On economic grounds, Managed Retreat is preferable to Hold the Line. Section 4.2.6 noted that the residual life of the defences is considerable (20 years). Hence, there will be opportunities to reconsider the value of continuing defence of RUN 1.06 at future revisions of the Strategy or through a defence length specific Project Appraisal. Such a study might also examine, in more detail, any interaction between the assets in this unit and those in the adjacent urban unit RUN 1.05 (see below for 1.07). However, allowing for the possibility that such a study might conclude on withdrawing defence (unless this has since been heralded by future revisions of the SMP) then sufficient time should be allowed to administer the social, as well as technical, implication of the policy change.

RUN 1.07 (b/c = 0.19)
The assets protected comprise properties on "Hillside" and "Conway Road". However, in the Do Nothing case, these assets are not lost until years 55 to 60. The situation is similar to that in RUN 1.06, except that the losses would occur rather sooner, resulting in a stronger, but still weak, economic case.

RUN 1.07 also contains Beeston Hill, a local landmark and part of the SSSI, which would be partially lost in the Do Nothing case. The SSSI is notified for its geological and sedimentary importance. In this respect, erosion of the cliff could be regarded as beneficial as it promotes continued fresh exposure of the cliff face. At one time the SSSI was noted for interest in the grasslands on top of the hill; in this case erosion could be detrimental to that conservation interest. However, it is understood that this aspect of the site is no longer important and hence, on balance, it would appear that a return to the natural regime would favour conservation.

If the Hold the Line policy is to be upheld then, logically, the cheapest solution (in this case the Option 4) should be applied.

On economic grounds, Managed Retreat is preferable to Hold the Line. Unlike units 1.01 and 1.06, RUN 1.07 has a short residual life (6 years). This means that, if the policy decision to Hold the Line were to be challenged, then the necessary procedures would need to be initiated soon. The best vehicle for this would be the preparation of a Project Appraisal study, in which the conservation issues, as well as the economic criterion, can be examined in greater depth.

RUN 1.08 (b/c = zero)
No significant assets (quantified in monetary terms) appear to be at risk in the case of discontinued defence (Do Nothing).

However, RUN 1.08 also contains part of Beeston Hill. Thus, the arguments for and against the continued defence, in respect of the Beeston Cliffs SSSI and the Beeston Hill landmark, are basically similar to those discussed for RUN 1.07 above.

It remains that if the Hold the Line policy is to be upheld then, logically, the cheapest solution (in this case the Option 3) should be applied.

On economic grounds, immediate retreat is preferable to Hold the Line. Given that the revetment in RUN 1.08 has already failed, the need to take remedial action is urgent. This means that, if the policy decision to Hold the Line were to be challenged, then the necessary procedures would need to be initiated now. The best vehicle for this would be the preparation of a Project Appraisal study, in which the conservation issues, as well as the economic criterion, can be examined in greater depth.

5.3.3 Urgent Issues

Section 5.3.2 identified the defence of RUN 1.07 and RUN 1.08 as requiring urgent action. Further to this, RUN 2.01.also requires urgent consideration.

RUN 1.07 (residual life = 6 years)
See Section 5.3.2

RUN 1.08 (residual life = nil)
See Section 5.3.2

RUN 2.01 (residual life = nil)
The continued defence of RUN 2.01 is not sustainable. The relic timber revetment and toe structure present a significant safety hazard and negative visual impact. The advised Strategy option (Option 4) is to remove the structures now. Factors to consider before the removal of the structures include:

- The toe structure does tend to hold up the beach behind; this effect, combined with the residual impedance created by the timber superstructure, must inhibit cliff erosion to a small degree. Whilst this makes little or no difference in the medium to long term, it could affect the cliff erosion patterns in the short term following structure removal.

- The action of removing the structures would entail plant movements to, from and on the beach. The structure is of considerable size, and so it can be envisaged that a large number of vehicle movements would be needed simply to remove the relic materials from site.
- The removal of the structure would allow waves to penetrate more readily to the upper beach, thus encouraging long shore transport to move the sediment deposits there, downdrift towards the Runtons and Cromer where it might benefit the environment and coastal protection installations.

In order to provide informed advice to those affected, it might be prudent to undertake a special study of the scheme, with particular reference to the factors listed above, and the Council may need to check the requirement for an EIA, given the extent of the works involved.

5.3.4 Reprise

It is, perhaps, no coincidence that the critical defence lengths alluded to in the section above are located at the ends of the (long time) defended frontage of Sheringham; viz: RUN 1.01 to the west, and RUNs 1.06/7/8 and 2.01 to the east. Apart from these areas being in the margins of the town's mainly developed area they are also in the margins of the coastal process regime.

The report on Littoral Sediment Processes identified that Sheringham is located at about the position of a drift divide; i.e. longshore transport tending to be westward going to the west of the town and eastward going to the east of the town (notwithstanding the vagaries in drift behaviour). The defences have held the position of the shore for more than a century, whilst the adjacent cliffs and shore have retreated naturally, thus forming a promontory at the town frontage. This is probably a contributory factor in the development of the sediment divide.

In effect the whole defence structure has acted rather like a large groyne; and, like a groyne, the area most affected by downdrift erosion is in the lee of the structure itself. Without a supply of material to feed the beaches in the downdrift zone, i.e. RUNs 1.06 to 2.01, it is not surprising that this is an area of high erosional pressure. There is no reason to suppose that this pressure will alleviate with time. This aspect of the coastal processes and their interaction with the defences is very important to future consideration of sustainability.

Similar reasoning applies to RUN 1.01, albeit the pressures appear to be much reduced when compared with those affecting the defence lengths further east.

5.4 PREDICTED EXPENDITURE STREAM

The strategic appraisal advises on a preferred mitigation option for each of the defence lengths. Table 5.17 has been prepared to show the predicted yearly expenditure for the next ten years. Values are not discounted or adjusted for future inflation. Costs are given both net of, and including, 60% optimism bias. The value and likely timing of major (capital) works are identified, though clearly the actual timing might vary from that indicated. For the expenditure stream given below it has been supposed that case (ii) of Table 5.16 applies, i.e. preservation of all defences in RUN 1 with the exception of the structures in RUN 1.08, which would be removed rather than reinstated.

Table 5.17 Predicted yearly expenses to 2017

Year	Item	Cost (not discounted) £	Cost (not discounted) +60% Optimism Bias £	Major Works Items
2007	monitoring	13,717	21,948	
	minor works	54,139	86,622	
	major works	434,561	695,297	RUN 1.08, 2.01: Remove defences
	total	502,417	803,867	
2008	monitoring	13,717	21,948	
	minor works	26,566	42,506	
	major works	0	0	
	total	40,283	64,453	
2009	monitoring	13,717	21,948	
	minor works	35,698	57,116	
	major works	1,342,060	2,147,296	RUN 1.02, 1.03: Wall refurbished, flint nourishment
	total	1,391,475	2,226,360	
2010	monitoring	13,717	21,948	
	minor works	24,696	39,513	
	major works	122,916	196,666	
	total	161,329	258,126	
2011	monitoring	13,717	21,948	
	minor works	24,696	39,513	
	major works	0	0	
	total	38,413	61,461	
2012	monitoring	13,717	21,948	
	minor works	56,973	91,157	
	major works	21,819	34,910	
	total	92,509	148,014	

Table 5.17 Predicted yearly expenses to 2017 (continued)

Year	Item	Cost (not discounted) £	Cost (not discounted) +60% Optimism Bias £	Major Works Items
2013	monitoring	13,717	21,948	
	minor works	32,270	51,633	
	major works	1,173,513	1,877,621	RUN 1.06: Reconstruct groyne. Run 1.07: Rock revetment
	total	1,219,501	1,951,201	
2014	monitoring	13,717	21,948	
	minor works	26,460	42,337	
	major works	73,822	118,116	
	total	114,000	182,400	
2015	monitoring	13,717	21,948	
	minor works	26,460	42,337	
	major works	122,916	196,666	
	total	163,094	260,950	
2016	monitoring	13,717	21,948	
	minor works	26,460	42,337	
	major works	0	0	
	total	40,178	64,284	
2017	monitoring	13,717	21,948	
	minor works	58,738	93,981	
	major works	49,088	78,541	
	total	121,543	194,469	

6. Concluding comments and Recommendations

6.1 CONCLUDING COMMENTS

The fundamental and important conclusions derived from the strategic appraisal are given below:

1. The strategy study area comprises three distinct zones, identified as separate Management Units MU1/CU1, RUN 1 and RUN 2. The central area, RUN 1, is characteristically different from those on either side, being the urban part of Sheringham town, whilst the adjacent units are largely rural with isolated properties, caravan and leisure parks. The most easterly unit, RUN 2, contains two engineered access points to the beach.
2. The relevant Shoreline Management Plans advise coastal defence policy options of Do Nothing (MU1/CU1), Hold the Line (RUN 1), and Managed Retreat (RUN 2).
3. For the purpose of this strategy a set of generic terms to categorise the proposed mitigation measures have been introduced; these are: Do Nothing; Monitor the shoreline; Maintain; Sustain; and Improve. Do Nothing and Monitor are self explanatory. For the remaining three measures, which all entail intervention, it was concluded as follows: Maintain means applying maintenance measures only up to the end of the residual life of a given defence; Sustain means maintaining and replacing structures such that present day standards are upheld; Improve means maintaining and replacing structures such that present day standards are improved upon until the end of the strategy time horizon (100 years).
4. Without going into further detail which can be derived from the main text, the Strategic options for the fourteen defence length are concluded in terms of their compliance with the SMP policy options as outlined in points 5. to 7. below:
5. If the policy options advised in the Shoreline Management Plan are to be upheld then the Strategic options are as follows: Do Nothing in MU1/CU1, RUN 2.03, and RUN 2.05; Managed Retreat in RUN 2.01; Sustain or Improve in RUNs 1.01 to 1.08, 2.02 and 2.04. As the small isolated RUNs 2.02 and 2.04 allow for setting the ramp installations back (landwards) at the time of future rebuilds, the Sustain options do comply with the SMP policy of Managed Retreat.
6. Hold the Line for certain defence lengths at the ends of RUN 1 yield poor economic performance; viz: RUN 1.01 (b/c = 0.065); RUN 1.06 (b/c = 0.056); RUN 1.07 (b/c = 0.19); and RUN 1.08 (b/c = zero). The low levels of benefits are due to there being few assets at risk (RUNs 1.01 and 1.08), and because significant damages (in the case of no intervention) do not occur for several tens of years into the strategy life (RUNs 1.06 and 1.07).
7. The Strategy Study has, therefore, concluded that holding the line in several defence lengths in RUN 1 is not justified economically. The strategic economic case is improved substantially if these units are designated as Managed Retreat. In this case, the Strategic Options are: Do Nothing in MU1/CU1, RUN 2.03, and RUN 2.05; Managed Retreat in RUNs 1.01, 1.06 to 1.08, and 2.01; Sustain or Improve in RUNs 1.02 to 1.05, 2.02 and 2.04. In RUN 1, defence lengths 1.01, 1.06 and 1.08 would be maintained for the remainder of their residual lives. RUN 1.08 would be retreated by removal now.
8. In the case of RUNs 1.01 and 1.06 there is some considerable residual life left in the defences (16 years and 22 years respectively); hence, there is time to give these

cases more timely consideration, benefiting from the many years of valuable monitoring data gathered in the interim.

9. In the case of RUNs 1.07 and 1.08 (in particular) the very short (or now exhausted) residual lives means that urgent action is needed to address the problems both at a strategic level (i.e. to confirm the appropriate defence policy) and, in the case of RUN 1.08, to translate the agreed policy into action on site by way of removal or reinstatement of the damaged structures.
10. Urgent action is also required in respect of RUN 2.01 where the derelict timber revetment and toe structure presents a significant safety hazard and negative impact in respect of beach amenity.
11. For the remaining defence lengths in RUN 2 the outlook is comparatively straightforward. Logically, defence of these sections can be categorised into Do Nothing (RUNs 2.03 and 2.05), and Sustain (2.02 and 2.04); in the latter cases, the economic motivation is derived from the beach access ramps plus the associated infrastructure and social value.

6.2 RECOMMENDATIONS

The Strategy has identified a number of issues requiring early or immediate action over the next five years. The recommendations relating to these actions are listed below:

1. Monitoring of the beaches and coastal structures is currently underway. This monitoring campaign should be continued, and the results collated periodically to facilitate utilisation in future appraisal, strategy and SMP updates.
2. The study has identified the need to carry out early works to remedy the derelict defences in the adjoining defence lengths RUN 1.08 and RUN 2.01. In view of the extent of works involved (both removal and/or reinstatement), and the fundamental issues relating thereto, the schemes should be preceded by the preparation of a Project Appraisal study, and possibly an EIA. Given that there are similar issues (in particular the question of sustainability) pertaining to adjoining defence lengths RUNs 1.06 and 1.07, these should be included in the study, albeit no major works are required in 1.06 for at least 20 years.
3. Pending the outcome of recommendation 2, there is likely to be a need to undertake design, tender and contract administration in respect of site works in RUNs 1.08 and 2.01, and possibly 1.07.

7. References

Defra (1999). Flood and Coastal Defence Appraisal Guidance – FCDPAG3 Economic Appraisal.

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.

Halcrow (2005). Kelling to Lowestoft Shoreline Management Plan (draft).

HM Treasury (2003). The Green Book: Appraisal and Evaluation in Central Government.

HR Wallingford (1995). "Sheringham Coast Protection Scheme 902, Stage2: Beach Recharge and Control Structures Physical Model Study, EX3147, May 1995.

Mouchel (1996). Kelling to Lowestoft Shoreline Management Plan.

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EX 4985

Kelling to Cromer Strategy Study

"Do nothing" - erosion probability and erosion losses

Report EX 4985
Release 2.0
November 2006

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Summary

Kelling to Cromer Strategy Study

"Do Nothing" - Erosion probability and erosion losses

Report EX 4985
November 2006

This report describes the predicted coastline changes between Kelling and Cromer, under the scenario commonly called the “Do Nothing” option or scenario. This means taking no active steps towards the future provision or maintenance of coastal defences, other than essential safety measures.

“Doing Nothing” is typically the first policy option to be considered in any strategic assessment of coastal defence policies for any particular frontage. This provides a “baseline” against which the benefits of other options, e.g. maintaining old defences, or alternatively installing new defences, can be properly assessed, costed and compared.

By first predicting the likely future coastline changes as existing defences deteriorate and fail, the future losses of land, properties and infrastructure can then be evaluated. Given an understanding of the potential extent and timing of such losses, the economic consequences of “Do Nothing” can then be evaluated.

The prediction of coastline evolution under the Do Nothing scenario also provides an indication of the location and timing of the greatest potential economic losses. This allows one to achieve a ranking for different parts of the frontage, indicating when and where coastal defences will most be needed, thus allowing a choice of realistic coastal defence policy options to be made.

The predictions of cliff changes that are used in this report are described in greater detail in a companion report entitled “Cliff Processes”. In the Do Nothing scenario, predictions of cliff top changes have been made for incremental times into the future, up to 100 years hence. By determining the geographical location of the various cliff top assets, this enables economic evaluation of the Do Nothing losses to be made, as specified in guidelines provided by Defra.

Estimates of the residual service life of the existing defences are used to assess when the defences will no longer provide protection against cliff toe erosion. These estimates have been obtained from a detailed inspection of the coastline, as described in the companion report entitled “Defence Condition Survey.”

All this information is combined/tabulated, so as to provide an economic assessment of the Do Nothing option.

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Appendix

Do Nothing Damages

1. Introduction

1.1 PURPOSE OF REPORT

This report describes the prediction of future changes in the coastline between Kelling and Cromer under the so-called "Do Nothing" scenario. This is the first policy option to be considered in the strategic assessment of other coastal defence options for this frontage, and provides a "baseline" against which the benefits of maintaining or installing defences can be properly assessed.

By predicting the future positions of the cliff-top line, the potential losses of land, of properties, and of infrastructure are evaluated. Given this understanding, the economic consequences of the "Do Nothing" scenario are then evaluated (see also the companion report entitled "Economic Evaluation" which provides further discussion on the assets at risk). Predictions of the beach and cliff top changes have been made at incremental time intervals from year zero to 100 years hence in order to complete the economic evaluation procedures as specified in guidelines provided by Defra.

1.2 BACKGROUND TO PREDICTION METHODS

The coastline examined here covers the frontage from Kelling eastwards towards Cromer. This frontage is shown in Figure 1.1, which has been taken from the "Littoral Sediment Processes" section of Report EX 4692. Figures 1.2 to 1.4 illustrate the management units in more details.

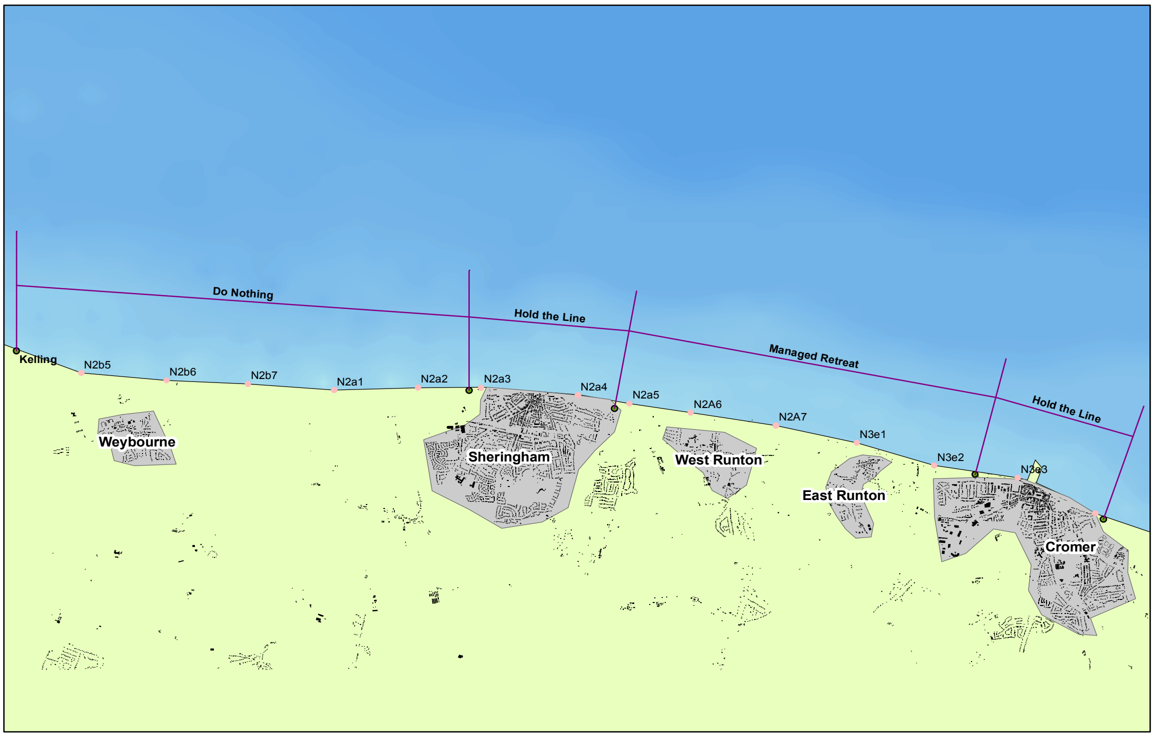

Figure 1.1 Study Area

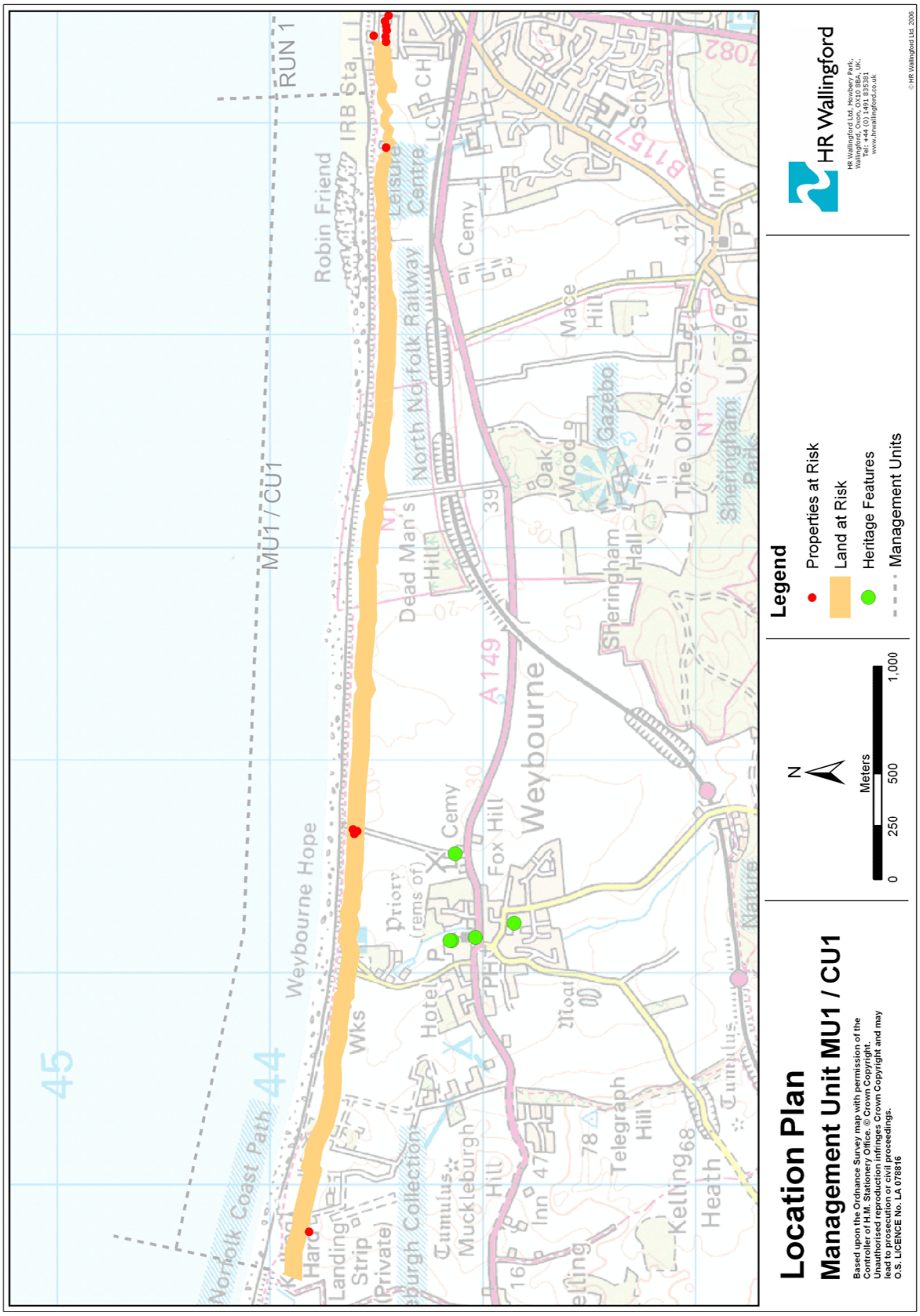

Figure 1.2 Location Management Unit MU1 CU1

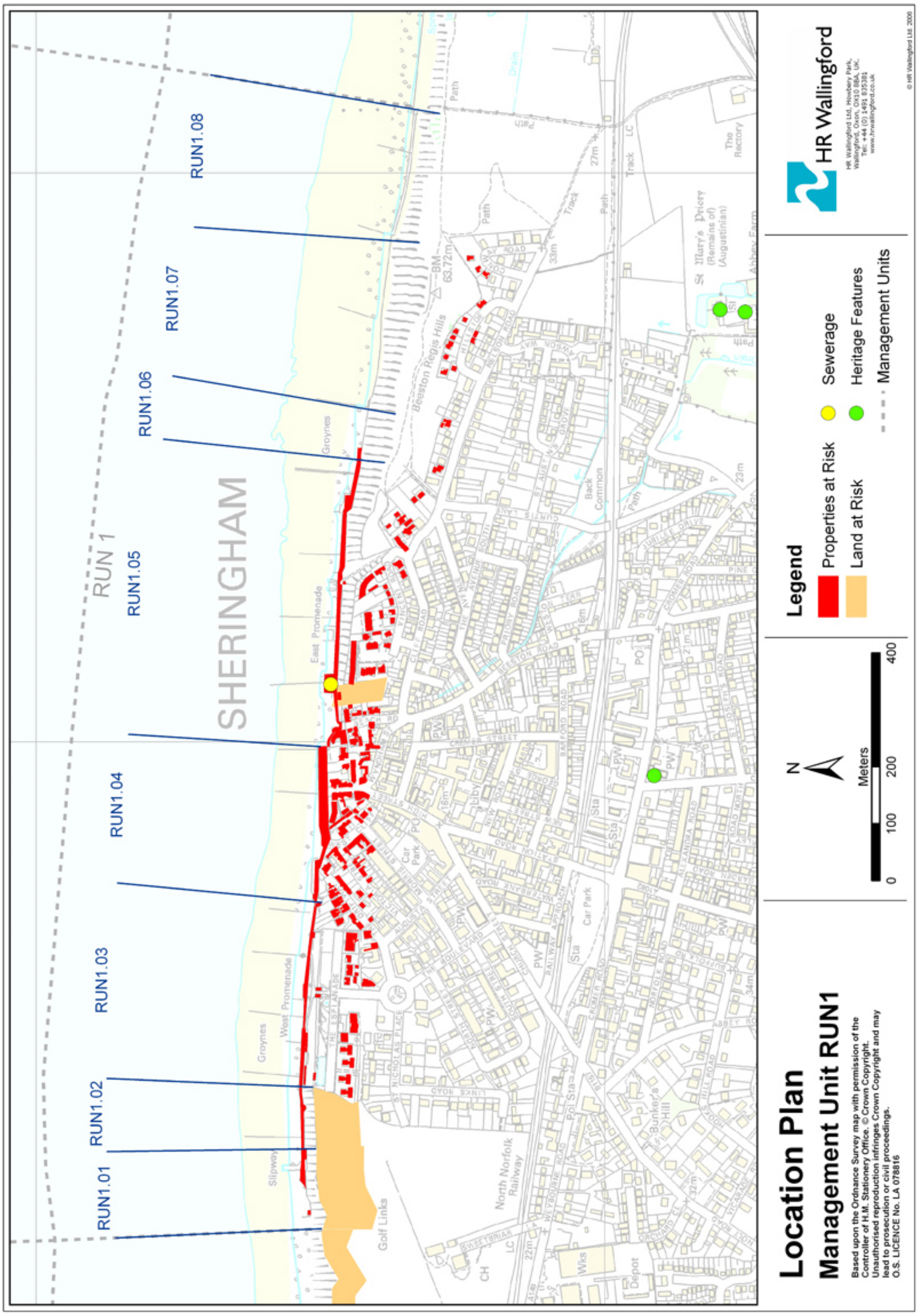

Figure 1.3 Location Management Unit RUN1

Figure 1.4 Location Management Unit RUN2

The coastline is characterised by weak and unstable cliffs that are susceptible to erosion. Prior to the construction of coastal defences the rate of cliff recession in this region averaged at between 0.3m and 0.75m per year (Cambers, 1976). After defences were constructed at Sheringham and Cromer, the observed erosion in the undefended coastal areas increased up to 1.0m per year (Clayton and Coventry, 1986).

Changes in the rate of cliff erosion occur in response to changes in the weather conditions, variations in cliff lithology, as well as changes in the strength and frequency of wave action at the cliff toe. In general, the cliff recession rate is virtually zero along defended stretches of coast and most rapid in between them, as shown in Figure 1.5, taken from the "Cliff Processes" section of report EX4985. It is also interesting to note that the higher rates of cliff retreat in this region tend to be east (down-drift) of the strongly defended frontages. This is exemplified by the high retreat east of Sheringham, southeast of Overstrand and south of Mundesley.

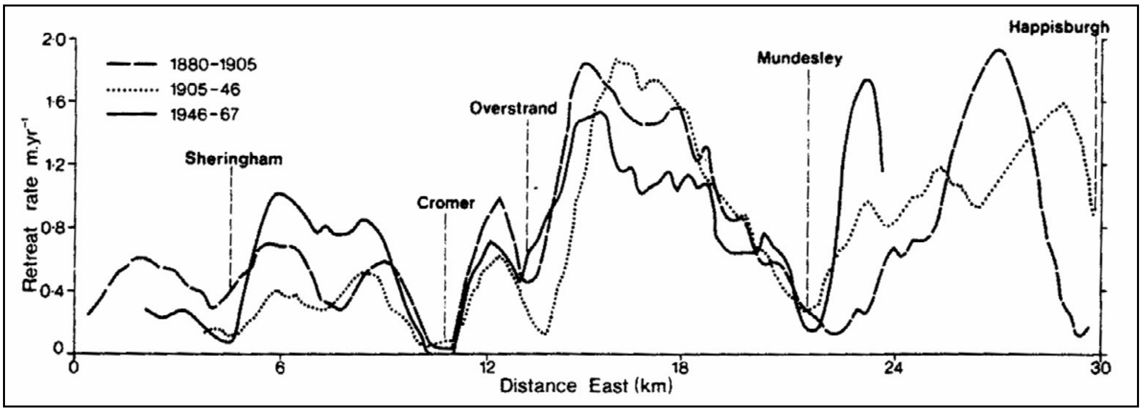

Figure 1.5 Variation in cliff recession rates along the North Norfolk coast (Cambers 1976)

Within the area covered by this study, the coastal defences are concentrated on the one centre of population at Sheringham, with less extensive defences also being present at the concrete ramps, which provide access to the sea for small boats through the cliffs at West Runton and East Runton.

The defences at Sheringham consist of concrete seawalls with the addition of timber and rock groynes. Where the walls are most exposed to wave action, rock armour stone has been added to the wall toe. Sheringham has been defended for so long that it now forms an artificial divide between beaches to the west and those to the east.

To the west of Sheringham the cliffs, which are unprotected, have relatively healthy shingle beaches and have an underlying chalk platform, itself an important source of beach material. The shingle beach continues uninterrupted into the next management unit to the west.

The cliffs to the east of Sheringham are protected by less robust defences, which tend to be less effective away from the town centre. Where these have failed, either due to abrasion damage, or due to earth pressure, there are now considerable gaps in the defences. The hard points at West and East Runton are flanked by rapidly eroding sandy-clayey cliffs. Thus, there is considerable interaction between defended and undefended frontages.

1.3 SHORELINE MANAGEMENT PLANS (SMP)

Before considering the impacts of the "Do Nothing" scenario, it is worthwhile recalling the policy options recommended by the adopted Shoreline Management Plans for this area SMP1 ((Sub-cell 3a) Mouchel 1996, (Sub-cell 3b) Halcrow, 1996.) and the draft recommendations of the second generation shoreline management plan, SMP2. (Halcrow, 2005).

In the SMP1, the coastline between Kelling and Cromer is sub-divided into three "Management Units", with the recommendation being to adopt a given coastal defence policy within each (see Figures 1.2 – 1.4). Briefly they are as follows:

Management Unit MU 1/CU 1	Muckleburgh and Weybourne	Do nothing
Management Unit RUN 1	Sheringham	Hold the line
Management Unit RUN 2	West Runton to Cromer	Do nothing

In the SMP2, the coastline between Kelling and Cromer is sub-divided into three "Policy Units", with the recommendation being to adopt a given coastal defence policy within each. The Policy Units correspond approximately to the Management Units. The recommended policy options for the area are as follows:

Policy Unit 3b01	Kelling Hard to Sheringham	No active intervention
Policy Unit 3b02	Sheringham	Hold the existing line
Policy Unit 3b03	Sheringham to Cromer	No active intervention

Both the adopted policies of SMP1 and the recommended policies of SMP2 indicate that the urban frontage of Sheringham (RUN1/3b02) will need to be defended into the foreseeable future (for the next 100 years or more). By contrast, the adjacent sections (MU1/CU1/3b01 and RUN 2/3b03) are mainly rural frontages and it is assumed that they will remain so.

For the purposes of this report, it is proposed to continue to identify the discrete lengths of coast by the use of the management unit identifiers referred to in SMP1.

1.4 MODELLING APPROACH

When evaluating alternative coastal defence policies, it is necessary to make predictions regarding the evolution of the cliff line in order to examine the impacts of those policies. Such predictions must allow for how the coastline will respond to changes in the coastal defences, littoral drift changes, sea level rise etc. This situation becomes more complicated when the coastline includes a "backshore" of cliffs. The way in which the modelling has been carried out is described briefly. For further details, see the companion report entitled "Cliff Processes."

The various cliffs sections were characterised in terms of their surface form, geology and landslide processes. Using these parameters, individual cliff units were identified. Cliff recession rates within each unit were then determined from historic records.

A probabilistic model of cliff top recession was derived, using appropriate adjustment factors to represent the impact on cliff retreat of changing environmental controls (sea level, winter rainfall, beach levels and the degree of shoreline exposure/protection). Probabilities were assigned to each of these controls.

Cumulative probability graphs were produced for the different cliff units within the study area. The cliff recession rates at a range of different probabilities for each cliff unit were then extracted from these graphs. They provide a range of possible future cliff-top positions with a probability ascribed to each. These recession rates were superimposed upon large-scale maps of the coastline, which extended far enough inland to include all the "assets" that might be affected by erosion within a 100-year lifespan. These recession rates form the backbone of the "Do Nothing scenario", by enabling one to determine which assets would be lost through cliff retreat, and hence the economic losses that would occur.

1.5 DESCRIPTION OF THE "DO NOTHING" SCENARIO

In this scenario, it is supposed that all the coastal defences along this frontage are allowed to deteriorate without intervention, and ultimately to fail at the mean estimated value of their residual life. Once a failure of the defences has occurred, no remedial action is taken except safety measures, and future shoreline changes are allowed to progress naturally. This is not a practical scenario in some situations. Nevertheless, this hypothetical scenario provides a standardised mechanism for assessing the value of defending a frontage, and is used as a "baseline" for the national prioritisation of coastal defence works.

In the Do-Nothing scenario the cliffs on either side of Sheringham (Weybourne and The Runtons) would continue to erode, whilst in Sheringham, coastal retreat would be delayed by the existing defences. Without maintenance, or rebuilding, these defences would gradually degrade until they failed structurally or were no longer effective in protecting the cliff toe from erosion. The hinterland then starts to erode.

In the "Do Nothing" scenario the defences are assumed to have failed at the end of their residual life. The residual life for each defence length was estimated from inspections made during the course of production of the companion report entitled "Defence Condition Survey".

The coastal defences at Sheringham are so old that they pre-date most of the Ordnance Survey map editions. Consequently, it was not possible to estimate the "pre defences" rate of cliff retreat directly. Following failure of the defences, the long-term recession rate for the Sheringham cliffs (i.e. for management unit RUN 1) has been taken as the average of the two adjacent undefended cliff units (in management units MU1/CU1 and RUN 2). However, because of the protuberant aspect of the Sheringham frontage, wave exposure will be higher than at adjacent stretches of coast, at least until the cliff line has smoothed out. Hence, the cliff processes at Sheringham, which have been held in abeyance for a number of years, will initially occur at a more rapid rate. To allow for this, the hinterland behind the existing defences is assumed to erode at double the average rate for the first twenty years after the defences fail.

1.6 METHOD OF CALCULATING ECONOMIC LOSSES

1.6.1 Methodology

The methodology and calculations presented in this report are based on the DEFRA guidance published in 'FCDPAG3 – Flood and Coastal Defence Project Appraisal Guidance – Economic Appraisal' (MAFF 1999).

1.6.2 Selected Base Date

The study uses a base date of July 2006.

1.6.3 Appraisal Period

An appraisal period of 100 years has been applied in accordance with UK Treasury Guidelines (HM Treasury 2003).

1.6.4 Discount Rate

All future damage values have been discounted to a Present Value (PV) using the date given in 1.6.2. This conversion uses the algorithm:

$PV = (\text{Sum in year } n)/(1 + r/100)^n$

Where r is the percentage discount factor, and the base date is taken as year n = 0.

The declining long term discount rates (r) given in the table below have been taken from the HM Treasury Green Book (HM Treasury 2003). By way of example, £1 in year 30 will be worth 70p (PV) and in year 100, £1 will be worth 4.6p (PV).

Declining Long Term Discount Rates (HM Treasury 2003)

Period of Years (n)	0-30	31-75	76-125
Discount Rate (r)	3.5%	3.0%	2.5%

The method of evaluating economic losses selects the most likely position of the erosion contour from the probabilistic model for each of the seven time periods and interpolates these to 5 year intervals up to the end of the appraisal period.

1.7 LAND AND PROPERTY

This section outlines the principal assets, both natural and man-made, in the areas potentially at risk. As it has been useful to discuss many of these attributes in the context of the greater frontage, some of the discussions are more detailed than appear in the respective Management Unit sections (2. to 4.).

1.7.1 Properties

Properties are defined as individual buildings digitised from the OS 1:10,000 scale map. Residential and Commercial properties are included, although a small number of commercial properties have been considered separately. The valuations of each property have taken into account the possibilities of multiple properties (e.g. flats) being part of the same digitised building and also that of lower value buildings (e.g. barns).

There are 712 properties within the study area that have some likelihood of being affected by up to 100 years coastal erosion. Of these, 681 are in the Sheringham area and 31 are in Cromer.

In accordance with FHRC “Yellow Manual” guidelines (Middlesex 1992), the maximum value of any property which can be included in the assessment of erosion losses over the appraisal period can be no greater than the present day free market value. The current value of each property near the cliff top in the principal coastal settlements has been obtained using property valuations conducted by Keys Auctioneers and Estate Agents (March 2004) and adjusted to 2006 values using regional house price increases (http://www.nationwide.co.uk/hpi/). Where no property valuation has been obtained by this process then an average estimate value (2006) has been assigned.

Given the intensive tourism and recreational uses of the coastline here, there will inevitably be development pressures in various locations along the frontage. Although it is impossible to consider future developments that may or may not happen, the economic evaluation presented should be updated in future to reflect any changes, and the options proposed should be sufficiently flexible to accommodate such change.

Properties are deemed unsafe and abandoned before the erosion contour reaches their digitised boundary. This is often due to the loss of the access road and / or services between the property itself and the cliff face. To account for this, properties have been economically lost when the erosion contour reaches within 5m of the digitised property boundary at its closest point.

1.7.2 Land

Land between Sheringham and Cromer is largely occupied by properties and caravan sites. To the west of Sheringham, three distinct areas of land are significantly affected by coastal erosion over the appraisal period: Sheringham Park (owned by the National Trust), Sheringham Golf Course, and agricultural land to the west of the golf course.

The September 2002 Defra survey of land values for the eastern region (Defra 2003) gives the average risk-market value of agricultural land as £6,769 / ha (2002). However, this sum includes a government subsidy (PAG3 1999). To account for this, the value of the land lost to erosion is given as the risk-market value multiplied by a factor of 0.45 before adjustment to 2006 values. This value has been assumed constant across the affected area. This stretch of land ends at the western fringe of the study area, in a private landing strip to the North West of Weybourne. No data is available for this landing strip and therefore, for valuation purposes, it has been assumed to be equivalent to agricultural land.

1.7.3 Caravan Sites

A number of camping and caravan sites are situated within the study area. The factors influencing the economic value lost due to the erosion of these assets have been applied as follows:

- Light caravans and tents can easily be moved to alternative locations and as such contribute no significant economic loss.
- The value of the land lost has been included in calculating the average property valuations.
- Any permanent structures associated with these sites have been included in the property calculations.
- 1140 larger caravans lie within the study area, some close to the cliff edge, both to the east and west of Sheringham. It is assumed that 200 of those to the East are affected during the appraisal period and 100 to the West. It is also assumed that these are evenly distributed throughout the region affected. The valuation of £2000 per caravan includes the costs of preparing an alternative site and moving the caravans to it.

Two caravan sites, Beeston Regis Caravan Park and Laburnum Caravan Park have a number of static caravans. Defra guidance to assessing the economic value of such assets is to assume that they are depreciating assets and, on average, are worth half their replacement cost. An analysis of the current market value of these caravans gives an average replacement cost of £30,000.

1.7.4 Car Parks

A small number of car parks lie within the area affected by coastal erosion. Those not already covered by other land types constitute small areas which have been valued at 5 times that of agricultural land.

1.7.5 Sheringham Golf Course

In additional to the value of the associated properties, the value of the land covered by Sheringham links golf course has been assumed to be five times that of agricultural land and constant across the area affected.

1.7.6 Sewerage System

Sewage from the communities of Weybourne, Sheringham, East Runton and West Runton is pumped via a system of mains for treatment at a plant on the outskirts of Cromer. After treatment, the effluent is pumped to a long sea outfall, 2km in length, located just to the east of West Runton Gap where it is discharged into the North Sea. At the core of the system are the pumping stations and storm tanks that are located very close to the sites of the original short sea outfalls in each of the communities. Weybourne is an exception to this where a small local treatment facility was replaced with a pumping station.

1.7.7 Sewerage Storm Tanks and Pumping Stations

Sheringham: There is a storm tank and pumping station located under the amenity building at The Mo. The 3500 m^3 storm tank was built within a 25 metre diameter segmental shaft with the control and odour control equipment sited in the amenity building. The pumping station also has an emergency generator, located on what is known locally as the Tank (root of groyne A10) which itself was once the site of the town's short sea sewage outfall. The tank and associated sewers intercept all of the sewage that once discharged into the sea.

This terminal pumping station will be lost if the seawall fails. The facility cannot be simply moved inland away from the threat of erosion. Given the complexity of the town's sewerage system, the layout of the town and topography, a more definitive identification of the least cost replacement scheme would require a detailed study. For the purposes of this assessment however, the hypothetical least cost replacement scheme is likely to involve the provision of a major pumping facility and rising main located 100 metres inland. This would be slightly smaller in size to the existing facility but would require the purchase and demolition of a large number of dwellings to create the site. An additional pumping facility would be built at the site of the existing 3,500 m^3 attenuation tank at the top of Beach Road, together with a rising main to link it to the main transferring flows to treatment at Cromer. The estimated cost of this least cost replacement scheme is given in the table below.

West Runton: The community here is served by a 364 m^3 storm tank and underground pumping station located adjacent to the road through the gap. Again, this tank intercepts all of the community's sewage at the site of what was once a short sea outfall and there is no existing alternative facility. As the pumping station and storm tank is remote from the community, it can be replaced by a similar facility inland with associated rerouting of sewers and pumping mains.

East Runton: The community here is served by a 295 m^3 storm tank and pumping station located under the toilet building in the public car park behind the gap. The building also houses the pumping station's controls and odour control equipment. Again, this tank intercepts all of the community's sewage at the site of what was once a short sea outfall and there is no alternative to this station. A replacement will involve the building of a similar sized pumping station inland, south of the A149, with diverted sewers and a diverted pumping main.

Sewerage Replacement Costs

Sewerage – Least Cost Replacement Schemes	
Sheringham	£5,634,848
West Runton	£166,554
East Runton	£409,861

1.7.8 Transportation – Roads

Coastal erosion scenarios within the appraisal period include the loss of the coastal A149 road on the Eastern edge of the study area as it enters Cromer itself. On the advice of NCC and due to the limited data available, annual traffic count figures for the A149 at Morston were taken as representative of traffic on the A149. For the year 2003, the annual traffic count gave 2199 vehicles per day. The NCC five-year average is 2032 vehicles per day and the annual growth rate is predicted to be 3.7%, giving an approximate figure of 2266 vehicles per day in 2006.

Should such a scenario arise, a large section of the town centre itself would also be lost. Since the road terminates in the town centre and does not continue along the coast at this point, a large proportion of the traffic demand on this road would no longer exist. Suitable diversions exist for the low volume of remaining local traffic; therefore no separate costs have been included to cover the replacement of this section of the A149.

1.7.9 Transportation - Rail

The most extreme worst case scenario (a 100 year appraisal period with a probability of 0.1) records coastal erosion to just under 9 metres short of the railway line carrying the National Rail Service from Norwich to Cromer and Sheringham (as digitised from the 1:10,000 OS map) at its closest point. This line also provides rail access to the North Norfolk Railway.

No separate estimate has been included covering any potential infrastructure repair or replacement arising from this scenario since the erosion falls short of affecting the railway itself. However, a potentially high impact would occur in a timescale just longer than the 100 year appraisal period.

1.7.10 Tourism and Recreation

The tourist industry is extremely important to the economy of North Norfolk. The following points have been taken from a document prepared by the East of England Tourist Board for NNDC in 2001. The statistics give a very good indication of the significance of the tourist trade and the importance of the tourism infrastructure.

The overall value of tourism to North Norfolk District in 1999 was an estimated £186.4 million. Of this, approximately £101.3 million (i.e. 54%) was generated by staying visitors and approximately £85.1 million (i.e. 46%) was generated by day visitors.

The figures given above relate to the greater area of the North Norfolk District. To put matters into perspective, values of tourism within the specific area between Kelling and Cromer are about 25% of these figures. This is a significant asset that would deteriorate in the case of the do nothing scenario due to the loss of beach and amenities. This potentially significant loss has not been evaluated directly within the present report. In this respect it can be concluded that the economic analysis underestimates the true benefits of any scheme that mitigates potential damage to tourism.

1.7.11 Commercial Activities

Within the study area, there are no significant commercial activities apart from agriculture (evaluated within 'Agricultural Land', above) and Tourism and Recreation (identified above).

1.7.12 Manufacturing and Distribution

There are no economically significant manufacturing or distribution businesses within the study area.

1.7.13 Commercial Fishery Activities

Both full time and part time inshore fishing boats operate from the beaches of Weybourne, Sheringham, West Runton and East Runton. The numbers of active boats are as follows;

Boat Numbers

Location	Number of Full-Time Boats	Number of Part-Time Boats
Weybourne	3	2
Sheringham	7	9
West Runton	3	2
East Runton	6	2

Weybourne:
It is considered that the fishermen operating off the beach at Weybourne will not be affected by ongoing erosion at this location. As the resource used by the fishermen, the boats, will not be damaged and they can continue to operate, only a transfer cost is involved.

Sheringham:
The situation at Sheringham, West and East Runton is different in that the fishermen can only launch using purpose built ramps. Hence, whilst the resource, the boats, can arguably relocate to another beach thereby only generating a transfer cost, the resources lost due to erosion are the two ramps and associated facilities. In the do-nothing option,

the ramps would be periodically reconstructed in the 100 year study period with some degree of protection against damage by the sea. The least cost replacement value for the ramps in Sheringham are estimated to be £48,000 for the east beach access ramp and £600,000 for the west beach ramp. The existing ramps have been given a life equating to that of the appropriate sea wall.

East and West Runton:
Similarly the launch ramps at East and West Runton have been given a value of £900,000 each. In the do-nothing option these ramps would also be periodically reconstructed throughout the study period.

For the purposes of this study, the life of each ramp reconstruction is assumed to be 25 years.

1.7.14 Sheringham Promenade (Properties north of the cliff line)

The promenade together with associated properties and facilities in Sheringham Promenade lie to the north of the cliff line, the base line for the erosion model. As such they have been given a life equating to that of the existing sea wall.

Each property in this area has been valued using the same method as the properties above.

1.7.15 RNLI Sheringham

The RNLI maintain an inshore lifeboat station at the western end of the promenade at Sheringham. The facilities there include a launch ramp, tractor shed, lifeboat shed with associated facilities, protection against damage by the sea (a sea wall) and a retaining wall supporting the cliff. Presently, access to the station is gained along the promenade that would be lost in the do-nothing scenario. The least cost replacement value of the lifeboat station is estimated to be £900,000, which includes the replacement of all existing facilities and permanent access to the replacement site down the cliff. Since it is essential that the lifeboat station remains on the sea front it is deemed to be rebuilt every 25 years, after initial failure with the associated sea wall.

1.7.16 Environmental Assets

The study area is particularly rich in environmental assets including:

Weybourne Cliffs SSSI
Beeston Cliffs SSSI
West Runton Cliffs SSSI
East Runton Cliffs SSSI
Kelling County Wildlife Site
Weybourne County Wildlife Site
East Runton to Overstrand County Wildlife Site (cliff and beach between East Runton SSSI and Overstrand Cliffs SSSI).

The study area with the exception of Sheringham is also part of an Area of Outstanding Natural Beauty which, together with the above designated sites, forms an area of high existence value.

1.7.17 Lower Bound Economic Value

In the DEFRA guidance note on Economic Appraisal (FCDPAG3) it is stated that the least contentious and lowest cost of deriving a proxy for the lower bound economic value of an environmental or heritage asset gained or lost as a result of a flood or coastal defence scheme can be taken to be the lowest of:

- the cost of creating a similar site elsewhere of equivalent environmental value
- the cost of relocating to another site (e.g. historic buildings or relocation of specially protected species)
- the cost of local protection.

This proxy approach has been adopted, where appropriate, in estimating the economic value of the environmental assets listed above.

1.7.18 Sites of Special Scientific Interest

All four of the SSSI in the study area have been designated in whole or in part because of their geological features which rely on continuing erosion to refresh the geological interest (although the grassland habitat on the cliff top at Beeston SSSI is currently declining). In this respect, the use of a proxy value is not appropriate as the sites cannot be relocated nor protected. FCDPAG3, Section 4.2.2 suggests that in such cases, it may be necessary to obtain a valuation using other monetary based techniques such as contingent valuation. However, it is felt that the economic value of the SSSI, if determined, is unlikely to affect the result of any benefit cost analysis within the study area. Hence, it is not proposed to do a contingent valuation and no economic value has been estimated for the four SSSI.

1.7.19 County Wildlife Sites

The East Runton Cliffs to Overstrand Cliffs County Wildlife Site (CWS) embraces a mixture of open eroding coast and, at Cromer, a defended frontage. Only the open coast section lies within the study area. The effect of this CWS is to extend the habitat protection offered by the flanking SSSI. As it is a coastal site, with eroding beach and cliff, it is not possible to relocate or reproduce it elsewhere. Hence, it cannot be assigned a proxy economic value.

The Kelling and Weybourne County Wildlife Sites differ in that they are shallow, swampy brackish pools offering a mixed habitat. These habitats, although unique, can plausibly be recreated elsewhere. The lower bound economic value for the sites includes the cost of land purchase, engineering works, planting and short term maintenance. The economic value does not include long-term maintenance or management as these are continuing expenditure and are regarded as transfer costs. The lower bound economic value of these two CWS is given below.

County Wildlife Sites (Kelling and Weybourne)

County Wildlife Site	Lower Bound Economic Value
Kelling	£355,494
Weybourne	£163,318

For the purposes of the 'do nothing' scenario, these values have been applied as though the sites were recreated elsewhere.

1.7.20 Heritage

The study area contains many Listed Buildings, Scheduled Ancient Monuments and archaeological features. For many of these features, there is a Statutory Duty to protect them.

The table below is a listing of all identified heritage features together with their respective grading, none of which are impacted directly by even the worst case 100 year scenario. The closest is the "Church of All Saints" in Beeston Regis, almost 90m away from the 100 year 0.1% probability erosion line.

Heritage Features

Name	Location	Listed Building Grade
Barn at Abbey Farm	Weybourne	2
Abbey Farmhouse	Weybourne	2
Weybourne Priory	Weybourne	1
All Saints Church	Weybourne	2*
Old Farm Cottage	Weybourne	2
Weybourne Mill	Weybourne	2
Church of St. Joseph	Sheringham	2
Beeston Priory	Beeston	1
Abbey Farmhouse	Beeston	2
Church of All Saints	Beeston Regis	1
Flint House	East Runton	2
Incleborough House	East Runton	2

1.8 DESCRIPTION OF COASTAL CHANGES BY MANAGEMENT UNITS

The consequences of doing nothing within each of the three Management Units between Kelling and Cromer are described in the following main sections 2 to 4. In each section, the coastal processes, present defences, cliff erosion characteristics and the environmental assets (natural and human) are outlined. Then, the consequences of adopting the "Do Nothing" policy option are outlined in terms of the loss of assets within the management unit itself, together with the impact on adjacent frontages.

2. Management Unit MU1/CU1: Muckleburgh and Weybourne

The rural Weybourne frontage covers the SMP management unit MU1/CU1 and extends from Kelling Hard at the western edge of the study area up to the western end of the defences protecting Sheringham.

2.1 COASTAL PROCESSES

The shoreline of Management Unit MU1/CU1 is characterised by sand beaches on the lower foreshore, grading to shingle "storm" beaches on the upper foreshore. At the western end of the frontage the shingle ridge continues westwards as Cley ridge, protecting low-lying marshland within the adjacent management unit (outside the study area). There is a strong interaction on this boundary. The cliffs and beach within MU1/CU1 are not artificially protected; nevertheless, Cley ridge, to the west, already suffers from a deficiency in shingle supply.

The shingle beach crest within MU1/CU1 is close to the toe of the clay cliffs. Consequently, natural protection to the cliff toe is provided only at mid to low tide. The shingle beach has pronounced storm ridges, indicating that it is fully formed. This frontage is exposed to wave action from a wide range of directions and the shingle ridge is very volatile. The volume of shingle reduces only slightly at the western outskirts of Sheringham.

A chalk shore platform exists on the upper beach and is exposed (intermittently) to the low water line and beyond. Erosion of the chalk platform (as at Robins Friend) provides an important source of shingle.

Longshore transport calculations, described in the Littoral Sediment Processes Report, indicate a generally weak (up to 12,000 m3/year) east to west net drift of sediment. This does not vary significantly between Kelling and Sheringham, but is weaker towards Sheringham. The drift varies seasonally and from year to year, producing an east to west drift in certain years. This is most marked near to Sheringham. This simple regime is made more complicated by the effects of tidal currents, which have put an east to west bias on the drift at the higher part of the beach, and a west to east bias at the lower part. Analysis of historic data shows a continuing trend of erosion between Kelling and Sheringham.

2.2 COASTAL DEFENCES

The management unit (MU1/CU1) continues uninterrupted into the adjoining management unit to the westward, which is outside the Strategy Study Area. MU1/CU1 stretches from Kelling Hard up to the western outskirts of Sheringham. The shoreline along this length is composed of a 5.5 km long shingle beach that is in "very good condition", having a wide, energy dissipative crest. The beach thins out slightly towards the lifeboat station at the western outskirts of Sheringham. In this area the chalk platform is normally exposed, having only small sand patches around it, as shown in the photograph below.

A short length of beach was once defended near Weybourne and this now fronts a small low lying area used for public car parking, otherwise there is no history of any defences in this management unit. The protection at Weybourne consisted of a steel gabion structure filled with the native beach material (large pebbles). This allowed the beach to adjust in profile, but prevented mass movement in a horizontal direction. The structure was removed approximately 5 to 10 years ago.

There is a potential risk of flooding of several isolated properties to landward of the car park at Weybourne, if the shingle bank was breached. The last known breach occurred in 1996, although there are no records of flood damage to any properties at that time. Elsewhere there is little immediate risk to cliff top properties.

2.3 CLIFF EROSION

Figure 7 in the companion report on “Cliff Processes” describes the cliffs along this frontage. The cliffs within Management Unit MU 1/CU 1 are identified as Cliff Units 1 and 2. The cliffs at the western end of the frontage, within Cliff Unit 1, are typically 10m to 20m high, generally rising going eastwards. Comprising glacial till over chalk, these cliffs yield large quantities of sand and small quantities of gravel. Based on findings of the Cliff Processes Report, the future erosion rate (50% exceedance probability) is estimated to be 0.83 to 0.84 m/year.

The cliffs in the eastern part within Cliff Unit 2 are typically 20 to 30m high. These have chalk outcropping at a lower level, to form a chalk shore platform, which yields flint. Comprising of glacial till the cliffs themselves yield large quantities of sand and small quantities of gravel. The chalk platform itself provides (unknown) quantities of flint. Based on findings of the Cliff Processes Report, the future erosion rate (50% exceedance probability) is estimated to be 0.41 to 0.63 m/year.

In general the cliffs are quite sandy in areas and are prone to undercutting rather than land slippage due to "internal instability" as shown in the photograph below.

2.4 HUMAN ENVIRONMENT AND ENVIRONMENTAL DESIGNATIONS

See also the generic details in Section 1.7.

Human Environment

The village of Weybourne, situated well inland, depends on tourism for a substantial part of its income. It is situated too far landward to be affected by cliff recession within the study timeframe. Within the hinterland there is a redundant military camp, which is now used by the Muckleburgh Military Collection.

The land use is principally agricultural, areas being owned by the National Trust. Sheringham Golf Club is located at the eastern end of the frontage.

Environmental designations

Weybourne Cliffs SSSI is a narrow strip that extends from Weybourne village to the western outskirts of Sheringham and essentially encompasses the cliff face. These cliffs afford the best Pleistocene sections in this area, showing the pre-Cromerian deposits of the Cromer Forest beds. The Pastonian 'Weybourne Crag', here at its type locality, with its marine molluscs, has been known since the early days of geology.

2.5 CONSEQUENCES OF THE DO NOTHING OPTION

Overview

Within this section there are very few properties and these are only at risk to erosion in the later years of the period considered in the strategy study.

Interaction of defence failure and cliff top retreat rates

There are no defences in this area. Continuing erosion of the cliffs and the chalk foreshore platform will continue to provide beach material. Sand will be dispersed over the lower foreshore, accreting to no significant depth. Shingle will tend to be transported westwards towards Cley ridge. (This ridge is already overtopped regularly and would do so more frequently if the shingle supply were affected in any way).

At the junction with the adjacent management unit RUN 1 the shingle beach is slightly lower than elsewhere. It is conceivable that the continuing erosion of the cliffs within MU1/CU1 could have an impact on RUN 1 by causing outflanking. Because the shingle beaches in this location are healthy such outflanking would be minor.

Summary of erosion and assets lost in the Do Nothing scenario

The Appendix tabulates the losses predicted to occur under the do nothing scenario, in 5 yearly increments. The incremental and cumulative economic losses resulting from the postulated damages are summarised in Section 5.

3. Management Unit RUN 1: Sheringham

The urban Sheringham frontage covers the SMP management unit RUN 1 and extends from the start of the coastal defences protecting Sheringham in the west to the end of the defences at the eastern edge of the town. There are no cliff units defined within this section since the coastline cannot presently erode, although there are eight defence lengths, representing various wall types, each with its own estimated residual life. These sub-units are referred to here as defence lengths RUN 1.01 to RUN 1.08.

3.1 COASTAL PROCESSES

Management unit RUN 1 comprises the defended length of cliffed coastline at Sheringham. Here the beaches have less shingle than the adjoining more lightly defended frontages. The presence of seawalls may be responsible for the narrowness of the shingle storm ridge which, in places, disappears. The frontage has been held forward of the natural line of the coasts both to the east and west, which have been able to erode more freely. This too, may be partly responsible for the low shingle levels in front of the seawalls. It is noticeable that at local “indentations”, such as Fishermens Beach, the shingle storm ridge is much healthier. The beaches are groyned and these extend over the wide, sandy lower foreshore.

The high, vertical seawalls have been subject to considerable wave forces at high tide, causing damage to the concrete fabric. To reduce wave action on the walls, some stretches have rock armouring at the seawall toe. The photograph below shows the way the walls were exposed to damage prior to the addition of the rock armour stone. Note how the short buttress groynes as well as the wall itself were subject to local undermining. The shingle ridge in this area provides only a small amount of protection and the walls are subject to heavy wave impact forces and experience some overtopping also.

The longshore transport regime also changes at Sheringham, changing from a near neutral drift, to one that is more dynamic and more generally eastwards going (see Littoral Sediment Processes Report). Thus, it follows that Sheringham is located at, or about, the position of a sediment drift divide. Due to the varying direction of littoral drift the groynes along this frontage were unusual, in that they were "flapped", to allow through-flow of shingle from one direction to another across them.

As a result of the early development of this frontage the shoreline recession has been halted for many decades. Of course, beach lowering continues to take place. However, analysis of historic data indicates that the volumetric losses appear to be slight, particularly in the western part of the frontage. There are more marked losses to the east of Fishermens Beach, where substantial repairs and rock armouring has been required in the recent past. Immediately to the east of Fishermens Beach only a remnant shingle beach remains. The shingle beach then gains width at the more lightly defended eastern end of the frontage, as shown in the photograph below.

3.2 COASTAL DEFENCES

In line with the importance of Sheringham, both as a fishing station and its development as a holiday resort, built defences at Sheringham date back to the nineteenth century. By 1886, the town had seawalls protecting its centre together with a launch ramp serving the Coastguard Station at the end of Driftway and its first groyne close to the site of the modern groyne, A10. As more land was released for development, there was a corresponding extension to the defences. The most significant of these was the construction of the seawall to the west of Driftway by the Upcher Estate in 1895 and the related groyne field. Those defences form the basis of today's system with the Upcher wall still in use.

In the period 1994 to 1997, the system was almost completely overhauled with the construction of new groynes and the refurbishment of the central seawalls. An important aspect of that project was the proposal to recharge the beaches with dredged sand. Despite the building of groynes to cater for recharge, a beach nourishment scheme was not implemented due to funding constraints.

The linear defences from west to east are classified as follows:

- Defence length RUN 1.01. (Start 615143E 343515N. Finish 615285E 343533N). Reinforced concrete seawall (in fair condition) fronted by volatile shingle beach (in good condition). Likely failure mechanism is cliff failure and/or sustained loss of beach shingle, leading to structural instability. Hinterland is semi-urban cliff top, with golf course and a number of residential properties.

- Defence length RUN 1.02. (Start 615285E 343533N. Finish 615396E 343536N). Concrete seawall, promenade and retaining wall (in very poor condition) fronted by volatile shingle beach (in good condition). Likely failure mechanism is overturning following large loss of beach shingle leading to major drop in beach crest. Hinterland is semi-urban cliff top, with golf course and a number of residential properties.

- Defence length RUN 1.03. (Start 615396E 343536N. Finish 615721E 343510N). Very old concrete seawall, promenade and retaining wall (in very poor condition) that relies on a high beach for continuing stability. Shingle beach is volatile and in fair condition. Likely failure mechanism is instability, following beach drawdown. Hinterland is urban cliff top with predominantly residential housing.

- Defence length RUN 1.04. (Start 615721E 343510N. Finish 615991E 343487N). Reinforced concrete facing to original seawalls. New steel pile toe and rock armour stone protection to base of walls (in very good condition). Shingle beach is volatile and in good condition. Likely failure mechanism is very severe and sustained beach lowering leading to toe failure. Hinterland is urban cliff top with both commercial and residential properties in town centre. Immediate hinterland also contains sewerage storm tank and pumping station.

- Defence length RUN 1.05. (Start 615991E 343487N. Finish 616517E 343434N). Concrete seawall, promenade and retaining walls. Original wall protected by rock revetment (in good condition, when wall is combined with revetment). Shingle beach is narrow and in fair condition. Likely failure mechanism is cliff failure leading to surcharge or overturning. Hinterland is urban cliff top with predominantly residential properties.

- Defence length RUN 1.06. (Start 616517E 343434N. Finish 616588E 343415N). Concrete seawall set in front of cliff, with rock armour revetment placed in 1995. Shingle beach is low and in fair condition. Likely failure mechanism is cliff failure causing overturning or surcharging, causing sliding. Hinterland is urban cliff top with a number of residential properties. Cliff face is Beeston Cliffs SSSI.

- Defence length RUN 1.07. (Start 616588E 343415N. Finish 616891E 343375N). Concrete seawall with slightly concave face set forward of the cliff, with apron and steel pile toe. Badly abraded, with exposed aggregate and rust stains from reinforcement. Shingle beach is low. Likely failure mechanism is cliff failure causing overturning or surcharging, causing sliding. Hinterland is urban cliff top with a number of residential properties. Cliff face is Beeston Cliffs SSSI.

- Defence length RUN 1.08. (Start 616891E 343375N. Finish 617114E 343328N). Derelict timber revetment on badly abraded concrete base. Steel pile toe very badly abraded with major loss of section. Health and safety hazard. Shingle beach is very low. Likely failure mechanism is cliff failure causing overturning or surcharging, causing sliding. Hinterland is urban cliff top with a number of residential properties. Cliff face is Beeston Cliffs SSSI.

Of main concern are the oldest sections of wall and the newer and less robust walls on the eastern flank (see second photograph above). Table 3.1 shows the mean residual life for each of the defence lengths.

Table 3.1 Mean residual life of defences in RUN 1

Location	Mean Residual Life	Duration of double erosion rates
RUN 1.01	16	20
RUN 1.02	3	0
RUN 1.03	3	0
RUN 1.04	25	20
RUN 1.05	25	20
RUN 1.06	20	20
RUN 1.07	6	20
RUN 1.08	0	10

3.3 CLIFF EROSION

The cliffs at Sheringham are isolated from the action of the sea by the seawall that runs the entire length of the town frontage. They are also regraded and built over, thereby inhibiting slippage whilst the seawalls remain in place.

Table 3.1 shows the numbers of years where recession rates are considered to be double the average rate once the defences have failed. Because defence lengths RUN 1.02 and 1.03 fail very early in the strategy period they initially erode at the average rate (not double) because they will be sheltered by the defence lengths to either side. Defence length RUN 1.08 is already failed, but since it is still partially protected to the west by the defence length RUN 1.07 the duration of increased initial erosion is limited to the first 10 years of the strategy.

Subsequent to this period of rapid erosion, the recession rate is assumed to be the average of the rates of the two undefended cliff units to either side of Sheringham, as discussed earlier in this report.

Based on findings of the Cliff Processes Report, the future erosion rate (50% exceedance probability) for the entire length comprising RUN 1.01 to RUN 1.08 is estimated to be 0.81 m/yr. This rate is doubled for a number of years following failure of the respective defences, as indicated in Table 3.1.

3.4 HUMAN ENVIRONMENT AND ENVIRONMENTAL DESIGNATIONS

See also the generic details in Section 1.7.

Human environment

Sheringham, grew in importance in the late 18th century, when the town developed as a resort for sea bathing and promenading. Apart from containing commercial and residential properties the immediate hinterland also contains important services that would be lost following failure of the defences. These include a sewerage storm tank and pumping station on the cliff slopes themselves.

North Norfolk Railway: One of the main tourist attractions in the Sheringham area is the North Norfolk Railway, running steam trains along a section of line parallel to the study area. The worst case coastal erosion scenario (a 100 year appraisal period with a probability of 0.1) indicates that coastal erosion would not encroach closer than 135 metres of the track at its closest point.

Sheringham Golf Course: In addition to the value of the associated properties, the value of the land covered by Sheringham lynx golf course has been assumed to be five times that of agricultural land and constant across the area affected.

Sheringham Park: Sheringham Park is owned by the National Trust and consists of grounds surrounding the privately occupied Sheringham Hall. These include gardens, woodlands and walks which cross the railway line and proceed up to the coast. The park is open to the public all year round including a programme of events. The value of Sheringham Park land lost to coastal erosion over the appraisal period has been assumed to be the same as that for agricultural land and, as before, constant across the area affected.

Environmental designations

There are no environmental designations within the town itself. However, the eastern outskirts of Sheringham contain the Beeston Cliffs SSSI, which is a nationally important site for the Beestonian Stage of the Pleistocene. (Recent assessment by English Nature indicates that its condition is unfavourable and declining).

3.5 CONSEQUENCES OF THE DO NOTHING OPTION

Overview

The hinterland in this section is very densely populated with a large number of properties close to the coastline. As soon as the defences fail, many of these properties will be at risk to erosion. However, the probability of any properties being lost to erosion before year 5 is low.

Interaction of defence failure and cliff top retreat rates

Defence failure would lead to an initially rapid rate of cliff recession as this frontage would be “forward” of the line of the coast adjacently. This erosion would release predominantly sandy sediments that would improve beach levels particularly to the eastward. Once the cliff plan shape had stabilised the rate of retreat would be more even over the whole study area. Beeston Cliffs SSSI would also benefit under the Do Nothing option for Sheringham.

Summary of erosion and assets lost in the Do Nothing scenario

The Appendix tabulates the losses predicted to occur under the do nothing scenario, in 5 yearly increments. The incremental and cumulative economic losses resulting from the postulated damages are summarised in Section 5.

4. Management Unit RUN 2: West Runton to Cromer

The Runtons covers the SMP management unit RUN 2 and extends from the eastern edge of the defences protecting Sheringham to the western edge of the defences protecting Cromer at the eastern edge of the study area.

4.1 COASTAL PROCESSES

RUN 2 is the third Management Unit examined in the strategy, extending from just east of Sheringham to the western outskirts of Cromer. Here, the beaches comprise sand on the upper foreshore and shingle on the lower foreshore. Sand predominates near to Cromer, but conditions are very variable, as defences have failed in certain areas and been maintained in others (as at the access points). Following failures of the defences, the cliffs immediately behind are open to wave attack, resulting in cliff instability, slips and erosion. The photograph below shows the conditions near West Runton. One can see that cliff retreat is taking place rapidly and that although the sloping timber breastworks do trap the shingle, there is a safety issue and risk is high in this area.

Modelling carried out for the Littoral Sediment Processes Report shows that the littoral drift is generally directed from west to east, with magnitude increasing in an eastward direction. This would be consistent with a retreating shoreline. Analysis of beach profiles shows accretion at each end of the frontage, where groynes are still functional, with beach retreat in between. As defences fail, so there will be more material available to be transported towards Cromer.

4.2 COASTAL DEFENCES

The earliest historical record of sea defences in this management unit is from 1930 in defence length 4 (East Runton Gap) where there is a concrete ramp that provides access onto the beach and to the sea for boats.

In 1976, defences were constructed in defence lengths 2.01 (West Runton) and 2.02 (Old Woman Hithe / West Runton Gap). As a reaction to increased rates of erosion and loss of cliff top land in defence length 2.01, a timber revetment with a steel pile toe together with timber groynes were erected. At the same time the concrete road and ramp in defence length 2.02 was first protected by flanking sea walls in 1976. Outflanking is an issue here.

It should be borne in mind that the defences in this area were always constructed under the constraints of relatively low cost. While the defences were maintained they appeared to function effectively. However, the defences become less effective as the shoreline recedes (leaving them increasingly more exposed to wave action).

In the last two decades the timber breastworks and the concrete defences at the access points have begun to deteriorate markedly and their condition is very variable and likely to deteriorate quickly from hereon. Further details are given in the companion report on "Defence Condition Survey".

Overall, almost all the defences in this area will have soon reached the end of their life; i.e. become ineffective.

The linear defences from west to east are classified as follows:

- Defence length RUN 2.01. (Start 617107E 343337N. Finish 618545E 343182N). Timber revetment with steel sheet pile toe in various stages of dereliction. The sill still retains beach material landward of the structure. Generally shallow shingle upper/sand lower beach that is in good condition. Defences have already failed. Hinterland is rural cliff-top land, with residential properties, mobile home sites and agricultural land adjacently.

- Defence length RUN 2.02. (Start 618545E 343182N. Finish 618666E 343117N). Concrete access ramp, protected by concrete walls with steel sheet pile toe on flanks, generally in good condition. The ramp itself was extended in 2005/06. Likely failure mechanism is beach lowering, resulting in steel pile failure, or cliff failure. Extensive areas of chalk exposure, with beaches eroding and no longer presenting the consistent expanses of sand that this location was well known for. Hinterland is mainly rural cliff-top land, with the village of West Runton set back from the cliffs. Well-used access by tourists and local fishermen alike. Area includes the West Runton SSSI.

- Defence length RUN 2.03. (Start 618666E 343117N. Finish 620073E 342799N). Extensive areas of chalk platform exposure. Beaches are eroding and no longer presenting the consistent expanses of sand that this location was well known for. Base of the cliffs is undefended and eroding. Hinterland is predominantly rural cliff-top land, mainly agricultural, but with also a few residential properties and mobile home sites. There is a long, sea treated effluent outfall in this area. The frontage includes both East and West Runtons SSSIs.

- Defence length RUN 2.04. (Start 620073E 342799N. Finish 620176E 342751N). Concrete access ramp and steps, protected by flanking concrete walls and rock armour. The ramp was extended and the flanking defences rehabilitated in 2006. Flat sandy beach in good condition. Likely failure mechanism is outflanking of the defences. Hinterland is urban cliff top land, containing both residential and a few commercial properties in East Runton. The area between residential properties and the cliff edge is filled with mobile homes for holiday visitors.

There is access to the beach for fishermen and for amenity use. Part of the East Runton SSSI.

- Defence length RUN 2.05. (Start 620176E 342751N. Finish 621255E 342494N). Cliffs are undefended. Sandy beach with exposed shore platform always exposed east of Runton Gap. Hinterland is semi-urban cliff-top land on the western outskirts of Cromer, containing a few residential properties, mobile home sites and public open space. The area between residential properties and the cliff edge is filled with mobile homes for holiday visitors. There is access to the beach for fishermen and for amenity use. Part of the East Runton SSSI.

4.3 CLIFF EROSION

The companion report on "Cliff Processes" identifies the cliffs within Management Unit RUN 2 as Cliff Units 3, 4 and 5. These cliffs vary in height from 18m to 40m. Comprising glacial till over a chalk shore platform, these cliffs comprise variable proportions of sand and gravel, viz: 13.9% to 69% sand, 0.5% to 7.6% gravel. These cliffs comprise less gravel bearing strata than do the cliffs to the west of Sheringham.

Analysis of beach profiles supports the view that the sloping timber breastworks have been effective in reducing cliff toe erosion. However, the timber breastworks are now at the end of their life and an increase in the rate of cliff recession is expected under the Do Nothing scenario.

Where there are existing defences at West and East Runton Gaps, no recession rate has been evaluated. Two methods to represent the annual recession rate were considered as possibilities. The first method is the same as that used at Sheringham (i.e. an average of two adjacent ones). The second method considers that no erosion would occur until the defences failed, but then the coastline would rapidly erode until the general cliff line was met. In essence, due to the short length of the defence lengths and the existing promontory nature of defended versus undefended areas, rapid outflanking would occur. Ultimately this would lead to a smooth transition zone being formed between the cliff units to either side of the short defence length. Having considered the processes being modelled and the mainly rural nature of this frontage, it was decided to adopt the latter method for estimating cliff retreat.

Based on findings of the Cliff Processes Report, the future erosion rate (50% exceedance probability) are estimated to be as follows.

Location:	Erosion rate m/yr:
Cliff Unit 3	1.20
Cliff Unit 4	0.48
Cliff Unit 5	0.48

4.4 HUMAN ENVIRONMENT AND ENVIRONMENTAL DESIGNATIONS

See also the generic details in Section 1.7.

Human environment

The villages of West Runton and East Runton are situated within the area of hinterland that may be affected by cliff recession in the long term. Both of these are small villages are primarily residential, although they also rely, to some degree, on tourism for their sustenance (there are mobile home sites at West Runton, East Runton and at the western outskirts of Cromer). The land is principally agricultural.

Transportation – Roads: Coastal erosion scenarios within the appraisal period include the loss of the coastal A149 road on the Eastern edge of the study area as it enters Cromer itself. Should such a scenario arise, a large section of the town centre itself would also be lost. Since the road terminates in the town centre and does not continue along the coast at this point, a large proportion of the traffic demand on this road would no longer exist. Suitable diversions exist for the remaining local traffic; therefore no separate costs have been included to cover the replacement of this section of the A149.

Transportation – Rail: The most extreme worst case scenario (a 100 year appraisal period with a probability of 0.1) records coastal erosion to just under 9 metres short of the railway line carrying the National Rail Service from Norwich to Cromer and Sheringham (as digitised from the 1:10,000 OS map) at its closest point. This line also provides rail access to the North Norfolk Railway.

No separate estimate has been included covering any potential infrastructure repair or replacement arising from this scenario since the erosion falls short of affecting the railway itself. However, a potentially high impact will occur in a timescale just longer than the 100 year appraisal period.

Environmental designations

This Management Unit includes three SSSI designations for the exposed cliffs. These designations reflect, in part, the interesting geology of the cliffs, which are largely of glacial origin:

- Beeston Cliffs SSSI: the cliffs provide sections in both marine and freshwater pre-Pastonian and Pastonian, Beestonian and Cromerian sediments. The SSSI frontage extends for a relatively modest distance of 430 metres, the cliffs reaching a height of 64 metres.
- West Runton Cliffs SSSI: the cliff and foreshore section at West Runton is one of the most important Pleistocene localities in the British Isles.
- East Runton Cliffs SSSI: The foreshore at East Runton exposes pre-Cromerian (Lower Pleistocene) sediments, including successively 'Weybourne Crag', Pastonian clay conglomerate and marine shell beds, overlain in turn by marine silts (Pa II pollen zone).

4.5 CONSEQUENCES OF THE DO NOTHING OPTION

Overview

Within this section there are very few properties and these are only at risk to erosion in the later years of the period considered in the strategy study. Therefore, in the initial years it is only agricultural land and caravan parks that are lost due to erosion. In the later years residential and commercial properties could potentially be lost to erosion.

Interaction of defence failure and cliff top retreat rates

Cliff recession within this frontage is likely to be rapid, now that the defences have largely failed. Some outflanking of the defences at the eastern end of Sheringham is likely. Continuing cliff erosion will produce a supply of “beach” material that will be transported towards Cromer. Hence, outflanking of the hard defences at Cromer is unlikely.

Summary of erosion and assets lost in the Do Nothing scenario

The Appendix tabulates the losses predicted to occur under the do nothing scenario, in 5 yearly increments. The incremental and cumulative economic losses resulting from the postulated damages are summarised in Section 5.

5. *Overview of the losses under the Do-Nothing scenario*

5.1 INTRODUCTION TO THE RESULTS

The expected economic losses due to coastal erosion of the study area have been calculated for the appraisal period of 100 years.

The Appendix lists the calculated losses by asset category and Management Unit in each five yearly increment of the appraisal period.

Combined incremental and cumulative damages (100 years) are listed in Tables 5.2 and 5.3, with Tables 5.4 and 5.5 providing further detail on the breakdown costs of RUN 1.01 to 1.08.

Figures 5.1 to 5.4 depict the cumulative losses for the whole frontage, followed by the losses in each of the Management Units respectively.

5.2 BRIEF DISCUSSION

The total discounted damages in the do nothing case amount to some £23 million. This figure is made up as follows:

Table 5.1 Summary of Total Losses in 100 years – Do nothing scenario

Management Unit	Do Nothing Damages (£)
MU1/CU1	838,657
RUN 1	19,647,180
RUN 2	2,927,329
TOTAL	23,413,167

The losses are dominated by damages within RUN 1, i.e. Sheringham. It may be noted from data given in the Appendix that, within RUN 1, some £2.12 million of damages are predicted to occur with the next five years. Of this figure, some £1.47 million are seaward of the present cliff-line, comprising promenade infrastructure and the lifeboat station; as such, they constitute the most imminent potential losses in the case of no intervention.

The calculated losses use the most likely predicted future erosion rates.

Damages due to the impact on tourism have been identified within the report but not calculated in monetary terms. As such, the losses as presented probably represent an underestimate of the true damages in the do-nothing scenario.

Table 5.2 Incremental Damages, 100years

Period	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)
5	42,064	37,984	2,342,690	2,115,485	28,326	25,579	2,413,080	2,179,048
10	42,064	31,982	1,380	1,049	28,326	21,537	71,770	54,568
15	42,064	26,928	1,380	883	194,880	124,758	238,324	152,569
20	197,464	106,436	820,702	442,372	28,326	15,268	1,046,492	564,076
25	340,064	154,335	7,312,550	3,318,739	2,788,826	1,265,685	10,441,440	4,738,760
30	462,164	176,605	5,877,176	2,245,822	861,576	329,231	7,200,916	2,751,657
35	42,064	13,728	6,371,326	2,079,272	499,576	163,036	6,912,966	2,256,035
40	164,164	46,214	6,334,490	1,783,228	326,326	91,864	6,824,980	1,921,307
45	164,164	39,865	6,147,040	1,492,709	28,326	6,879	6,339,530	1,539,452
50	682,976	143,063	2,398,228	502,358	2,076,326	434,929	5,157,530	1,080,351
55	42,064	7,601	10,310,428	1,863,003	28,326	5,118	10,380,818	1,875,722
60	42,064	6,556	5,748,528	895,999	28,326	4,415	5,818,918	906,970
65	42,064	5,656	4,635,128	623,199	28,326	3,808	4,705,518	632,663
70	42,064	4,879	6,103,728	707,903	194,826	22,596	6,340,618	735,377
75	42,064	4,208	2,256,078	225,708	2,272,326	227,333	4,570,468	457,249
80	42,064	3,682	4,016,728	351,645	438,187	38,361	4,496,979	393,688
85	42,064	3,255	4,004,128	309,828	276,326	21,381	4,322,518	334,464
90	42,064	2,877	2,809,178	192,120	28,326	1,937	2,879,568	196,934
95	340,064	20,556	5,377,128	325,031	28,326	1,712	5,745,518	347,299
100	42,064	2,247	3,197,428	170,827	2,281,676	121,901	5,521,168	294,975

Table 5.3 Cumulative Damages, 100 years

Period	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)
5	42,064	37,984	2,342,690	2,115,485	28,326	25,579	2,413,080	2,179,048
10	84,128	69,967	2,344,070	2,116,534	56,652	47,116	2,484,850	2,233,617
15	126,192	96,895	2,345,450	2,117,418	251,532	171,873	2,723,174	2,386,186
20	323,656	203,331	3,166,152	2,559,790	279,858	187,141	3,769,666	2,950,262
25	663,720	357,667	10,478,702	5,878,529	3,068,684	1,452,827	14,211,106	7,689,022
30	1,125,884	534,271	16,355,878	8,124,351	3,930,260	1,782,057	21,412,022	10,440,679
35	1,167,948	547,999	22,727,204	10,203,622	4,429,836	1,945,093	28,324,988	12,696,715
40	1,332,112	594,213	29,061,694	11,986,851	4,756,162	2,036,957	35,149,968	14,618,021
45	1,496,276	634,077	35,208,734	13,479,560	4,784,488	2,043,836	41,489,498	16,157,474
50	2,179,252	777,141	37,606,962	13,981,918	6,860,814	2,478,765	46,647,028	17,237,824
55	2,221,316	784,741	47,917,390	15,844,922	6,889,140	2,483,883	57,027,846	19,113,547
60	2,263,380	791,298	53,665,918	16,740,921	6,917,466	2,488,299	62,846,764	20,020,517
65	2,305,444	796,953	58,301,046	17,364,119	6,945,792	2,492,107	67,552,282	20,653,180
70	2,347,508	801,832	64,404,774	18,072,022	7,140,618	2,514,703	73,892,900	21,388,557
75	2,389,572	806,040	66,660,852	18,297,730	9,412,944	2,742,036	78,463,368	21,845,806
80	2,431,636	809,723	70,677,580	18,649,375	9,851,131	2,780,397	82,960,347	22,239,495
85	2,473,700	812,977	74,681,708	18,959,203	10,127,457	2,801,778	87,282,865	22,573,959
90	2,515,764	815,854	77,490,886	19,151,323	10,155,783	2,803,716	90,162,433	22,770,893
95	2,855,828	836,410	82,868,014	19,476,354	10,184,109	2,805,428	95,907,951	23,118,191
100	2,897,892	838,657	86,065,442	19,647,180	12,465,785	2,927,329	101,429,119	23,413,167

Table 5.4 Incremental Damages, 100 years RUN 1.01 – 1.08

Period	RUN1.01		RUN1.02		RUN1.03		RUN1.04		RUN1.05		RUN1.06		RUN1.07		RUN1.08		Total	
	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)
5	0	0	1,613,690	1,457,187	729,000	658,298	0	0	0	0	0	0	0	0	0	0	2,342,690	2,115,485
10	0	0	1,380	1,049	0	0	0	0	0	0	0	0	0	0	0	0	1,380	1,049
15	0	0	1,380	883	0	0	0	0	0	0	0	0	0	0	0	0	1,380	883
20	125,572	67,685	1,380	744	693,750	373,943	0	0	0	0	0	0	0	0	0	0	820,702	442,372
25	4,572	2,075	1,380	626	693,750	314,853	280,000	127,076	6,332,848	2,874,110	0	0	0	0	0	0	7,312,550	3,318,739
30	4,572	1,747	1,501,380	573,716	444,000	169,664	2,510,750	959,423	1,416,474	541,272	0	0	0	0	0	0	5,877,176	2,245,822
35	4,572	1,492	1,380	450	0	0	3,230,100	1,054,138	3,135,274	1,023,192	0	0	0	0	0	0	6,371,326	2,079,272
40	2,286	644	1,380	388	510,600	143,739	1,224,850	344,809	4,595,374	1,293,648	0	0	0	0	0	0	6,334,490	1,783,228
45	2,286	555	1,380	335	0	0	3,422,650	831,135	2,720,724	660,684	0	0	0	0	0	0	6,147,040	1,492,709
50	2,286	479	1,380	289	0	0	1,409,700	295,291	984,862	206,300	0	0	0	0	0	0	2,398,228	502,358
55	2,286	413	1,501,380	271,286	5,794,200	1,046,961	1,576,200	284,805	1,436,362	259,538	0	0	0	0	0	0	10,310,428	1,863,003
60	2,286	356	1,066,980	166,306	3,113,550	485,296	111,000	17,301	655,512	102,172	0	0	799,200	124,568	0	0	5,748,528	895,999
65	2,286	307	1,380	186	0	0	2,334,850	313,923	1,219,912	164,019	0	0	1,076,700	144,764	0	0	4,635,128	623,199
70	2,286	265	1,380	160	3,446,550	399,727	621,600	72,092	2,031,912	235,659	0	0	0	0	0	0	6,103,728	707,903
75	2,286	229	1,380	138	596,000	59,626	699,300	69,961	679,612	67,991	0	0	277,500	27,762	0	0	2,256,078	225,708
80	2,286	200	1,501,380	131,438	553,300	48,439	444,000	38,870	1,515,762	132,698	0	0	0	0	0	0	4,016,728	351,645
85	2,286	177	1,380	107	0	0	2,181,150	168,771	1,458,562	112,859	0	0	360,750	27,914	0	0	4,004,128	309,828
90	2,286	156	1,380	94	0	0	995,600	68,089	1,488,012	101,765	0	0	321,900	22,015	0	0	2,809,178	192,120
95	2,286	138	1,380	83	2,508,600	151,637	1,017,800	61,523	1,403,062	84,811	0	0	444,000	26,838	0	0	5,377,128	325,031
100	2,286	122	1,380	74	177,600	9,488	897,400	47,945	409,362	21,871	876,900	46,849	832,500	44,477	0	0	3,197,428	170,827

Table 5.5 Cumulative Damages, 100 years RUN 1.01 – 1.08

Period	RUN1.01		RUN1.02		RUN1.03		RUN1.04		RUN1.05		RUN1.06		RUN1.07		RUN1.08		Total	
	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)	Un-discounted (£)	Discounted (£)
5	0	0	1,613,690	1,457,187	729,000	658,298	0	0	0	0	0	0	0	0	0	0	2,342,690	2,115,485
10	0	0	1,615,070	1,458,236	729,000	658,298	0	0	0	0	0	0	0	0	0	0	2,344,070	2,116,534
15	0	0	1,616,450	1,459,120	729,000	658,298	0	0	0	0	0	0	0	0	0	0	2,345,450	2,117,418
20	125,572	67,685	1,617,830	1,459,863	1,422,750	1,032,241	0	0	0	0	0	0	0	0	0	0	3,166,152	2,559,790
25	130,144	69,760	1,619,210	1,460,490	2,116,500	1,347,093	280,000	127,076	6,332,848	2,874,110	0	0	0	0	0	0	10,478,702	5,878,529
30	134,716	71,507	3,120,590	2,034,206	2,560,500	1,516,757	2,790,750	1,086,498	7,749,322	3,415,381	0	0	0	0	0	0	16,355,878	8,124,351
35	139,288	72,999	3,121,970	2,034,656	2,560,500	1,516,757	6,020,850	2,140,636	10,884,596	4,438,573	0	0	0	0	0	0	22,727,204	10,203,622
40	141,574	73,643	3,123,350	2,035,045	3,071,100	1,660,497	7,245,700	2,485,445	15,479,970	5,732,221	0	0	0	0	0	0	29,061,694	11,986,851
45	143,860	74,198	3,124,730	2,035,380	3,071,100	1,660,497	10,668,350	3,316,580	18,200,694	6,392,905	0	0	0	0	0	0	35,208,734	13,479,560
50	146,146	74,677	3,126,110	2,035,669	3,071,100	1,660,497	12,078,050	3,611,871	19,185,556	6,599,204	0	0	0	0	0	0	37,606,962	13,981,918
55	148,432	75,090	4,627,490	2,306,955	8,865,300	2,707,458	13,654,250	3,896,676	20,621,918	6,858,742	0	0	0	0	0	0	47,917,390	15,844,922
60	150,718	75,446	5,694,470	2,473,261	11,978,850	3,192,754	13,765,250	3,913,977	21,277,430	6,960,914	0	0	799,200	124,568	0	0	53,665,918	16,740,921
65	153,004	75,754	5,695,850	2,473,446	11,978,850	3,192,754	16,100,100	4,227,901	22,497,342	7,124,933	0	0	1,875,900	269,332	0	0	58,301,046	17,364,119
70	155,290	76,019	5,697,230	2,473,607	15,425,400	3,592,480	16,721,700	4,299,993	24,529,254	7,360,592	0	0	1,875,900	269,332	0	0	64,404,774	18,072,022
75	157,576	76,248	5,698,610	2,473,745	16,021,400	3,652,107	17,421,000	4,369,954	25,208,866	7,428,583	0	0	2,153,400	297,094	0	0	66,660,852	18,297,730
80	159,862	76,448	7,199,990	2,605,183	16,574,700	3,700,546	17,865,000	4,408,824	26,724,628	7,561,281	0	0	2,153,400	297,094	0	0	70,677,580	18,649,375
85	162,148	76,625	7,201,370	2,605,290	16,574,700	3,700,546	20,046,150	4,577,595	28,183,190	7,674,140	0	0	2,514,150	325,008	0	0	74,681,708	18,959,203
90	164,434	76,781	7,202,750	2,605,384	16,574,700	3,700,546	21,041,750	4,645,685	29,671,202	7,775,905	0	0	2,836,050	347,022	0	0	77,490,886	19,151,323
95	166,720	76,919	7,204,130	2,605,468	19,083,300	3,852,183	22,059,550	4,707,207	31,074,264	7,860,716	0	0	3,280,050	373,861	0	0	82,868,014	19,476,354
100	169,006	77,041	7,205,510	2,605,541	19,260,900	3,861,671	22,956,950	4,755,152	31,483,626	7,882,587	876,900	46,849	4,112,550	418,338	0	0	86,065,442	19,647,180

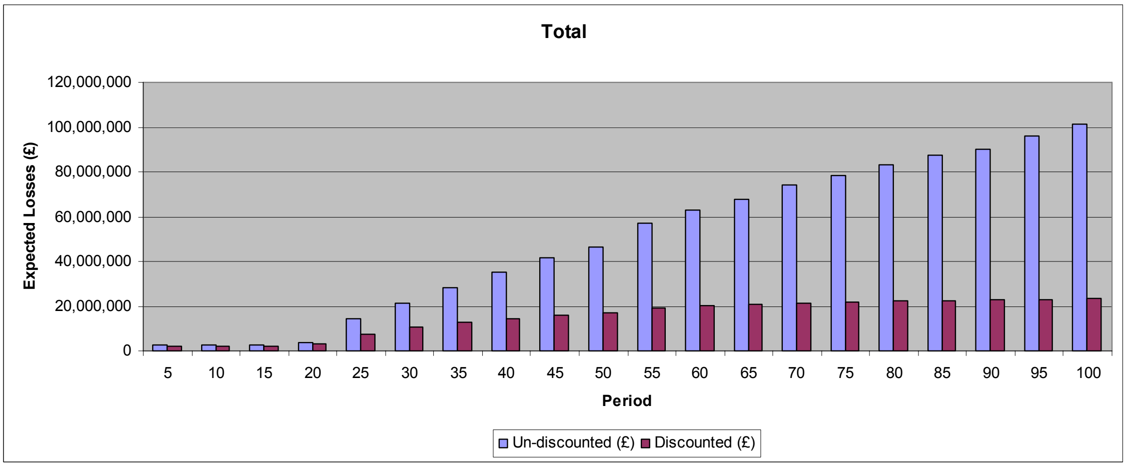

Figure 5.1 Total Damages

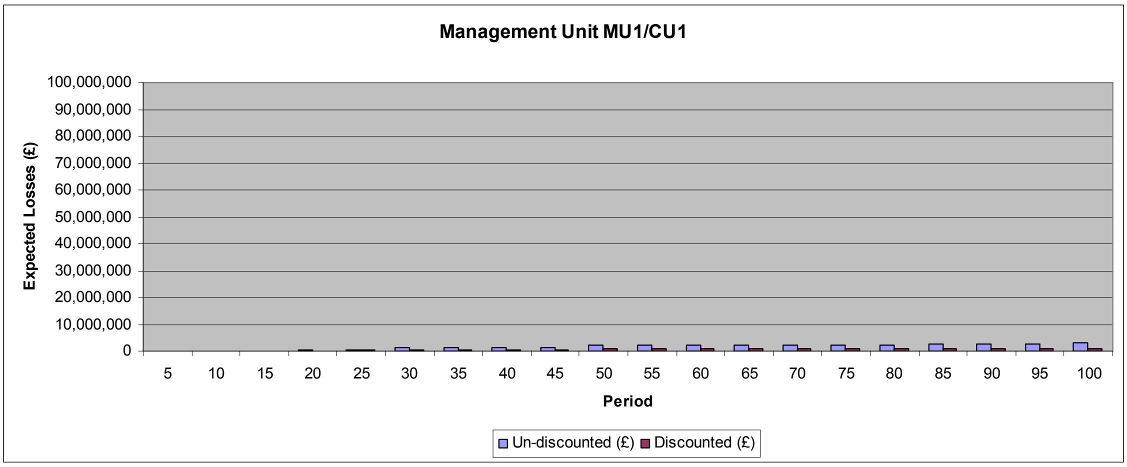

Figure 5.2 Damages in Management Unit MU1/CU1

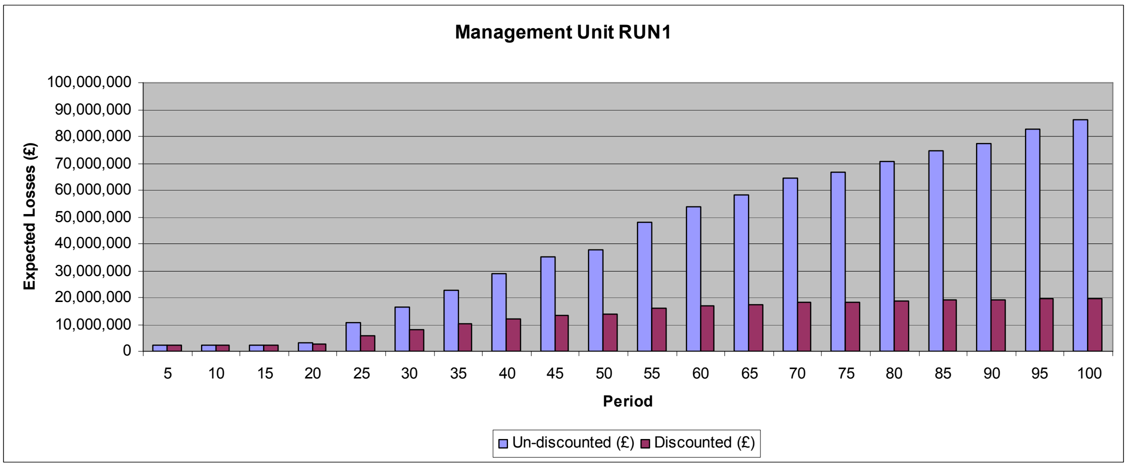

Figure 5.3 Damages in Management Unit RUN 1

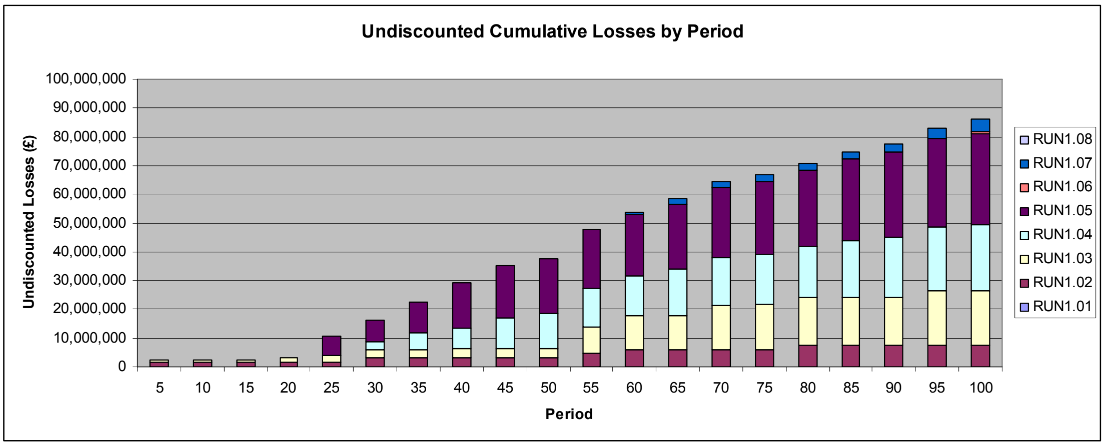

Figure 5.4 Breakdown of Damages in Management Unit RUN 1 (Undiscounted)

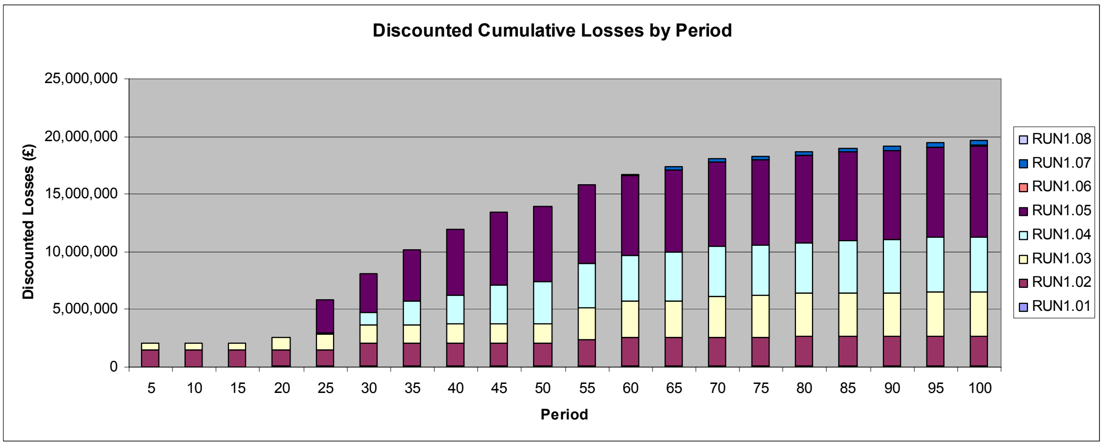

Figure 5.5 Breakdown of Damages in Management Unit RUN 1 (Discounted)

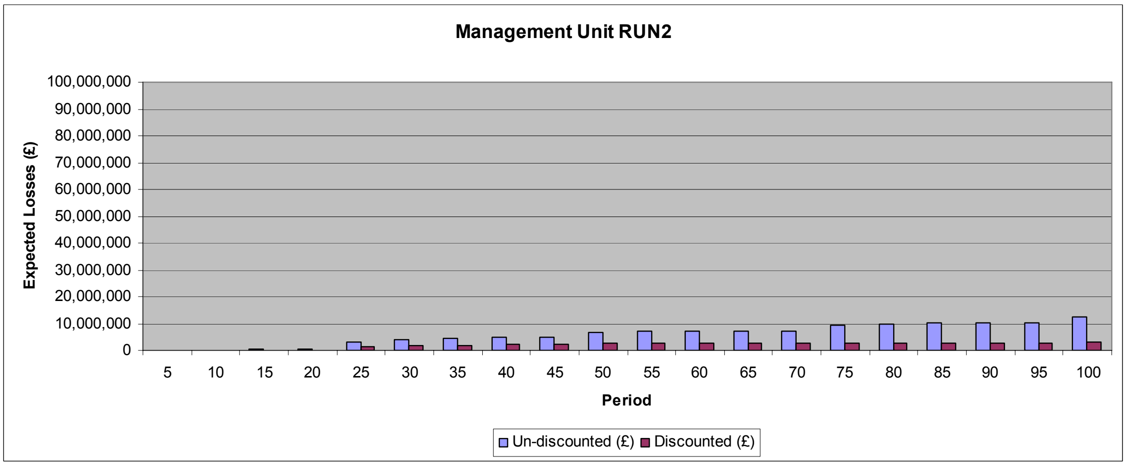

Figure 5.6 Damages in Management Unit RUN 2

6. References

HM Treasury 2003 The Green Book: Appraisal and Evaluation in Central Government; 'Greenbook.treasury.gov.uk', 2003.

FHRC: The Economics of Coastal Management, "Yellow Manual", Middlesex, 1992.

Kelling to Lowestoft Shoreline Management Plan, 1996, Mouchel.

Sheringham to Lowestoft Shoreline Management Plan, 1996, Halcrow.

Kelling to Lowestoft Shoreline Management Plan, Halcrow (draft 2005).

FCD PAG3, Flood and Coastal Defence Project Appraisal, Economic Appraisal, 1999, MAFF.

Appendix

Do Nothing Damages

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 0 and 5 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	111,000	100,235	0	0	111,000	100,235
Properties (North of Cliff)	0	0	1,631,000	1,472,818	0	0	1,631,000	1,472,818
Land (Agricultural)	10,267	9,271	0	0	3,847	3,474	14,114	12,745
Land (Golf Course)	18,694	16,881	690	623	0	0	19,384	17,504
Land (National Trust)	3,103	2,802	0	0	0	0	3,103	2,802
Land (Car Park)	0	0	0	0	4,479	4,045	4,479	4,045
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	600,000	541,809	0	0	600,000	541,809
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	9,030	0	0	20,000	18,060	30,000	27,090
Total	42,064	37,984	2,342,690	2,115,485	28,326	25,579	2,413,080	2,179,048
Cumulative Total	42,064	37,984	2,342,690	2,115,485	28,326	25,579	2,413,080	2,179,048

** Discount Factor:* 0.9030154

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 6 and 10 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	0	0	0	0	0	0
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	7,806	0	0	3,847	2,925	14,114	10,731
Land (Golf Course)	18,694	14,213	1,380	1,049	0	0	20,074	15,263
Land (National Trust)	3,103	2,359	0	0	0	0	3,103	2,359
Land (Car Park)	0	0	0	0	4,479	3,405	4,479	3,405
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	7,603	0	0	20,000	15,206	30,000	22,810
Total	42,064	31,982	1,380	1,049	28,326	21,537	71,770	54,568
Cumulative Total	84,128	69,967	2,344,070	2,116,534	56,652	47,116	2,484,850	2,233,617

** Discount Factor:* 0.7603218

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 11 and 15 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	0	0	0	0	0	0
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	6,573	0	0	3,847	2,463	14,114	9,035
Land (Golf Course)	18,694	11,967	1,380	883	0	0	20,074	12,851
Land (National Trust)	3,103	1,986	0	0	0	0	3,103	1,986
Land (Car Park)	0	0	0	0	4,479	2,867	4,479	2,867
Sewerage	0	0	0	0	166,554	106,624	166,554	106,624
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	6,402	0	0	20,000	12,804	30,000	19,205
Total	42,064	26,928	1,380	883	194,880	124,758	238,324	152,569
Cumulative Total	126,192	96,895	2,345,450	2,117,418	251,532	171,873	2,723,174	2,386,186

** Discount Factor:* 0.6401765

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 16 and 20 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	155,400	83,763	693,750	373,943	0	0	849,150	457,706
Properties (North of Cliff)	0	0	121,000	65,221	0	0	121,000	65,221
Land (Agricultural)	10,267	5,534	0	0	3,847	2,074	14,114	7,608
Land (Golf Course)	18,694	10,076	5,952	3,208	0	0	24,646	13,285
Land (National Trust)	3,103	1,673	0	0	0	0	3,103	1,673
Land (Car Park)	0	0	0	0	4,479	2,414	4,479	2,414
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	5,390	0	0	20,000	10,780	30,000	16,170
Total	197,464	106,436	820,702	442,372	28,326	15,268	1,046,492	564,076
Cumulative Total	323,656	203,331	3,166,152	2,559,790	279,858	187,141	3,769,666	2,950,262

** Discount Factor:* 0.5390164

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 21 and 25 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	298,000	135,245	693,750	314,853	960,500	435,915	1,952,250	886,012
Properties (North of Cliff)	0	0	930,000	422,073	0	0	930,000	422,073
Land (Agricultural)	10,267	4,660	0	0	3,847	1,746	14,114	6,406
Land (Golf Course)	18,694	8,484	5,952	2,701	0	0	24,646	11,185
Land (National Trust)	3,103	1,408	0	0	0	0	3,103	1,408
Land (Car Park)	0	0	0	0	4,479	2,033	4,479	2,033
Sewerage	0	0	5,634,848	2,557,328	0	0	5,634,848	2,557,328
Commercial	0	0	48,000	21,784	1,800,000	816,915	1,848,000	838,699
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	4,538	0	0	20,000	9,077	30,000	13,615
Total	340,064	154,335	7,312,550	3,318,739	2,788,826	1,265,685	10,441,440	4,738,760
Cumulative Total	663,720	357,667	10,478,702	5,878,529	3,068,684	1,452,827	14,211,106	7,689,022

** Discount Factor:* 0.4538416

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 26 and 30 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	420,100	160,531	4,370,000	1,669,891	83,250	31,812	4,873,350	1,862,234
Properties (North of Cliff)	0	0	900,000	343,913	0	0	900,000	343,913
Land (Agricultural)	10,267	3,923	0	0	3,847	1,470	14,114	5,393
Land (Golf Course)	18,694	7,143	5,952	2,274	0	0	24,646	9,418
Land (National Trust)	3,103	1,186	0	0	0	0	3,103	1,186
Land (Car Park)	0	0	1,224	468	4,479	1,712	5,703	2,179
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	600,000	229,276	0	0	600,000	229,276
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	3,821	0	0	770,000	294,237	780,000	298,058
Total	462,164	176,605	5,877,176	2,245,822	861,576	329,231	7,200,916	2,751,657
Cumulative Total	1,125,884	534,271	16,355,878	8,124,351	3,930,260	1,782,057	21,412,022	10,440,679

** Discount Factor:* 0.38212599

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 31 and 35 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	6,364,150	2,076,930	381,250	124,420	6,745,400	2,201,350
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	3,351	0	0	3,847	1,255	14,114	4,606
Land (Golf Course)	18,694	6,101	5,952	1,942	0	0	24,646	8,043
Land (National Trust)	3,103	1,013	0	0	0	0	3,103	1,013
Land (Car Park)	0	0	1,224	399	4,479	1,462	5,703	1,861
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	3,263	0	0	110,000	35,898	120,000	39,162
Total	42,064	13,728	6,371,326	2,079,272	499,576	163,036	6,912,966	2,256,035
Cumulative Total	1,167,948	547,999	22,727,204	10,203,622	4,429,836	1,945,093	28,324,988	12,696,715

** Discount Factor:* 0.3263484

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 36 and 40 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	122,100	34,372	6,329,600	1,781,852	298,000	83,890	6,749,700	1,900,115
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	2,890	0	0	3,847	1,083	14,114	3,973
Land (Golf Course)	18,694	5,263	3,666	1,032	0	0	22,360	6,295
Land (National Trust)	3,103	874	0	0	0	0	3,103	874
Land (Car Park)	0	0	1,224	345	4,479	1,261	5,703	1,605
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	2,815	0	0	20,000	5,630	30,000	8,445
Total	164,164	46,214	6,334,490	1,783,228	326,326	91,864	6,824,980	1,921,307
Cumulative Total	1,332,112	594,213	29,061,694	11,986,851	4,756,162	2,036,957	35,149,968	14,618,021

** Discount Factor:* 0.281511

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 41 and 45 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	122,100	29,650	6,142,150	1,491,522	0	0	6,264,250	1,521,172
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	2,493	0	0	3,847	934	14,114	3,427
Land (Golf Course)	18,694	4,540	3,666	890	0	0	22,360	5,430
Land (National Trust)	3,103	754	0	0	0	0	3,103	754
Land (Car Park)	0	0	1,224	297	4,479	1,088	5,703	1,385
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	2,428	0	0	20,000	4,857	30,000	7,285
Total	164,164	39,865	6,147,040	1,492,709	28,326	6,879	6,339,530	1,539,452
Cumulative Total	1,496,276	634,077	35,208,734	13,479,560	4,784,488	2,043,836	41,489,498	16,157,474

** Discount Factor:* 0.2428338

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 46 and 50 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	122,100	25,576	2,345,950	491,408	248,000	51,949	2,716,050	568,933
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	2,151	0	0	3,847	806	14,114	2,956
Land (Golf Course)	18,694	3,916	3,666	768	0	0	22,360	4,684
Land (National Trust)	3,103	650	0	0	0	0	3,103	650
Land (Car Park)	0	0	612	128	4,479	938	5,091	1,066
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	48,000	10,055	1,800,000	377,047	1,848,000	387,102
Nature Conservation	518,812	108,676	0	0	0	0	518,812	108,676
Caravan Sites	10,000	2,095	0	0	20,000	4,189	30,000	6,284
Total	682,976	143,063	2,398,228	502,358	2,076,326	434,929	5,157,530	1,080,351
Cumulative Total	2,179,252	777,141	37,606,962	13,981,918	6,860,814	2,478,765	46,647,028	17,237,824

** Discount Factor:* 0.2094706

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 51 and 55 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	8,806,150	1,591,194	0	0	8,806,150	1,591,194
Properties (North of Cliff)	0	0	900,000	162,622	0	0	900,000	162,622
Land (Agricultural)	10,267	1,855	0	0	3,847	695	14,114	2,550
Land (Golf Course)	18,694	3,378	3,666	662	0	0	22,360	4,040
Land (National Trust)	3,103	561	0	0	0	0	3,103	561
Land (Car Park)	0	0	612	111	4,479	809	5,091	920
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	600,000	108,415	0	0	600,000	108,415
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	1,807	0	0	20,000	3,614	30,000	5,421
Total	42,064	7,601	10,310,428	1,863,003	28,326	5,118	10,380,818	1,875,722
Cumulative Total	2,221,316	784,741	47,917,390	15,844,922	6,889,140	2,483,883	57,027,846	19,113,547

** Discount Factor:* 0.1806912

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 56 and 60 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	5,744,250	895,332	0	0	5,744,250	895,332
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	1,600	0	0	3,847	600	14,114	2,200
Land (Golf Course)	18,694	2,914	3,666	571	0	0	22,360	3,485
Land (National Trust)	3,103	484	0	0	0	0	3,103	484
Land (Car Park)	0	0	612	95	4,479	698	5,091	794
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	1,559	0	0	20,000	3,117	30,000	4,676
Total	42,064	6,556	5,748,528	895,999	28,326	4,415	5,818,918	906,970
Cumulative Total	2,263,380	791,298	53,665,918	16,740,921	6,917,466	2,488,299	62,846,764	20,020,517

** Discount Factor:* 0.1558658

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 61 and 65 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	4,630,850	622,623	0	0	4,630,850	622,623
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	1,380	0	0	3,847	517	14,114	1,898
Land (Golf Course)	18,694	2,513	3,666	493	0	0	22,360	3,006
Land (National Trust)	3,103	417	0	0	0	0	3,103	417
Land (Car Park)	0	0	612	82	4,479	602	5,091	684
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	1,345	0	0	20,000	2,689	30,000	4,034
Total	42,064	5,656	4,635,128	623,199	28,326	3,808	4,705,518	632,663
Cumulative Total	2,305,444	796,953	58,301,046	17,364,119	6,945,792	2,492,107	67,552,282	20,653,180

** Discount Factor:* 0.1344512

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 66 and 70 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	6,099,450	707,407	166,500	19,310	6,265,950	726,717
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	1,191	0	0	3,847	446	14,114	1,637
Land (Golf Course)	18,694	2,168	3,666	425	0	0	22,360	2,593
Land (National Trust)	3,103	360	0	0	0	0	3,103	360
Land (Car Park)	0	0	612	71	4,479	519	5,091	590
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	1,160	0	0	20,000	2,320	30,000	3,479
Total	42,064	4,879	6,103,728	707,903	194,826	22,596	6,340,618	735,377
Cumulative Total	2,347,508	801,832	64,404,774	18,072,022	7,140,618	2,514,703	73,892,900	21,388,557

** Discount Factor:* 0.1159788

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 71 and 75 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	2,203,800	220,478	444,000	44,420	2,647,800	264,897
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	1,027	0	0	3,847	385	14,114	1,412
Land (Golf Course)	18,694	1,870	3,666	367	0	0	22,360	2,237
Land (National Trust)	3,103	310	0	0	0	0	3,103	310
Land (Car Park)	0	0	612	61	4,479	448	5,091	509
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	48,000	4,802	1,800,000	180,080	1,848,000	184,882
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	1,000	0	0	20,000	2,001	30,000	3,001
Total	42,064	4,208	2,256,078	225,708	2,272,326	227,333	4,570,468	457,249
Cumulative Total	2,389,572	806,040	66,660,852	18,297,730	9,412,944	2,742,036	78,463,368	21,845,806

** Discount Factor:* 0.1000443

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 76 and 80 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	2,512,450	219,953	0	0	2,512,450	219,953
Properties (North of Cliff)	0	0	900,000	78,791	0	0	900,000	78,791
Land (Agricultural)	10,267	899	0	0	3,847	337	14,114	1,236
Land (Golf Course)	18,694	1,637	3,666	321	0	0	22,360	1,958
Land (National Trust)	3,103	272	0	0	0	0	3,103	272
Land (Car Park)	0	0	612	54	4,479	392	5,091	446
Sewerage	0	0	0	0	409,861	35,881	409,861	35,881
Commercial	0	0	600,000	52,527	0	0	600,000	52,527
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	875	0	0	20,000	1,751	30,000	2,626
Total	42,064	3,682	4,016,728	351,645	438,187	38,361	4,496,979	393,688
Cumulative Total	2,431,636	809,723	70,677,580	18,649,375	9,851,131	2,780,397	82,960,347	22,239,495

** Discount Factor:* 0.0875451

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 81 and 85 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	3,999,850	309,497	248,000	19,190	4,247,850	328,686
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	794	0	0	3,847	298	14,114	1,092
Land (Golf Course)	18,694	1,446	3,666	284	0	0	22,360	1,730
Land (National Trust)	3,103	240	0	0	0	0	3,103	240
Land (Car Park)	0	0	612	47	4,479	347	5,091	394
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	774	0	0	20,000	1,548	30,000	2,321
Total	42,064	3,255	4,004,128	309,828	276,326	21,381	4,322,518	334,464
Cumulative Total	2,473,700	812,977	74,681,708	18,959,203	10,127,457	2,801,778	87,282,865	22,573,959

** Discount Factor:* 0.0773771

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 86 and 90 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	2,804,900	191,827	0	0	2,804,900	191,827
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	702	0	0	3,847	263	14,114	965
Land (Golf Course)	18,694	1,278	3,666	251	0	0	22,360	1,529
Land (National Trust)	3,103	212	0	0	0	0	3,103	212
Land (Car Park)	0	0	612	42	4,479	306	5,091	348
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	684	0	0	20,000	1,368	30,000	2,052
Total	42,064	2,877	2,809,178	192,120	28,326	1,937	2,879,568	196,934
Cumulative Total	2,515,764	815,854	77,490,886	19,151,323	10,155,783	2,803,716	90,162,433	22,770,893

* *Discount Factor:* 0.0683901

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 91 and 95 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	298,000	18,013	5,372,850	324,772	0	0	5,670,850	342,785
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	621	0	0	3,847	233	14,114	853
Land (Golf Course)	18,694	1,130	3,666	222	0	0	22,360	1,352
Land (National Trust)	3,103	188	0	0	0	0	3,103	188
Land (Car Park)	0	0	612	37	4,479	271	5,091	308
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	604	0	0	20,000	1,209	30,000	1,813
Total	340,064	20,556	5,377,128	325,031	28,326	1,712	5,745,518	347,299
Cumulative Total	2,855,828	836,410	82,868,014	19,476,354	10,184,109	2,805,428	95,907,951	23,118,191

** Discount Factor:* 0.0604469

Kelling to Cromer - Do Nothing Scenario

Expected Losses between 96 and 100 Years

	Management Unit MU1 / CU 1		Management Unit RUN 1		Management Unit RUN 2		Total	
	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)	Un-discounted (£)	Discounted* (£)
Properties (South of Cliff)	0	0	3,145,150	168,034	453,350	24,221	3,598,500	192,254
Properties (North of Cliff)	0	0	0	0	0	0	0	0
Land (Agricultural)	10,267	549	0	0	3,847	206	14,114	754
Land (Golf Course)	18,694	999	3,666	196	0	0	22,360	1,195
Land (National Trust)	3,103	166	0	0	0	0	3,103	166
Land (Car Park)	0	0	612	33	4,479	239	5,091	272
Sewerage	0	0	0	0	0	0	0	0
Commercial	0	0	48,000	2,564	1,800,000	96,167	1,848,000	98,732
Nature Conservation	0	0	0	0	0	0	0	0
Caravan Sites	10,000	534	0	0	20,000	1,069	30,000	1,603
Total	42,064	2,247	3,197,428	170,827	2,281,676	121,901	5,521,168	294,975
Cumulative Total	2,897,892	838,657	86,065,442	19,647,180	12,465,785	2,927,329	101,429,119	23,413,167

** Discount Factor:* 0.0534262

HR Wallingford
Working with water

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EX 4985

Kelling to Cromer Strategy Study

Consultation (Issues and Concerns)

Report EX 4985
Release 1.0
November 2006

Document Information

Project	Kelling to Cromer Strategy Study
Report title	Consultation (Issues and Concerns)
Client	North Norfolk District Council
Client Representative	Mr Peter Frew
Project No.	CDR3567
Report No.	EX 4985
Project Manager	Dr Noel Beech
Project Sponsor	Dr Keith Powell

Document History

Date	Release	Prepared	Approved	Authorised	Notes
07/11/06	1.0	PAJL	KAP	KAP	Final

Prepared ____________________

Approved ____________________

Authorised ____________________

Summary

Kelling to Cromer Strategy Study

Consultation (Issues and Concerns)

Report EX 4985
November 2006

This report was prepared in order to describe the process of consultation with both statutory consultees and stakeholders. It describes the methodology used and summarises the responses from consultees.

The initial consultation, being the subject of this report, was carried out in May 2004 with all consultees being sent an explanatory letter, a plan of the study area, a statement of the objectives of the strategy plan and a reply form. The response to the consultation is detailed in this report.

By agreement with North Norfolk District Council, the Final Strategy Report has not been consulted on at this stage, November 2006.

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1. Introduction

1.1 CONSULTATION PHILOSOPHY

The DEFRA Guidance for the Strategic Planning and Appraisal (MAFF 2001) recognises the essential nature of consultation in strategy development. In accordance with this guidance, the two key principles underlying the consultation exercise for the Kelling to Cromer Coastal Defence Strategy Study were openness and access. Thus, the project was undertaken in a transparent manner, with all relevant information available to interested parties.

The two main objectives in undertaking 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 an 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 Shoreline Management Plan (Halcrow 1996) and that associated with the various coastal defence and other types of planning and development initiatives.

By agreement with North Norfolk District Council, the Final Strategy Report has not been consulted on at this stage, November 2006.

1.2 RANGE OF INTERESTS CONSULTED

There are very 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. Potentially interested parties 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
- Other organisations known to members of the consultant's team.

In addition to statutory consultees, those representing the following types of organisations were invited to participate in the consultation process:

- Adjacent local authorities,
- Town, parish and district councils,
- Councillors and elected representatives,
- Conservation organisations,
- Landowners,
- Commercial interests,
- Fisheries and angling, and
- Recreation, leisure and tourism.

A full list of organisations consulted is shown in Table 2.1 below.

2. *Methodology*

The consultation was undertaken by post. Documents sent to selected consultees included an overview of the aims and objectives of the strategy study, and a two-page questionnaire. Consultees were invited to comment on all aspects of the study and to express their concerns and aspirations for any future strategy. The list of consultees was identified in conjunction with North Norfolk District Council and is listed in Tables 2.1. A copy of the documents sent out during the consultation is given in Appendix 1.

Table 2.1 Initial Consultees

Organisation	Contact Person
Crown Estate	.
Government Office for Eastern Region	.
Ministry of Defence	.
Environment Agency	Mr. S. Jeavons
ACAG	Mr. K. Tyrrell
English Nature	Mr. P. Lambley
The National Trust	.
English Heritage	.
CPRE	Dr. I. Shepherd
The Royal Society for the Protection of Birds	.
Norfolk Coast Project	Mr. T. Venes
Norfolk Wildlife Trust	Mr. J. Hisket
The Countryside Agency	Ms. E. Patterson
East of England Tourist Board	Mr. N. Warren
North Norfolk Fishermens Society	Mr. I. Large
NNDC	Cllr. HC Cordeaux
NNDC	Cllr. BJ Hannah
NNDC	Cllr. Mrs. SM Pointer
NNDC	Cllr. Mrs. HT Nelson
NNDC	Cllr. CA Fenn
NNDC	Cllr. JPF Sweeney
NNDC	Cllr. Mrs. MA Craske
Clerk to Weybourne Parish Council	Mrs. G Williamson
Clerk to Upper Sheringham Parish Council	Mrs. P Palmer
Clerk to Beeston Regis Parish Council	Mr. P Bullimore
Clerk to Runtons Parish Council	Mr. V M Howard
Clerk to Sheringham Town Council	Mrs. C Ashton
Cromer Town Council	Mrs. D. Dann

3. *Summary of responses*

Table 3.1 below provides a summary of the responses received from the consultation and the issues emphasised. Each of these responses were reviewed and taken into consideration when later developing the long-term management strategy. If appropriate, consultees were contacted for additional information and recommended leads and contacts were followed up.

Table 3.1 Summary of Consultee Concerns – Initial Consultation

Consultees	Summary of response
Crown Estate	Foreshore leased to NNDC
Government Office for Eastern Region	No reply
Ministry of Defence	Erosion loss at RAF Weybourne. Damage to local habitat. Coastal path passes through MOD land, concerned that erosion does not damage this facility. Seeks improvement for all users and habitats
Environment Agency	No reply
ACAG	No reply
English Nature	Potential disruption to natural processes. Sea defences should not damage the environment. Move towards reinstating a naturally functioning coast. Aspires to sustainable tourism that does not constrain nature conservation.
The National Trust	No reply
English Heritage	Erosion damage to archaeology.
CPRE (Formerly The Norfolk Society)	Balance between the defence of settlements and the natural environment. Off-shore dredging. Climate change impact. Visitor pressure on the environment.
The Royal Society for the Protection of Birds	No reply
Norfolk Coast Project	No reply
Norfolk Wildlife Trust	No reply
The Countryside Agency	No reply
East of England Tourist Board	Continuing protection of tourist sites. Coastal defences should not inhibit tourism business.
North Norfolk Fishermens Society	No reply
NNDC Cllr. HC Cordeaux	No reply
NNDC Cllr. BJ Hannah	No reply
NNDC Cllr. Mrs. SM Pointer	No reply
NNDC Cllr. Mrs. HT Nelson	No reply
NNDC Cllr. CA Fenn	No reply
NNDC Cllr. JPF Sweeney	No reply
NNDC Cllr. Mrs. MA Craske	No reply
NNDC Mr. P. Frew	No reply
Clerk to Weybourne Parish Council	Existing beach in bad shape. Wish to have a secondary bank.
Clerk to Upper Sheringham Parish Council	No reply
Clerk to Beeston Regis Parish Council	No reply
Clerk to Runtons Parish Council	No reply
Clerk to Sheringham Town Council	Outflanking of the town's defences is a concern. Maintain/improve natural environment. Defences to enhance tourism activity.
Cromer Town Council	No reply

4. References

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 & the National Rivers Authority.

DEFRA 2001 Flood and Coastal Defence Project Appraisal Guidance: Strategic Planning and Appraisal. (FCDPAG2).

Appendices

Appendix 1 Documents sent out during consultation

«Title» «First_Name» «Last_Name»
«Department»
«Company_Name»
«Address»
«City»
«StateProvince»
«PostalCode»

Your reference
Our reference

Dear Sir or Madam

Kelling to Cromer Coastal Strategic Studies

You may recall that North Norfolk District Council (NNDC) completed Shoreline Management Plans (SMP) for its coastline some years ago. Two Shoreline Management Plans were adopted by the Council, one covering the coast from Snettisham to Sheringham, the other from Sheringham to Lowestoft. The next stage in the shoreline planning process is to develop a series of Coastal Strategy Plans; each covering just a portion of the coastline contained in the SMP but in more detail.

In association with HR Wallingford, I have been commissioned by NNDC to complete a study for the Kelling to Cromer frontage (plan enclosed). This study will consider wave and tidal processes, sediment transport, the condition and performance of the existing coastal defences and how they interact with the human and natural environment. The study will go on to identify the most appropriate future method of managing this stretch of coastline and where appropriate protecting land from erosion and environmental degradation in so far as it affects or is affected by shoreline management. Where possible, opportunities to enhance the local amenity and natural environment through improved shoreline management will be explored.

On the reverse of the location plan, you will find the main objectives in developing a Coastal Strategy Plan, as set out by the Department for Environment, Food and Rural Affairs (DEFRA).

We can only achieve all of the objectives if we are fully aware of the needs and concerns of all interested parties. However, our understanding can only be as detailed as the information we receive from you. I have attached a form that highlights a range of issues that may be of concern. Please complete this form and send it back to me at the above address, if possible by 3rd June 2004. If you have any difficulty in responding by this date or wish to clarify any particular points, please feel free to contact me directly. If I have left insufficient room for your comments also feel free to expand on as many additional sheets as necessary. Responses will then be compiled and, where necessary, further information will be sought to ensure that we fully understand the interests and issues.

At this stage, I only wish to make you aware of the development of the Strategy Plan for Kelling to Cromer and to collate your initial thoughts, comments and relevant information. As the project proceeds, interested parties will be kept informed of the plans and there will be another round of consultation.

I look forward to receiving your comments.

Yours faithfully

Peter A.J. Lawton

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: ______________________________

Principal Contact: ______________________________

Job Title (if appropriate)______________________________

Telephone: ______________ Facsimile: ______________

Email: ______________________

1. Areas of Interest

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence)

3. Concerns regarding sea defence

4. Concerns regarding erosion

5. Concerns regarding the natural environment

6.	Aspirations for enhancement of the natural environment
7.	Aspirations for improved recreation / tourism
9.	Future development aspirations
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact)
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)?
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list.
13.	Any other comments

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

Kelling to Cromer Coastal Strategic Study

The main objectives in developing a Coastal Strategy Plan, as set out by the Department for Environment, Food and Rural Affairs (DEFRA), are as follows:

- To develop a Strategy Plan that builds on the coastal policies established through the Shoreline Management Plan.
- To improve the understanding of the coastal processes and predict the likely future evolution of the coast.
- To identify all the natural and manmade assets within the area which are likely to be influenced by coastal processes.
- To identify an optimal approach to shoreline management and coast defence based on an integration of economic constraints, engineering and environmental issues.
- To develop a phased programme of sustainable works and maintenance for each of the discrete coastal frontages identified in the SMP.
- To develop an understanding of the likely extent of potential flooding both now and in the future.
- To develop an understanding of the environmental sensitivities and to enhance the environment (both human and natural). If necessary, effective mitigation measures against environmental degradation arising from proposed shoreline management activities will be identified.
- To take advantage of appropriate opportunities to improve recreation, agriculture and commercial activities.
- To ensure effective consultation and reflect, in the strategy, the views of all interested parties as expressed through the sensitive development of preferred options.
- To establish a programme of monitoring and a method of review for the adopted strategy.
- To report the findings of the study as a detailed non-statutory plan (the Coastal Strategy Plan) for managing the coastline. This will then form the basis for the development of capital schemes (where appropriate) and the implementation of management plans. (It is worth noting that this document will be subject to revision based on developments in the understanding of coastal processes and on unforeseen changes to the demands in the coastal zone).

Kelling to Cromer
Coastal Strategic Study

Extent of Study

Appendix 2 Consultation Responses

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: The Crown Estate

Principal Contact: Jacqueline Gray

Job Title (if appropriate) Deputy Coastal Manager

Telephone: 020 7210 4321 Facsimile: 020 7839 7847

Email: Jacqueline.gray@thecrownestate.co.uk

1. Areas of Interest

Landowner of foreshore + seabed

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence)

3. Concerns regarding sea defence

4. Concerns regarding erosion

5. Concerns regarding the natural environment

6. Concerns regarding recreation use of the coastal zone

7.	Aspirations for enhancement of the natural environment
8.	Aspirations for improved recreation / tourism
9.	Future development aspirations
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact)
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)?
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list. No.
13.	Any other comments Foreshore is leased to North Norfolk District Council in parts

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

We Just ask that we are kept informed of progress

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: DEFENCE ESTATES.

Principal Contact: DAVID TYE

Job Title (if appropriate) ESTATE SURVEYOR

Telephone: 01223 - 255416 Facsimile: 01223-255406

Email: david.tye@de.mod.uk

1. Areas of Interest
RAF WEYBOURNE

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence)
Nature Conservation
Coastal Erosion.

3. Concerns regarding sea defence
MoD owns land which fronts the sea at Weybourne. Over the years much has been lost to the sea due to rising levels & erosion

4. Concerns regarding erosion

5. Concerns regarding the natural environment
Rising sea levels & coastal erosion are causing land to be lost to the sea & therefore also habitats of the local flora & fauna.

6. Concerns regarding recreation use of the coastal zone
North Norfolk coastal path & Peddars way pass directly through MoD land. It is hoped that the users & MoD can live in harmony without causing damage to either enjoyment of the land.

DEFENCE ESTATES

7.	Aspirations for enhancement of the natural environment It is hoped that any coastal works will improve the area for all users & residents (human/animal etc.)
8.	Aspirations for improved recreation / tourism
9.	Future development aspirations
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact)
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)?
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list.
13.	Any other comments

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: ENGLISH NATURE

Principal Contact: PETER LAMBLEY

Job Title (if appropriate) LEAD CONSERVATION OFFICER

Telephone: 01603 598417 Facsimile: 01603 762552

Email: peter.lambley@english-nature.org.uk

1. Areas of Interest
NATURE CONSERVATION (INCLUDING GEOLOGICAL INTERESTS)

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence)
NATURE CONSERVATION

3. Concerns regarding sea defence
POTENTIAL TO DISRUPT NATURAL PROCESSES.

4. Concerns regarding erosion
NONE SPECIFICALLY FOR GEOLOGICAL SITES. IT MAY MEAN CHANGE OF TYPE OF EXPOSURE BUT THIS IS NOT A CONCERN

5. Concerns regarding the natural environment
NEED TO ENSURE THAT ANY ESSENTIAL SEA DEFENCES DAMAGE THE ENVIRONMENT AS LITTLE AS POSSIBLE

6. Concerns regarding recreation use of the coastal zone
ALONG THIS STRETCH RELATIVELY FEW CONCERNS THOUGH NEED TO BE AWARE OF THE IMPORTANCE OF THE ROCKY SHORE AT WEST RUNTON AND THE NEED NOT TO PUT UNDUE PRESSURE ON THIS STRETCH. THIS AREA IS HEAVILY USED BY SCHOOL PARTIES ON FIELDWORK.

ENGLISH NATURE

7.	Aspirations for enhancement of the natural environment THAT WE SHOULD BE MOVING TOWARDS REINSTATING A NATURALY FUNCTIONING COASTLINE
8.	Aspirations for improved recreation / tourism SUSTAINABLE TOURISM WHICH DOES NOT DAMAGE OR CONSTRAIN NATURE CONSERVATION INTERESTS
9.	Future development aspirations —
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact) —
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)? AERIAL PHOTOS INC LUFFTWAFFE SERIES INFORMATION HELD AT UEA (KEITH CLAYTON ET AL)
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list. PROBABLY NOT DIRECTLY RELEVANT BUT VEGETATION SURVEY OF OVERSTRAND CLIFFS (JUST OUTSIDE AREA)
13.	Any other comments

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: ENGLISH HERITAGE

Principal Contact: PETER MURPHY

Job Title (if appropriate) REGIONAL ADVISOR FOR ARCHAEOLOGICAL SCIENCE

Telephone: 07775 920956 01223 582759 Facsimile: 01223 582701

Email: peter.murphy@english-heritage.org.uk

1. Areas of Interest
HISTORIC ENVIRONMENT.

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence)
BURIED ARCHAEOLOGY, STANDING HISTORIC BUILDINGS AND OTHER STRUCTURES; HISTORIC SHIPWRECKS.

3. Concerns regarding sea defence
PRINCIPALLY, CONCERN THAT GROUNDWORKS MAY DAMAGE OR DESTROY ARCHAEOLOGICAL DEPOSITS AND/OR AFFECT BUILDINGS, ETC.

4. Concerns regarding erosion
LOSS OF DEPOSITS AND STRUCTURES.

5. Concerns regarding the natural environment
NO DIRECT CONCERN

6. Concerns regarding recreation use of the coastal zone
LOSS OF PUBLIC ENJOYMENT OF HISTORIC ASSETS.

ENGLISH HERITAGE

7.	Aspirations for enhancement of the natural environment N/A
8.	Aspirations for improved recreation / tourism IN GENERAL, ENGLISH HERITAGE SEEKS TO ENHANCE APPRECIATION AND ENJOYMENT OF THE HISTORIC ENVIRONMENT.
9.	Future development aspirations NO SPECIFIC DEVELOPMENT PROPOSALS FOR THIS AREA.
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact) UNDERLINED ISSUES ALL RELEVANT.
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)? "COASTAL DEFENCE AND THE HISTORIC ENVIRONMENT ENGLISH HERITAGE GUIDANCE" MAY, 2003. AVAILABLE AS A PDF ON THE ENGLISH HERITAGE WEBSITE > POLICY > COASTAL POLICY.
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list. NATIONAL MAPPING PROGRAMME – A DIGITISED DATABASE OF ARCHAEOLOGICAL SITES ETC IS NOW AVAILABLE FOR NORFOLK COAST. CONTACT SARAH MASSEY, NORFOLK LANDSCAPE ARCHAEOLOGY (01 362 869280 or
13.	Any other comments

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

sarah.massey.mus@norfolk.gov.uk

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: CPRE NORFOLK
Principal Contact: IAN SHEPHERD.
Job Title (if appropriate) POLICY CO-ORDINATOR.
Telephone: home 01263-713370 Facsimile:
Email: home Andianshep@aol.com.

1. Areas of Interest AS MISSION STATEMENT ON ATTACHED SLIP !

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence) WE HAVE A WIDE-RANGING INTEREST ON ALL ISSUES RELATING TO THE COUNTRYSIDE — IN NORFOLK THIS INCLUDES WHAT HAPPENS AROUND OUR COAST.

3. Concerns regarding sea defence WE ACCEPT THAT SEA DEFENCE HAS TO WORK WITH NATURAL PROCESSES, NOT AGAINST; BUT HOW BEST TO RETAIN DEFENCES FOR MAJOR SETTLEMENTS SUCH AS CROMER; HOW TO RETAIN/CREATE ELSEWHERE VALUABLE HABITATS, eg. SALT MARSHES, FRESH-WATER GRAZING MARSH

4. Concerns regarding erosion WHETHER OFF-SHORE DREDGING ACCELERATES NATURAL COASTAL EROSION PROCESSES.

5. Concerns regarding the natural environment AS ABOVE: HOW BEST TO WORK WITHIN COASTAL SEDIMENT FLOW PROCESSES, AND CHANGES CONSEQUENT FROM CLIMATE CHANGE

6. Concerns regarding recreation use of the coastal zone NORTH NORFOLK COAST, LANDSCAPE & WILDLIFE IS UNDER PRESSURE FROM "TOO MANY PEOPLE"; WEIGHT OF NUMBERS, DOGS DISTURBING WILDLIFE DUE TO "UNAWARE" OWNERS, ETC. PLUS SPECIFICS WHICH DISTURB TRANQUILLITY (AND OFTEN WILDLIFE), SUCH AS JET SKIS,

CPRE

7. Aspirations for enhancement of the natural environment

MORE SCHEMES SUCH AS BETWEEN WEYBOURNE & S'HAM GOLF COURSE – REVERSION FROM ARABLE TO GRASSLAND, HUGE BOOST TO NESTING SKYLARKS; ALTHOUGH OUTSIDE STUDY AREA, CREATION OF WETLAND HABITAT SUCH AS AT STIFFKEY FEN.

8. Aspirations for improved recreation / tourism

THE NORFOLK COAST PARTNERSHIP HAVE WORKED HARD ON THIS OVER THE YEARS WITH SOME SUCCESS – BUT UPHILL BATTLE AGAINST CONTINUOUS INCREASE IN NUMBER OF VISITORS.

9. Future development aspirations

CENTRES ON REPLACEMENT LANDSCAPES AND HABITATS IN FACE OF NATURAL & CLIMATE CHANGE.

10. Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact)

THERE ARE A NUMBER OF ISSUES WHICH SHOULD CONSTRAIN DEVELOPMENT; ONE IS WATER RESOURCE.

11. Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)?

INTERACTIONS BETWEEN ACTIVITIES OF MAN & NATURAL CHANGES. IN PAST, BUILDING OF SEA WALLS FOR LAND RECLAMATION; FOR PRESENT, OFF-SHORE DREDGING AS EXAMPLES.

12. Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list.

FURTHER STUDIES ON TRANSPORT OF SEDIMENT, WHICH YOU WILL BE WELL AWARE OF.

13. Any other comments

WELCOME THE STUDY.

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email. pajl@paston.co.uk

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: East of England Tourist Board

Principal Contact: Mike Dowdall

Job Title (if appropriate): Business Development Manager

Telephone: 01473 825610   Facsimile: 01473 823063

Email: mdowdall@eetb.org.uk

1. Areas of Interest

Tourism

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence)

Tourism

3. Concerns regarding sea defence

To be assured that key tourist sites are protected and that proposed sea defences do not inhibit tourism businesses.

4. Concerns regarding erosion

Commercial viability for existing operators

5. Concerns regarding the natural environment

6. Concerns regarding recreation use of the coastal zone

This stretch of the coastline is very important in terms of visitor attractions and accommodation provision.

EAST ENGLAND TOURIST BOARD

7.	Aspirations for enhancement of the natural environment
8.	Aspirations for improved recreation / tourism Major public investment is going into the area to improve its visitor "offer". We hope that the volume and value of the local tourism economy can be maintained at the very least
9.	Future development aspirations
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact) The risk of "tourist hotspots" where erosion is accellerated being closed to the public for certain times of the year.
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)?
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list.
13.	Any other comments

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: Weybourne Parish Council.

Principal Contact: Malcolm Felmingham.

Job Title (if appropriate) Chairman.

Telephone: 01263 588 300 Facsimile:

Email: Malcolm_felmingham@onetel.net

1. Areas of Interest

Weybourne Beach.

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence)

Coastal Defence.

3. Concerns regarding sea defence

erosion of bank.. over many years. well over due for large storm

4. Concerns regarding erosion

the existing bank is in bad shape and cannot prevent a storm breach of the Bank.

5. Concerns regarding the natural environment

No Concerns.

6. Concerns regarding recreation use of the coastal zone

No concerns

WEYBOURNE
PARISH COUNCIL

7.	Aspirations for enhancement of the natural environment —	
8.	Aspirations for improved recreation / tourism —	
9.	Future development aspirations For a secondary Bank making the primary bank a sacrificial.	
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact) —	
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)? In 1953 the storm water reached the Village Hall in Beach road.	
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list. NNDC Survey and recommendation for a second Bank	
13.	Any other comments That the secondary bank defence is built soon!	

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

Kelling to Cromer Coastal Strategic Study
May 2004
Initial Consultation Reply Form
(Please expand if necessary)

Organisation: SHERINGHAM TOWN COUNCIL.

Principal Contact: CHERRY ASHTON

Job Title (if appropriate) TOWN CLERK

Telephone: 01263 822213 Facsimile: 01263 822213

Email: CLERK@SHERCOUNCIL.GO-PLUS.NET

1. Areas of Interest SHERINGHAM (AREA OF RUN 1)

2. Subjects/ Activities of interest (e.g. historic, archaeology, nature conservation, recreation, coastal defence) COASTAL DEFENCE
EROSION
HISTORIC
RECREATION

3. Concerns regarding sea defence
THE SEA WALLS AT SHERINGHAM WERE REBUILT WITHIN THE LAST TEN YEARS AND APPEAR TO PROVIDE ADEQUATE PROTECTION THE ROCK ARMOUR GROYNES, ALTHOUGH UNSITELY, APPEAR TO BE DOING THEIR JOB.

4. Concerns regarding erosion
THE LONG TERM CONCERN IS THAT WITHOUT PROTECTION EITHER SIDE OF SHERINGHAM THAT THE TOWN WILL EVENTUALLY PROJECT INTO THE SEA AND ITS DEFENCES WILL RECEIVE MORE WAVE ACTION.

5. Concerns regarding the natural environment
AS A LARGE PART OF THE SURROUNDING AREA IS AN AREA OF OUTSTANDING NATURAL BEAUTY ANY LOSS OR ALTERATION WILL BE A SEVERE ECOLOGICAL BLOW.

6. Concerns regarding recreation use of the coastal zone
AS AN AREA NOTED FOR ITS CLIFF TOP WALKS AND GOLF COURSE AMONGST VISITORS ANY LOSS WOULD AFFECT THE ECONOMIC BALANCE OF THE AREA.

SHERINGHAM TOWN COUNCIL

7.	Aspirations for enhancement of the natural environment IN THE LONG TERM A SIGNIFICANT PART COULD BE LOST TO EROSION IF ADEQUATE MEASURES OF PREVENTION ARE NOT TAKEN.
8.	Aspirations for improved recreation / tourism THE AREA IS CURRENTLY WELL-BALANCED AND ANY FUTURE INTRODUCTION OF ACTIVITIES SHOULD SEEK TO ENHANCE, NOT DISRUPT, THE BALANCE
9.	Future development aspirations THERE NEEDS TO BE A LIMITATION ON HOUSE BUILDING AS A MUCH HIGHER POPULATION WOULD UPSET THE ECOLOGICAL BALANCE OF THE AREA
10.	Particular issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact) AREA OF OUTSTANDING NATURAL BEAUTY PROTECTED ENVIRONMENT FOR WILD LIFE RISK OF EROSION.
11.	Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs of flooding / erosion)? REPORT OF NORTH NORFOLK COASTAL ADVISORY MEETING HELD AT WELLS ON 20TH MAY 2004
12.	Are you aware of any studies undertaken since the completion of the Shoreline Management Plan that you think may be relevant? Please list.
13.	Any other comments

If you wish to discuss the development of the Strategy Plan further, please contact Peter Lawton on 01263 577322 or by email, pajl@paston.co.uk

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Working with water

EX 4985

Kelling to Cromer Strategy Study
Environmental Review

Report EX 4985
Release 2.0
November 2006

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Project Sponsor	Mr Paul Sayers

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Summary

Kelling to Cromer

Environmental Review

Report EX 4985
November 2006

The coastal dynamics along the study frontage are of particular interest in terms of maintaining the exposure of the cliffs and providing a sediment supply along the coast. However, the threat that these dynamics pose to the environment through continuing and sometimes rapid erosion is crucial.

Four sections of cliff within the frontage have been designated as Sites of Special Scientific Interest. Any works carried out along the seafront at Sheringham or the gaps at East Runton and West Runton would potentially affect these sites.

The geology of the coastal cliffs in North Norfolk has an intrinsic value in contributing to the understanding of 'Earth heritage.' The dynamic nature of the soft cliffs results in the creation of a varied flora and fauna, including specialised species that depend on disturbance of the ground to survive. Many of the cliffs along the coastline form important habitats for wildlife, including rare invertebrates and plant communities.

In terms of tourism, the area from Sheringham to Cromer grew in importance in the late 18th century. The town of Sheringham and the villages of East Runton, West Runton and Weybourne still depend on tourism for a substantial part of their income. As the character of the town of Sheringham particularly depends upon its seafront, any coastal defence schemes need to reflect this interrelationship. In addition, the safety of the large number of people that visit the beach and seafront in this region must be taken into consideration when designing any coastal defences. This report therefore presents an assessment of the Environmental issues of this frontage.

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1. Introduction

1.1 BACKGROUND

This report provides an overview of the environmental value of the Kelling to Cromer study area and forms part of a series of reports that comprise the Kelling to Cromer Strategy Study to include various national and international designations. It also includes a brief review of tourism and recreational activities in the area as well as its geology, flora, and fauna.

This report was drafted in 2005 and updated in respect of the inclusion of the Overstrand Cliffs SAC for the current issue.

1.2 OUTLINE OF THE REPORT

The structure of the report is as follows:

- Section 2 presents the environmental designations, with discussion of Special Areas of Conservation, Sites of Special Scientific Interest (SSSI), County Wildlife Sites, and an Area of Outstanding Natural Beauty (AONB).
- Section 3 discusses the geology of the region and details the flora and fauna typical in the study area.
- Section 4 provides discussion of the historical environment and issues related to tourism and recreation.

2. Environmental designations

Various environmental designations have been assigned to land within the limits of the strategy study. Figures 2.1, 2.2 and 2.3 at the end of this section provide details of the boundaries of the assigned designations. Information pertinent to the individual designations is given below and in the appendices where appropriate.

2.1 SITES OF SPECIAL SCIENTIFIC INTEREST (SSSI), SPECIAL AREA OF CONSERVATION (SAC), AND COASTAL HABITAT MANAGEMENT PLAN (CHAMP)

Under Section 28 of the Wildlife and Countryside Act 1981, sections of cliff at Beeston (east of Sheringham), Weybourne, West Runton and East Runton have been designated as Sites of Special Scientific Interest (SSSI). These designations reflect, in part, the interesting geology of the cliffs, which are largely of glacial origin.

All the sites lie within the frontage covered in this report. Any works carried out along the seafront at Sheringham have the potential to influence all of the SSSI along the study frontage.

The reasons for designation of the SSSIs, as provided by English Nature, are briefly summarised below. Further description of these three sites, with more details on their biological and geological attributes, is provided in Appendices A and B to this report.

2.1.1 *Weybourne Cliffs SSSI*

The cliffs east of Weybourne afford the best Pleistocene sections (Plate 2.1), showing the pre-Cromerian deposits of the Cromer Forest bed. The Pastonian 'Weybourne Crag', here at its type locality, with its marine molluscs, has been known since the early days of geology. This is a historic site with outstanding Pleistocene sections of national importance. The marine "crags" here have yielded both large and small mammal remains, of Pastonian and probably also pre-Pastonian age. Little has been published on these important fossils and the site remains one with considerable potential for future vertebrate finds. Additionally, biological interest is provided by colonies of sand martins in the cliff-face and of fulmars (73 pairs in 1982) on the cliff ledges.

The cliffs extend for a distance of 4.1km reaching heights of 20+ metres. The hinterland is predominately agricultural, but of important amenity value, and largely owned by the National Trust. The eastern extremity of the SSSI fronts Sheringham Golf Club which is, again, an important amenity asset.

Plate 2.1 Cliffs East of Weybourne

2.1.2 Beeston Cliffs SSSI

This is the type site for the Beestonian Stage of the Pleistocene. The cliffs provide sections in both marine and freshwater pre-Pastonian and Pastonian, Beestonian and Cromerian sediments. The Beestonian is especially well-developed, with freshwater fluviatile and pool deposits, and marine beach gravels and sands. Pollen spectra have been obtained from many horizons throughout this varied sequence, recording the pattern of vegetational changes that occurred as the sediments were being deposited. This is a nationally important Pleistocene reference site.

The SSSI frontage extends for a relatively modest distance of 430 metres, the cliffs reaching a height of 64 metres. English Nature's latest assessment done in June 2003, showed its condition to be unfavourable and declining.

2.1.3 West Runton Cliffs SSSI

The cliff and foreshore section at West Runton (Plate 2.2) is one of the most important Pleistocene localities in the British Isles. The sediments exposed in the eroding cliffs provide evidence for the repeated fluctuations in climate during the ice ages, with two temperate stages and three cold stages being represented. The sequence records several major advances and retreats of the sea, represented by alterations of marine and non-marine sediments. These beds include the famous West Runton freshwater bed that was laid down during earlier temperate climate phases and which has yielded many fossil animals. The glacial elements at the top of the cliff section show structures typical of deposition by ice and have also yielded the fossil remains of a woolly elephant. (The West Runton Elephant)

2.1.4 East Runton Cliffs SSSI

The foreshore at East Runton exposes pre-Cromerian (Lower Pleistocene) sediments, including successively 'Weybourne Crag', Pastonian clay conglomerate and marine shell beds, overlain in turn by marine silts (Pa II pollen zone). In the cliff can be seen spectacular rafts of chalk (Plate 2.3) of glacitectonic origin (i.e. ice transported) and highly deformed 'Contorted Drift'. The marine Lower Pleistocene deposits, here of pre-

Pastonian and probable Pastonian age, contain an extensive vertebrate fauna which includes marine fish, voles, carnivores, extinct horse, rhinoceros, and elephant, and (notably) several species of 'comb-antlered' deer, Euctenoceras. This is the best available locality for fossil vertebrates of this age.

Plate 2.2 West Runton Foreshore and cliffs

Plate 2.3 Raft of chalk (East Runton cliffs)

2.1.5 Norfolk Coast SAC and CHaMP

The North Norfolk Coast SAC (EU code UK0030232) embraces the coastal habitat to the west of Kelling Quag, immediately to the west of the study area, with its eastern boundary at Kelling Hard. The general site character is made up of tidal rivers, estuaries, mud flats, sand flats, lagoons, sand dunes, beaches, machair, shingle, sea cliffs, islets, bogs marshes water fringed vegetation, fens, and improved grassland.

This SAC is a complex site incorporating Special Protection Area, SSSI and RAMSAR designations. It is of international environmental importance and is, correspondingly, of enormous value to the local economy. The area is also the subject of a Coastal Habitat Management Plan (CHaMP) that extends from Snettisham to Sheringham. However, the CHaMP deals only with Natura 2000 and RAMSAR designated features and does not consider all of the nature conservation interests within the area of the plan.

2.1.6 Overstrand Cliffs SAC

Overstrand Cliffs (EU code UK0030232) are one of the UKs best examples of vegetated soft cliffs on the North Sea coast, being unprotected and up to 70m high. The designated area covers the shoreline between Cromer and Overstrand, and is thought unlikely to be affected by any management decisions undertaken within the study frontage.

2.1.7 Operations likely to damage SSSIs

As shown in Table 2.1, multiple operations have been highlighted by English Nature (2002) as potentially damaging to the above SSSIs (i.e. Potential Damaging Operations, or PDOs) and SACs. In addition to providing summary material concerning the above sites, Table 2.2 lists the specific PDOs relevant to each site.

Table 2.1 Potentially Damaging Operations for North Norfolk SSSIs and SAC (English Nature 2002)

Standard Ref. No.	Type of Operation
1	Cultivation, including ploughing, rotovating, harrowing, and re-seeding.
4	Changes in the mowing or cutting regime (including hay making to silage and cessation).
5	Application of manure, fertilisers and lime.
6	Application of pesticides, including herbicides (weedkillers).
7	Dumping, spreading, or discharge of any materials.
8	Burning.
9	The release into the site of any wild, feral, or domestic animal*, plant, or seed.
10	The killing or removal of any wild animal*, including pest control.
11	The destruction, displacement, removal, or cutting of any plant or plant remains, including tree, shrub, herb, dead or decaying wood, moss, lichen, fungus, or turf.
12	The introduction of tree and/or woodland management (including planting, clear and selective felling, thinning, coppicing, changes in species composition).
13a	Drainage (including gripping and the use of mole, tile, tunnel, or artificial drains).
13b	Modification of the structure of springs, as by realignment.
15	Infilling of pools, marshes, or pits.
17	Reclamation of land from sea, estuary, or marsh.

Standard Ref. No.	Type of Operation
19	Erection of sea defences or coast protection works, including cliff or landslip drainage or stabilisation measures.
20	Extraction of minerals, including sand and gravel, topsoil, subsoil, chalk, shells, and spoil.
21	Construction, removal, or destruction of roads, tracks, walls, fences, hardstands, bank, ditches, or other earthworks, or the laying, maintenance, or removal of pipelines and cables, above or below ground.
22	Storage of materials.
23	Erection of permanent or temporary structures, or the undertaking of engineering works, including drilling.
24	Modification of natural or man-made features including battering, buttressing, or grading faces and infilling of pits.
26	Use of vehicles or craft likely to damage or disturb features of interest.
27	Recreational or other activities likely to damage features of interest.

* The term ‘animal’ includes any mammal, reptile, amphibian, bird, fish, or invertebrate.

Table 2.2 Description of SSSIs and SAC

Area	Description of feature / attribute	Scale of importance	Substitutable	Rarity	Nature conservation value	Potentially damaging operations
Weybourne Cliffs	Biological features: Colonies of sand martins and fulmars Geological features: Type locality for Weybourne Crag. Pleistocene sections of national importance	National	No	Unique	High	7, 17, 19, 21, 22, 23, 24.
Beeston Cliffs SSSI	Biological features: Rare plant life. Geological features: Type locality for the Beestonian stage of the Pleistocene.	National	No	Unique	Very high	1 – 12, 17, 19 – 24, 26 – 28.
West Runton Cliffs SSSI	Biological features: Typical North Norfolk Cliff habitat. Geological features: One of the most important Pleistocene localities in the UK	National	No	Unique	Moderate	7, 17, 19, 21, 22, 23, 24.
East Runton Cliffs SSSI	Biological features: Typical North Norfolk Cliff habitat. Geological features: Pre Cromerian sediments. Spectacular rafts of chalk of glacitectonic origin in the cliffs. Fossil vertebrates	Local	No	Important	Moderate	7, 17, 19, 21, 22, 23, 24.

2.2 COUNTY WILDLIFE SITES

The area studied in this strategy encompasses three County Wildlife Sites. These designations reflect the interesting flora and fauna living on foreshore, cliff, and cliff-top land.

2.2.1 Kelling Hard County Wildlife Site

This 2.6 hectare site comprises a mosaic of unimproved, slightly calcareous and neutral grassland, common reed and marshy grassland. A coastal influence is evident in all communities, although particularly noticeable in a short, sparse sward present where topsoil has been removed. It once formed part of the disused Weybourne Military Camp, and it lies immediately inland from the shingle sea defences.

2.2.2 Beach Lane County Wildlife Site

This site of 1.9 hectares is predominantly an area of reed bed occupying a shallow silty pool situated just inland from the shingle sea defences at Weybourne Hope. The pool is brackish towards the north, but is fed by a small freshwater stream entering from the east.

2.2.3 Cromer Sea Front County Wildlife Site

This site, of 39 hectares, comprises the coastal cliffs, beach and intertidal zone between East Runton Cliffs SSSI to the west and Overstrand Cliffs SSSI to the east. The cliffs rise from 20 metres at Cromer pier to 30 metres at either end of the side. This change is accompanied by a decreasing influence of development and lower visitor pressure, although the entire sea front and beach are well used by the general public. Semi-natural vegetation is confined to the cliff faces that are predominately populated with a range of grasses, scattered throughout are patches of flora that are species rich.

2.3 AREA OF OUTSTANDING NATURAL BEAUTY (AONB) AND HERITAGE COAST

Much of the coastline and immediate hinterland of North Norfolk, stretching from Mundesley to Heacham, forms the major part of the Norfolk Coast AONB. However, the town of Sheringham and the cliff top hinterland between Sheringham and Cromer are not included in this designation, and the objectives and policies of the AONB need not be applied to the management of these sections of coastline and its defences. Whilst Sheringham to Cromer is not included in the designation, the preservation and enhancement of the coastline and coastal land elsewhere is of importance. Plots of the limits of the AONB are provided in Appendix C as well as the AONB Management Strategy document (published March 2004). This strategy is the first AONB Management Plan for the Norfolk Coast under Part IV of the Countryside and Rights of Way (CRoW) Act 2000.

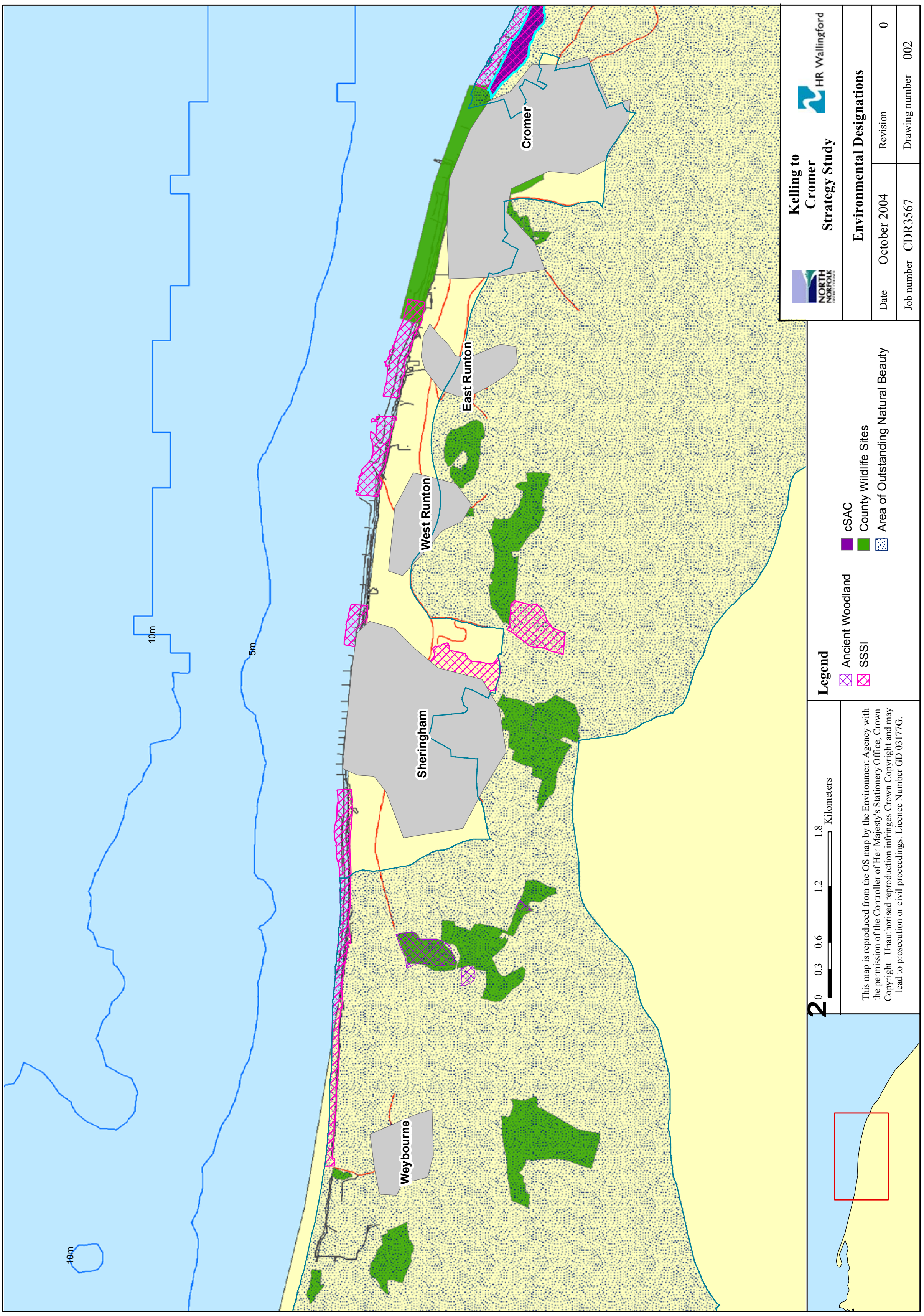


Figure 2.1 Environmental designations along the North Norfolk coast

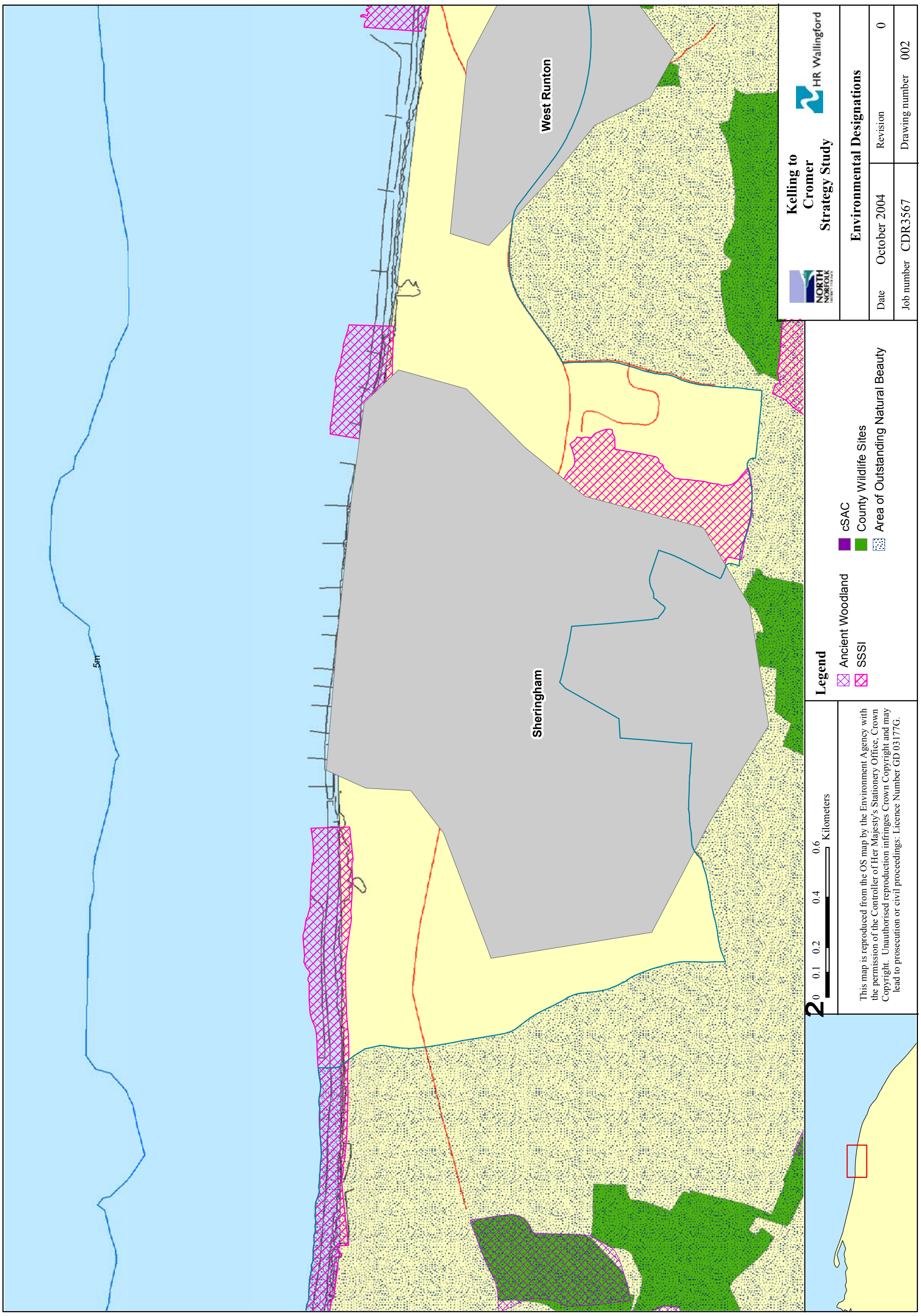


Figure 2.2 Environmental designations along the North Norfolk coast

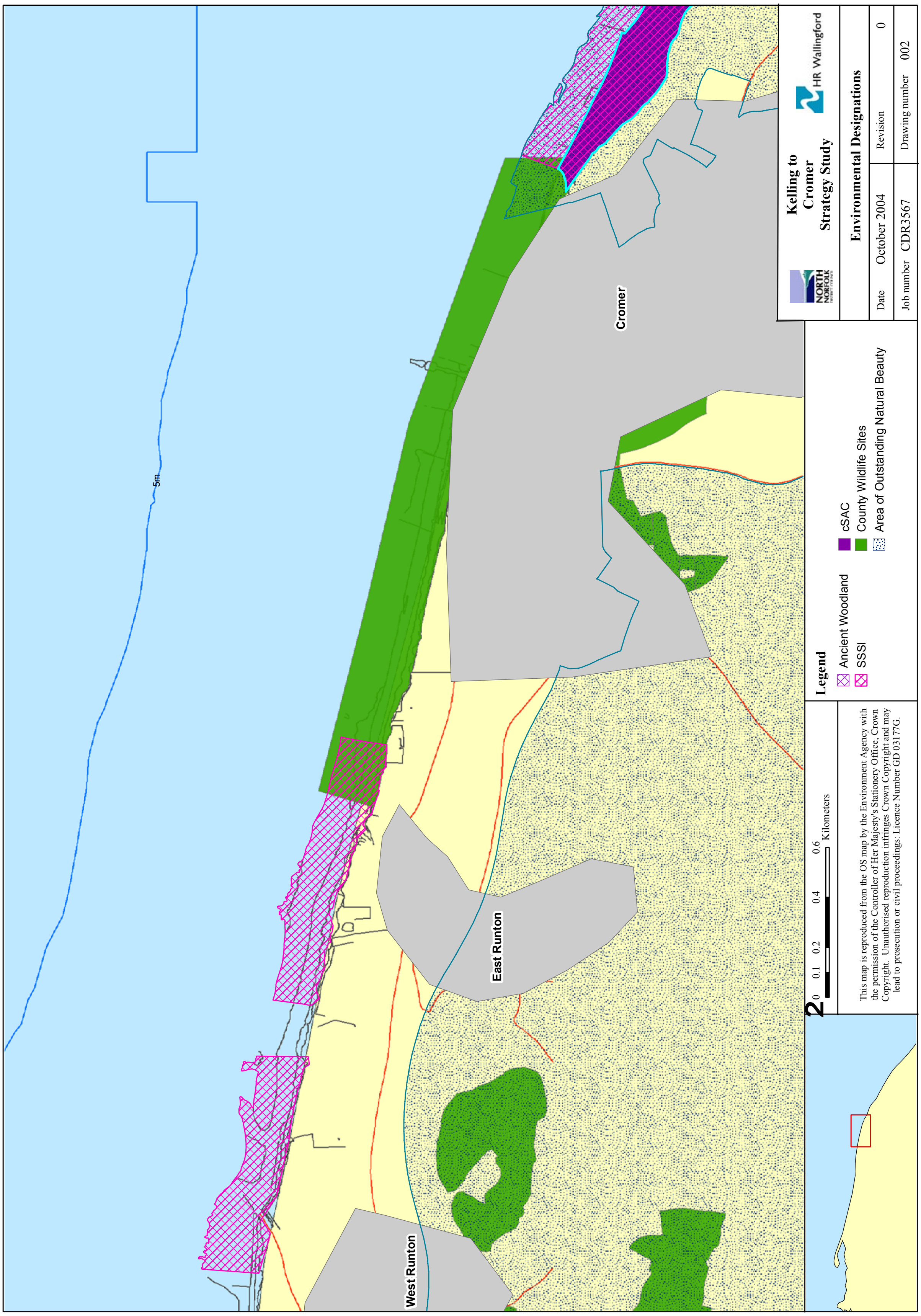


Figure 2.3 Environmental designations along the North Norfolk coast

3. Geology, flora and fauna

The geology of the coastline (above and below the high tide level) is important in this study because it:

- influences past and future shoreline changes both locally and along adjacent stretches of coastline;
- affects the character of the seabed, beaches, and the cliff top land and their use; and
- influences the choice, performance, and longevity of coastal defence structures.

In addition, the geology of the coastal cliffs in North Norfolk has an intrinsic value in contributing to the understanding of 'earth science' (i.e. geological processes and evolution, not just locally, but on a broader scale, both nationally and internationally). This aspect is referred to by DEFRA (2001) as 'Earth heritage.' Finally, the dynamic nature of the soft cliffs, which if unprotected are subject to occasional large-scale slumping or landslides, results in the creation of a varied flora and fauna. This includes specialised species that depend on disturbance of the ground to survive.

Various previous reports have described the geological character and evolution of the cliffs. In this study, the University of Newcastle was commissioned to undertake a site-specific study of the cliffs along this frontage, the results of which are presented in the accompanying Cliff Processes report. However, some discussion of the particular flora and fauna present on the cliffs is also given here.

3.1 CLIFF STABILISATION, SEDIMENT YIELD, AND CONSERVATION

Because of the development of the region as seaside resorts, considerable efforts have been made over the last 200 years to stabilise the cliffs, hence allowing the building of commercial and residential properties on the cliff top. In urban areas, there is a natural desire to maintain these assets, and this is reflected in the coastal defence policy for Sheringham as set out in the Shoreline Management Plan (Halcrow 1996). This plan envisages 'holding the line' of the present coastal defences at Sheringham. ('Hold the line' equates to keeping the defences approximately at about their present location and hence, in combination with drainage and other slope stabilisation measures, maintaining the position of the cliff top.) The Shoreline Management Policies to the west of Sheringham were published by Mouchel in 1996.

'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 report on Cliff Processes.

Recognising that the geological (and biological) attributes of the cliffs along the seafront have already 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 Weybourne Cliffs SSSI, Beeston Cliffs SSSI, West Runton Cliffs SSSI and East Runton Cliffs SSSI.

Consideration should also be given to the geomorphological consequences of coastal defence schemes. The present policy at Sheringham is 'Hold the Line,' but the coastline on both sides is allowed to retreat. (Specific policies are "Do Nothing" along the management unit between Sheringham and Kelling Quag and "Managed Retreat" between Sheringham and Cromer.) Over a long period, this will result in Sheringham becoming even more of a promontory. This may disrupt the natural longshore transport of beach sediment, either retaining it on the updrift side of the defences (presently to the west) or causing it to be lost offshore. It should be noted that at both East and West Runton there are small but locally important defended gaps providing beach access to tourists and fishermen alike. In a small way, the defences at these gaps have the potential to disrupt longshore transport.

Many of the cliffs along the coastline of Norfolk also form important habitats for wildlife with the cliff grassland forming over 1% of the total resource in England. Several areas have been notified as Sites of Special Scientific Interest partly or predominantly because of their flora and fauna, and the Overstrand Cliffs SSSI, east of Cromer, is now a SAC.

The sea cliffs along the study frontage are partly vegetated, the nature of which depends on the cliff geology, erosion, geographical location and the degree of exposure to wind and salt spray. Plant species include rock sea-spurrey *Spergularia rupicola*, thrift *America maritima*, rock samphire *Crithmum maritumum* and Scots lovage *Ligusticum scoticum.* 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 forms an integral part of the cliff habitat. The Red Book species, purple broomrape, probably has its main centre of distribution in the Britain in cliff top grassland on this coast, notably on Beeston Cliffs.

Along the main Sheringham frontage, 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.

On the remainder of the cliff-tops, the land is predominantly used for arable farming or tourism/recreation, 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. English Nature is not aware of any particular biological interest other than that previously mentioned in this report (the designated SAC, SSSIs, and Wildlife Trust Sites).

4. History, tourism and recreation

General discussion of the historical environment is given below, in addition to relevant considerations with respect to tourism and recreation on the study frontage.

4.1 HISTORICAL ENVIRONMENT

In assessing the coastal defence strategy for a coastline, it is appropriate to consider the 'historic environment' of the areas at risk from erosion of flooding. DEFRA (2001) defines the historic environment as comprising all traces of past human activity and includes:

- Archaeological remains (on land and the seabed);
- Historic buildings, parks and gardens; and
- Historic landscapes.

Coastal management techniques, and particularly coastal defences, may affect these assets in a number of ways, either directly, i.e. changing the risk to them from the action of the sea, or indirectly by affecting their visual aspects or setting.

In this study, enquiries were made regarding such assets that exist, and might be at risk, between Kelling and Cromer. English Heritage and the Archaeological Unit of Norfolk County Council (Gressenhall) were asked to provide information on any buildings or archaeological features of interest within a reasonable distance from the cliff edge. However, no direct response about any such assets was received from either organisation. Nevertheless, it is anticipated that preservation of older buildings in the centre of Sheringham would be an important consideration in the sensitive management of the frontage.

4.1.1 Sheringham

In 1883, White records that Lower Sheringham is a considerable fishing station, having a road and rivulet winding down to the beach through a ravine in the lofty sea-cliffs. It has three curing-houses, and 23 large and about 150 small fishing boats. Cod, skate, whiting, crabs, and lobsters are taken in abundance, especially the two latter, of which great quantities are sent to London. As at Cromer, the sea here is continually encroaching on the cliffs, of which about a yard disappears every year. In 1800, a large inn was tumbled in a heap of ruins upon the beach; and on St. Thomas' Day, 1862, a large portion of the cliff was washed away.

Historically the parish of Sheringham comprised the two villages of Upper Sheringham, a farming community, and Lower Sheringham, which combined farming with fishing. Upper Sheringham is in the Domesday Book and there is evidence of occupation by the Romans. It was probably an earlier Icini settlement and there has been habitation for 2000 years.

Lower Sheringham has existed for about 700 years. In the 1300s the village was a mile to the west and there were a few merchants dealing in fish landed at Blakeney; later some owned ships that sailed as far as Iceland. By 1600, that village had been swallowed by the sea and a new village was developing on the present site. The crab and lobster fishing began in the 1700s when local fishermen became major suppliers to the London markets.

The mid 1800s was a boom time for the fishing industry, with over 100 inshore boats catching crabs and many luggers crewed by local men working out of Great Yarmouth and Grimsby. During that time the population of Lower Sheringham swelled from a few hundreds to one thousand. In the 1870s, the crab industry collapsed due to over-fishing and never regained its supremacy. The opening of the railway line in 1887 revived the fortunes of Lower Sheringham and it quickly became a thriving holiday resort, popular with the middle class Londoners, only a four-hour train trip away. There was subsequently a major recession in farming and all of the land in the lower village was sold for development. In 1889 Sheringham Hotel opened and in the 1890s The Grand and The Burlington were accommodating the society visitors. Many large houses were built to be let as apartments and all types of shops opened to cater for the holiday-makers. In 1901 the village became a town when it was granted status as a self-governing urban district. The town lost its identity as a primitive fishing community and became a modern resort thriving on tourism, and continues to be so.

4.2 TOURISM AND RECREATION

As discussed briefly above, the study frontage, particularly Sheringham, grew in importance in the late 18th century, when the town developed as a resort for sea bathing and promenading. Sheringham's popularity stemmed in part from its north-facing aspect, which is unusual in the UK. In the summer, this results in both sunrise and sunset taking place over the sea.

The villages of Weybourne, West Runton and East Runton still depend on tourism for a substantial part of their income; and the character of Sheringham depends upon its seafront. Thus, any coastal defence schemes need to reflect this interrelationship.

The safety of the large number of people that visit the beach and seafront in this region must be taken into consideration when designing coastal defences. Both waves and tidal currents can be dangerous, and the formation of seaward flowing rip currents must be avoided. If beach volumes are increased, this will reduce the present dangers posed by the vertical drop between the edge of the promenade and beach level. Care should also be taken to ensure that any rock structures, e.g. groynes, breakwaters or revetments, do not have large voids that could result in beach users, particularly children, becoming trapped.

5. References

DEFRA 2001 Shoreline Management Plans: A guide for coastal defence authorities. June.

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.

English Nature 2002 PDO lists for North Norfolk SSSIs.

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, & the National Rivers Authority.

LG Mouchel and Partners 1996 North Norfolk Shoreline Management Plan Sub-cell 3A, Sheringham to Snettisham Scalp. North Norfolk District Council, Environment Agency, Kings Lynn and West Norfolk Borough Council.

Appendices

Appendix A SSSI designations

COUNTY: NORFOLK **SITE NAME:** NORTH NORFOLK COAST

DISTRICT: BOROUGH OF KING'S LYNN & WEST NORFOLK,
NORTH NORFOLK

Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981 as amended.

Local Planning Authority: West Norfolk District Council & North Norfolk District Council

National Grid Reference: TF 690443 to TG 095440 **Area:** 7,700 (ha.) 19,027 (ac.)

Ordnance Survey Sheet 1:50,000: 132, 133 **1:10,560:** TF 74 SW
1:10,000: TF 64 SE, TF 74 NE, SE
TF 84 NW, NE, SW, SE
TF 94 NW, NE, SW, SE
TG 04 NW, SW, SE

Date Notified (Under 1949 Act): 1954 – Blakeney Point, Holme Dunes, Cley & Salthouse Marshes
1968 – Morston Saltmarshes, Brancaster Manor
1969 – Stiffkey Saltmarshes
1972 – Thornham Marshes
1973 – Titchwell Marshes

Date Notified (Under 1981 Act): 1986 **Date of Last Revision:** –

Other Information:
This is a composite site made up of two National Nature Reserves at Scolt Head and Holkham, and the former separate Sites of Special Scientific Interest at Holme Dunes, Thornham Marshes, Titchwell Marshes, Brancaster Manor, Stiffkey Saltmarshes, Morston Saltmarshes, Blakeney Point, Cley and Salthouse Marshes, plus several substantial additions. The area is described in the Nature Conservation Review. Scolt Head, Holkham, Blakeney Point, Cley and Salthouse Marshes are recognised as a RAMSAR wetland site and are included in the UNESCO list of Biosphere Reserves. The whole of the North Norfolk Coast SSSI has now been proposed as a RAMSAR site and also for designation as a Special Protection Area under the EEC Birds Directive. Most of the coast is managed for nature conservation by the National Trust, the Norfolk Naturalists' Trust, Norfolk Ornithologists Association, the Royal Society for the Protection of Birds and the Nature Conservancy Council. It has also been designated as a Heritage Coast by the Countryside Commission and is part of the Norfolk Coast Area of Outstanding Natural Beauty.

Reasons for Notification:
The North Norfolk marshland Coast extends for some 40kms between Hunstanton and Weybourne. The area consists primarily of intertidal sands and muds, saltmarshes, shingle banks and sand dunes. There are extensive areas of brackish lagoons, reedbeds and grazing marshes. The coast is of great physiographic interest and the shingle spit at Blakeney Point and the offshore shingle bank at Scolt Head Island are of special importance. The whole coast has been intensively studied and is well documented.

A wide range of coastal plant communities is represented and many rare or local species occur. The whole coast is of great ornithological interest with nationally and internationally important breeding colonies of several species. The geographical position of the North Norfolk Coast and its range of habitats make it especially valuable for migratory birds and wintering waterfowl, particularly brent and pink-footed geese. The area, much of which remains in its natural state, now constitutes one of the largest expanses of undeveloped coastal habitat of its type in Europe.

Intertidal Sands and Muds
Extensive intertidal areas are present along the entire coast. Intertidal flats mostly consist of sand or mud and shingle and are unvegetated. Some mudbanks have seasonal growths Eel Grass *Zostera marina* and green algae (mostly *Enteromorpha* sp. and *Vaucheria* sp.) which provide valuable feeding grounds for wintering ducks and geese. The mudflats also have locally abundant concentrations of invertebrates of importance as wildfowl and wader food sources.

Saltmarsh
The saltmarshes are the finest coastal marshes in Britain and among the best in Europe. They have accreted in sheltered positions either behind sand bars such as on Scolt Head or on sheltered parts of the coast as at Stiffkey. Differences in marsh height reflect differences in age. The saltmarsh flora is exceptionally diverse and includes a number of uncommon species.

Succession is clearly shown from scarcely vegetated mud at the seaward boundary of the marsh to maritime grassland on the upper marsh. The foremarsh is characterised by colonising species such as glasswort *Salicornia spp.* and cord grass *Spartina anglica*. Sea Aster *Aster tripolium* is often dominant on the lower marsh which in turn grades into the extensive areas of midmarsh. Sea lavender *Limonium vulgare* is dominant with sea purslane *Halimione portulacoides* lining the banks of the creeks. Other species occurring in this zone include sea plantain *Plantago maritima*, sea arrow grass *Triglochin maritima*, annual seablite *Suaeda maritima* and sea wormwood *Artemisia maritima*. The upper saltmarsh is characterised by grasses such as sea couch grass *Elymus pycnanthus* and sea poa grass *Puccinellia maritima*. A shorter vegetation is often found on the upper marsh near the saltmarsh-shingle interface. It is diverse and includes two rare species; matted sea lavender *Limonium bellidifolium* and sea heath *Frankenia laevis*.

The saltmarshes, with their associated shingle structures, form a geomorphological unit of the highest importance for tracing the post-glacial evolution of the area.

Dunes
Dune systems occur at a number of localities along the coast but are best developed at Holme and Holkham. On Scolt Head Island and at Blakeney Point sand dunes have developed on a shingle base. The stabilised, mature dunes hold a rich flora including a number of uncommon halophytic (salt tolerant) species.

The foredunes are generally comprised of wind-blown sand with scattered plants of the primary colonising species sand couch-grass *Elymus farctus* and lyme-grass *Leymus arenarius*. Ephemeral species such as sea rocket *Cakile maritima* and saltwort *Salsola kali* also occur in this zone. The yellow dunes are further consolidated by the binding rhizomes of marram grass *Ammophila arenaria* and several other species occur including sea holly *Eryngium maritimum*, sea sandwort *Honkenya peploides* and sand sedge *Carex arenaria*. The vegetation is most diverse on the stable grey dunes. Marram grass is still abundant but red fescue *Festuca rubra* is often co-dominant. The calcareous nature of the dunes is revealed by the presence of such species as spring whitlow-grass *Erophila verna agg.*, centaury *Centaurium erythraea*, bird’s-foot trefoil *Lotus corniculatus*, pyramidal orchid *Anacamptis pyramidalis*, and bee orchid *Ophrys apifera*. Two rare plants, Jersey cudweed *Gnaphalium luteo-album* arid grey hair-grass *Corynephorus canescens* are associated with the grey dunes.

Corsican pine *Pinus nigra* var. *maritima*, has been planted at Holkham to stabilize the dunes, and has spread through self-seeding. Creeping ladies’ tresses *Goodvera repens* and yellow bird’s-nest *Monotropa hypopitys* occur locally under the mature pines. Secondary mixed woodland and scrub have developed on the landward side of the pines which provide valuable cover for migratory passerine birds.

Dune slacks are present behind the main dune systems at Holme and Holkham. These wet areas have a characteristic flora that includes pennywort *Hydrocotyle vulgaris*, marsh helleborine *Epipactis palustris* and southern marsh orchid *Dactylorhiza praetermissa*.

Shingle

The North Norfolk Coast is rich in shingle structures consisting of material derived and re-worked from glacial drift. Scolt Head Island is an extensive offshore barrier island with a complex sequence of shingle ridges and dunes and is of the highest national importance as a geomorphological site, and Blakeney Point is a large shingle spit; both are important educational and research sites, that have been well studied and feature extensively in the literature.

The shingle banks are colonised by a variety of specialised plants. Characteristic species include biting stonecrop *Sedum acre*, thrift *Armeria maritima*, sea campion *Silene maritima*, yellow horned-poppy *Glaucium flavum*, sea sandwort, sea beet *Beta vulgaris* ssp. *maritime* and bird's-foot-trefoil. At the saltmarsh-shingle interface, a discrete community occurs including shrubby seablite *Suaeda vera*, an uncommon species in Britain, which is often abundant here with rock sea lavender *Limonium binervosum* and sea wormwood.

Brackish Lagoons and Reedbeds

Natural brackish lagoons are present at Holme and in the Cley-Salthouse area. In addition, artificial lagoons have been created at Titchwell and Cley. The shallow water, and an abundant invertebrate fauna in the mud, make these coastal lagoons important feeding sites for wintering and passage waders and waterfowl.

Extensive reedbeds have developed at Cley, Brancaster and Titchwell; here Reed *Phragmites australis* is dominant with mud rush *Juncus gerardii*, brackish water-crowfoot *Ranunculus baudotii*, sea club-rush *Scirpus maritimus* and great reed-mace *Typha latifolia*. Many of the reedbeds are managed to provide the conditions favoured by rare breeding birds.

Maritime Pasture and Grazing Marsh

Maritime pasture is present on the Cley and Salthouse Marshes, where several plants characteristic of damp grazed areas occur including marsh fox-tail *Alopecurus geniculatus*, annual beard-grass *Polypogon monspeliensis*, jointed rush *Juncus articulatus* and silverweed *Potentilla anserina*.

Extensive areas of permanent grazing marsh derived from reclaimed saltmarsh are present in several places along the coast. The dominant grass species in the sward are creeping bent *Agrostis stolonifera*, common fox-tail *Alopecurus pratensis* and perennial rye-grass *Lolium perenne*. The wet, rough grassland is suitable breeding habitat for several species of wader and is a valuable feeding area for wintering wildfowl.

A number of relict saltmarsh creeks on the marshes have developed into brackish reedbeds of considerable ornithological importance. The grazing marsh at Holkham was reclaimed in the 17th and 18th centuries. A network of clear water dykes is present with a variety of marginal plants including reed, lesser spearwort *Ranunculus flammula*, water mint *Mentha aquatica* and gipsy-wort *Lycopus europaeus*. Amongst several interesting species of water plant recorded are the uncommon soft hornwort *Ceratophyllum submersum* and blunt-leaved pondweed *Potamogeton obtusifolius*. A fringe of dry grassland is present above the saltmarsh at Holkham and is annually mown and occasionally grazed.

Vertebrate Fauna

The breeding bird communities of the North Norfolk Coast are of national and international importance. Most noteworthy are breeding colonies totalling up to 4,500 pairs of sandwich terns *Sterna sandvicensis* which represent about 1/12th of the world population. The largest colony of little terns *Sterna albifrons* in Western Europe is located on Blakeney Point. On the North Norfolk Coast as a whole, there are up to 400 pairs of little terns which constitute over 20% of the British population. Bird species with breeding populations of national importance include up to 1,000 pairs of common terns *Sterna hirundo*, 27 pairs (in 1982) of avocets *Recurvirostra avosetta* and up to 100 pairs of bearded tits *Panurus biarmicus*. Bitterns *Botaurus stellaris* and marsh harriers *Circus aeruginosus* are regular breeders in small numbers and garganey *Anas querquedula* and black-tailed godwit *Limosa limosa* breed on occasions.

Migratory birds, notably waders and passerines, are often present in great abundance in the spring and autumn. Wintering birds include large numbers of brent geese *Branta bernicla* and smaller numbers of pink-footed geese *Anser brachyrhynchus* and white-fronted geese *Anser albifrons*. Ducks and waders are also present in great abundance on the marshes and intertidal areas. The shingle banks and foreshore provide suitable habitats for wintering passerines such as twite *Acanthis flavirostris*, snow buntings *Plectrophenax nivalis* and shore larks *Eremophila alpestris*.

The natterjack toad *Bufo calamita*, a rare amphibian in Britain, breeds in shallow pools in the dune slacks at two sites on the coast.

Red squirrels *Sciurus vulgaris* occurred in the dune pine woods until 1981 at Holkham. Otters *Lutra lutra* breed and hunt within the whole site.

COUNTY: Norfolk SITE NAME: WEST RUNTON CLIFFS

DISTRICT: North Norfolk

Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981

Local Planning Authority: North Norfolk District Council

National Grid Reference: TG 183432 TG 192430 Area: 17.56 (ha) 43.39 (ac)

Ordnance Survey Sheet 1:50,000: 133 1:10,000: TG 14 SE

Date Notified (Under 1949 Act): 1954 Date of Last Revision: –

Date Notified (Under 1981 Act): 1984 Date of Last Revision: –

Other Information:
The site area has been reduced but 2 other sites, East Runton Cliffs and Beeston Cliffs include much of the former SSSI.

Reasons for Notification:
West Runton is one of the most important Pleistocene localities in the British Isles. In the cliff and foreshore are exposed a series of sediments representing two temperate stages (Pastonian, Cromerian) and three cold stages (Pre-Pastonian, Beestonian, Anglian). Pollen spectra indicative of temperate forests have been obtained from the temperate stages, while the cold stage deposits show permafrost structures and subarctic herb floras. The whole Cromer Forest-bed Formation sequence is overlain by glacial tills of the Anglian Glaciation. The sequence records several periods of transgression and regression (major advances and retreats of the sea) represented by alternations of marine and non-marine sedimentation. The entire Cromerian Interglacial vegetational cycle is represented within the West Runton Freshwater Bed and overlying marine sediments, and this locality has been designated the stratotype for the Cromerian stage. Molluscan and vertebrate fossils occur at several horizons, especially in the West Runton Freshwater Bed.

The West Runton Freshwater Bed (Cromerian Interglacial) has yielded by far the richest fauna of any open Pleistocene site in Britain. Fossils, dated to pollen Zones Cr Ib – IIb, include a wide range of large and small mammals, freshwater fish and other vertebrates. The fauna has considerable international importance for its value in correlations with early Middle Pleistocene deposits across Europe and beyond. Marine gravels above with pollen dated to Zone Cr III have also yielded an interesting but sparse vertebrate assemblage. The Pastonian 'crag' below the Freshwater Bed contains abundant vertebrates, of particular note are the voles and marine fish – the only known fauna which can with certainty be assigned to this lower Pleistocene stage. An internationally important locality for its vertebrate faunas.

COUNTY: Norfolk SITE NAME: WEYBOURNE CLIFFS+

DISTRICT: North Norfolk

Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981

Local Planning Authority: North Norfolk District Council

National Grid Reference: TG 111437 to TG 152435 Area: 39.8 (ha) 98.3 (ac)

Ordnance Survey Sheet 1:50,000: 133 1:10,000: TG 14 SW, SE

Date Notified (Under 1949 Act): +1964 *1954 Date of Last Revision: –

Date Notified (Under 1981 Act): 1985 Date of Last Revision: –

Other Information:
The site has been extended to include the former Skelding Hill Cliffs SSSI* and includes an extension which bridges the gap between the two old sites.

Reasons for Notification:
Cliffs east of Weybourne afford the best Pleistocene sections showing the pre-Cromerian deposits of the Cromer Forest bed. The Pastonian 'Weybourne Crag', here at its type locality, with its marine molluscs has been known since the early days of geology. An historic site with outstanding Pleistocene sections of national importance.

The marine "crags" here have yielded both large and small mammal remains, of Pastonian and probably also pre-Pastonian age. Little has been published on these important fossils and the site remains one with considerable potential for future vertebrate finds.

Additional biological interest is provided by colonies of sand martins in the cliff-face and of fulmars (73 pairs in 1982) on the cliff ledges.

COUNTY: NORFOLK SITE NAME: EAST RUNTON CLIFFS

DISTRICT: NORTH NORFOLK

Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981 as amended.

Local Planning Authority: North Norfolk District Council

National Grid Reference: TG 194430 to TG 205427 Area: 19.7 (ha.) 48.6 (ac.)

Ordnance Survey Sheet 1:50,000: 133 1:10,000: TG 14 SE, TG 24 SW

Date Notified (Under 1949 Act): 1954* Date of Last Revision: –

Date Notified (Under 1981 Act): 1985 Date of Last Revision: –

Other Information:
This site comprises part of former West Runton Cliffs* SSSI with an extension.

Description:
The foreshore at East Runton exposes pre-Cromerian (Lower Pleistocene) sediments, including successively 'Weybourne Crag', Pastonian clay conglomerate and marine shell beds, overlain in turn by marine silts (Pa II pollen zone). In the cliff can be seen spectacular rafts of chalk of glacitectonic origin (ie. ice transported) and highly deformed 'Contorted Drift'.

The marine Lower Pleistocene deposits, here of pre-Pastonian and probable Pastonian age, contain an extensive vertebrate fauna which includes marine fish, voles, carnivores, extinct horse, rhinoceros, and elephant, and (notably) several species of 'comb-antlered' deer, *Euctenoceras*. This is the best available locality for fossil vertebrates of this age.

Appendix B County Wildlife Site designations

County Wildlife Site
(Ref No: 1156)

Site Name: Beach Lane **Parish: Weybourne**

Grid Reference: TG 109437 **Area: 1.9 ha**

Site Description:

This site is an area of reed bed occupying a shallow silty pool situated just inland from the shingle sea defences at Weybourne Hope. The pool is brackish towards the north, but is fed by a small freshwater stream entering from the east.

Reed swamp occupies a large part of the site. The stand is dominated by uniform common reed (*Phragmites communis*) and has evidently not been cut for some time. A small patch of bulrush (*Typha latifolia*) is present towards the centre of the site. Occasional willow (*Salix* sp.) also occurs, becoming dense in a slightly raised, drier patch adjacent to Beach Lane, where great willowherb (*Epilobium hirsutum*) is also present. In the west, the common reed is gradually extending around the boundary of the adjacent sewage works.

Open brackish water occurs at the northern extreme of the site below a wall supporting the base of the sea defences, and extending some way along the eastern boundary. This is generally clear, showing the shingle substrate which rapidly becomes more silty into the reed bed. *Enteromorpha* spp. is abundant in the deeper water.

To the south reed grades into a drier tall herb community around the level of the small inflowing stream. This is characterised by Alexander's (*Smyrnium olusatrum*) and fennel (*Foeniculum vulgare*), with rosebay willowherb (*Chamerion angustifolium*) replacing great willowherb. The sward is generally tall, including frequent coarse grasses such as false oat grass (*Arrhenatherum elatius*) and cock's foot (*Dactylis glomerata*), with locally abundant wall barley (*Hordeum murinum*). Other herbaceous species present include common mallow (*Malva sylvestris*), mugwort (*Artemesia vulgaris*), perennial sow thistle (*Sonchus arvensis*), broad-leaved dock (*Rumex obtusifolius*), creeping thistle (*Cirsium arvense*), great plantain (*Plantago major*), and spear-leaved orache (*Atriplex prostrata*), with silverweed (*Potentilla anserina*), amphibious bistort (*Polygonum amphibium*), and sea club-rush (*Scirpus maritimus*) in damper areas. There is also a little hawthorn (*Crataegus monogyna*) scrub and a defunct elder (*Sambucus nigra*).

The freshwater stream is very overgrown, but supports a small amount of water cress (*Nasturtium officinale)* and brooklime (*Veronica beccabunga*).

Survey Date: 04/05/1994

County Wildlife Site.
(Ref No: 1156)

Site Name: Beach Lane **Parish: Weybourne**

Grid Reference: TG 109437 **Area: 1.9 ha**

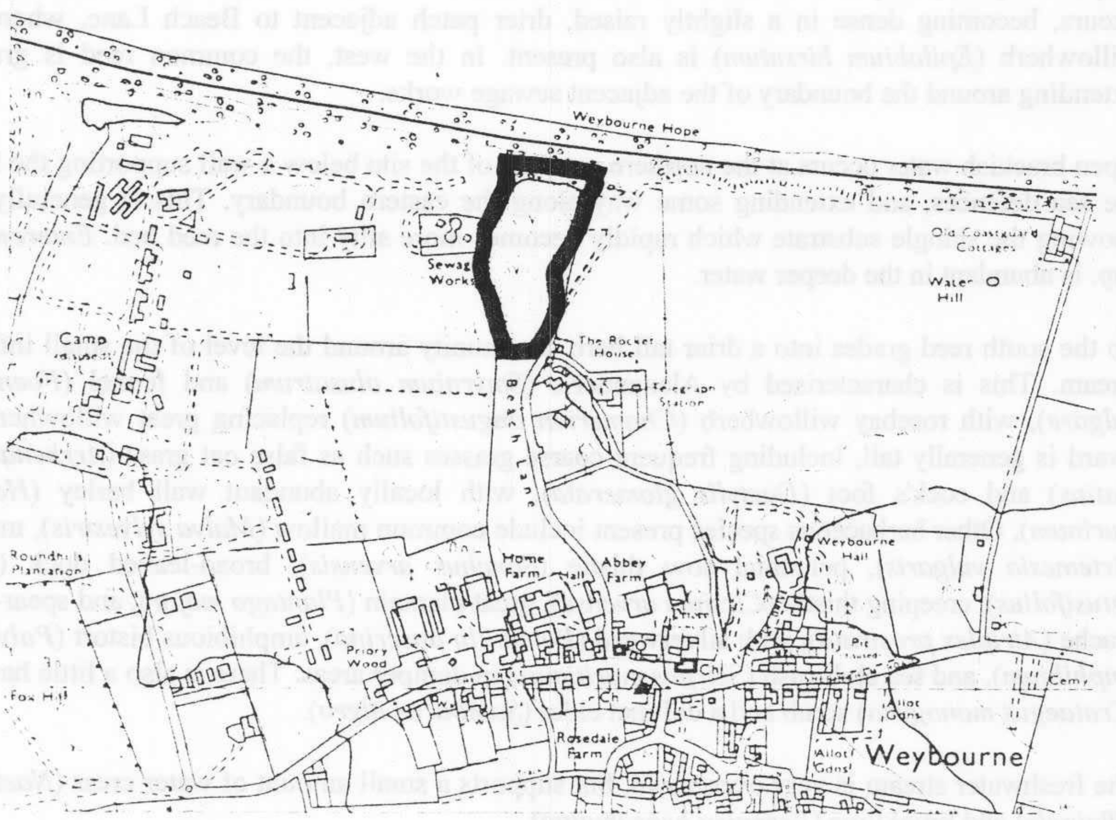
Site Description:

This site is an area of reed bed occupying a shallow silty pool situated just inland from the shingle sea defences at Weybourne Hope. The pool is brackish towards the north, but is fed by a small freshwater stream entering from the east.

Reed swamp occupies a large part of the site. The stand is dominated by uniform common reed (*Phragmites australis*) and has evidently not been cut for some time. A small patch of bulrush (*Typha latifolia*) is present towards the centre of the site. Occasional willow (*Salix* sp.) also occurs, becoming dense in a slightly raised, drier patch adjacent to Beach Lane, where great willowherb (*Epilobium hirsutum*) is also present. In the west, the common reed is gradually extending around the boundary of the adjacent sewage works.

Open brackish water occurs at the [illegible] of the site below a [illegible] forming the base of the sea defences and extending some way along the eastern boundary. This is generally clear, showing the shingle substrate which rapidly becomes more silty into the reed bed. *Enteromorpha* spp. is abundant in the deeper water.

To the south reed grades into a drier tall herb community around the level of the small inflowing stream. This is characterised by Alexanders (*Smyrnium olusatrum*) and fennel (*Foeniculum vulgare*) with rosebay willowherb (*Chamerion angustifolium*) replacing great willowherb. The sward is generally tall, including frequent coarse grasses such as false oat grass (*Arrhenatherum elatius*) and cock's foot (*Dactylis glomerata*), with locally abundant wall barley (*Hordeum murinum*). Other herbaceous species present include common mallow (*Malva sylvestris*), mugwort (*Artemisia vulgaris*), [illegible] broad-leaved dock (*Rumex obtusifolius*), creeping thistle, [illegible] (*Plantago* [illegible]) and spear-leaved orache (*Atriplex prostrata*) [illegible] amphibious bistort (*Polygonum amphibium*), and [illegible]. There is also a little hawthorn (*Crataegus monogyna*) [illegible].



The freshwater stream [illegible] supports a small amount of water cress (*Nasturtium officinale*) and brooklime (*Veronica beccabunga*).

Survey Date: 09/05/1994

County Wildlife Site
(Ref No: 1201)

Site Name: Cromer Sea Front **Parish: Cromer**

Grid Reference: TG 216425 **Area: 39.0 ha**

Site Description:

This site comprises the coastal cliffs, beach and intertidal zone between East Runton Cliffs SSSI to the west and Overstrand Cliffs SSSI to the east. The cliffs rise from 10 metres at Cromer pier to 30 metres at either end of the site. This change is accompanied by a decreasing influence of development and lower visitor pressure, although the entire sea front and beach are well used by general public.

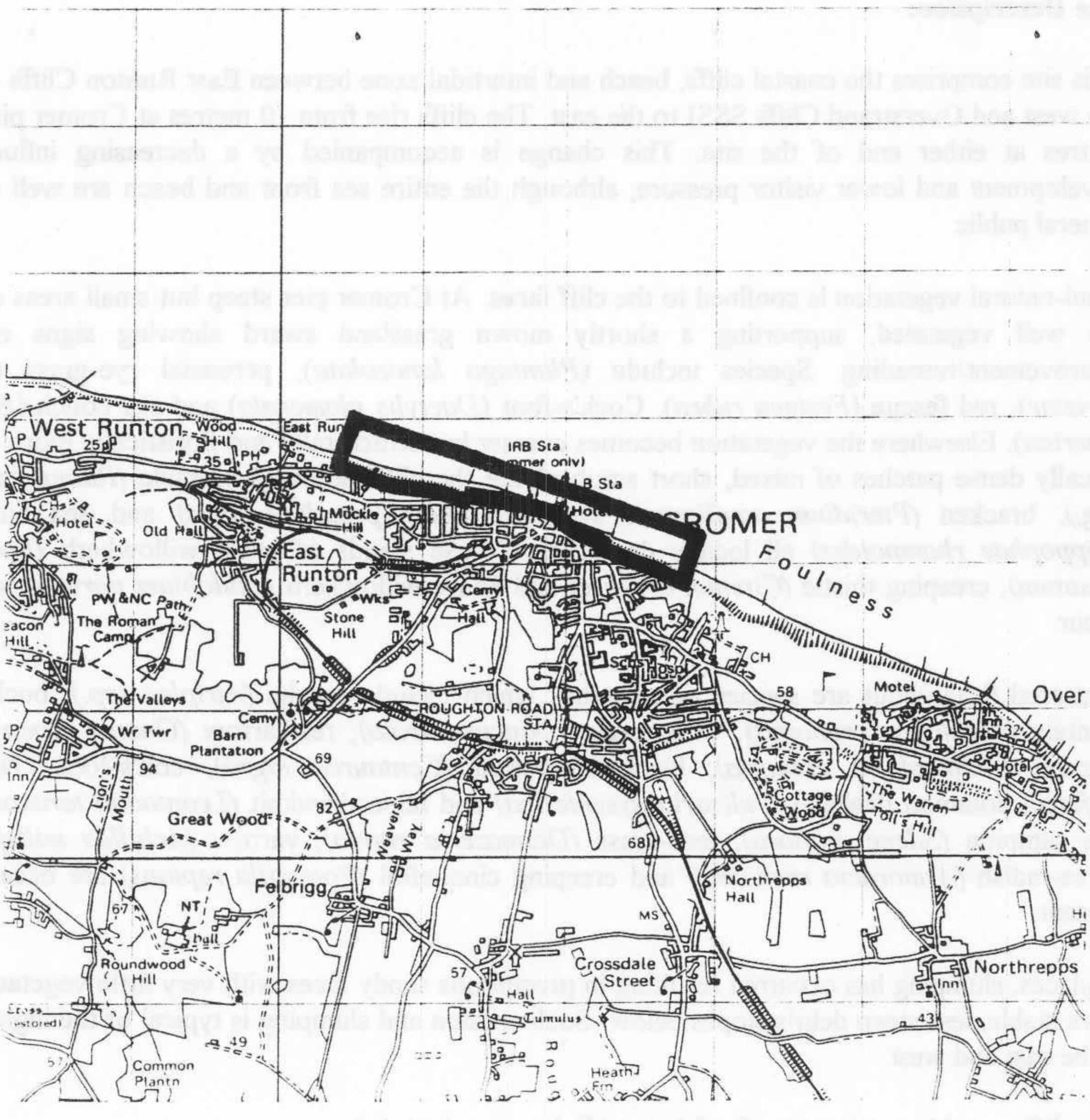
Semi-natural vegetation is confined to the cliff faces. At Cromer pier steep but small areas of slope are well vegetated, supporting a shortly mown grassland sward showing signs of local improvement/reseeding. Species include (*Plantago lanceolata*), perennial rye-grass (*Lolium perenne*), red fescue (*Festuca rubra*), Cock's-foot (*Dactylis glomerata*) and sea couch (*Elytrigia atherica*). Elsewhere the vegetation becomes coarser but structurally and floristically more diverse. Locally dense patches of mixed, short scrub clothe the cliff face with bramble *(Rubus fruticosus* agg.*)*, bracken *(Pteridium aquilinum)*, sycamore *(Acer pseudoplatanus)* and sea buckthorn *(Hippophae rhamnoides)* all locally dominant. Coarse stands of great willowherb *(Epilobium hirsutum)*, creeping thistle *(Cirsium arvense)* and hoary willowherb *(Epilobium parviflorum)* also occur.

Scattered throughout are species rich patches which include orache *(Atriplex spp.)*, buck's-horn plantain *(Plantago coronopus)*, wild carrot *(Daucus carota)*, restharrow *(Ononis repens)*, with marram *(Ammophilia arenaria)*, black knapweed *(Centaurea nigra)*, colt's-foot *(Tussilago farfara)*, common fleabane *(Pulicaria dysenterica)* and lesser hawkbit *(Leontodon taraxacoides)*. Sea campion *(Silene uniflora)*, fern-grass *(Desmazeria rigida)*, yarrow *(Achillea millefolium)*, horse-radish *(Armoracia rusticana)* and creeping cinquefoil *(Potentilla reptans)* are occasionally present.

In places, slumping has occurred resulting in precipitous sandy faces with very little vegetation and more stable, less steep debris slopes below. Such erosion and slumping is typical of the higher cliffs in the east and west.

The cliffs provide nesting sites for fulmars (*Fulmarus glacialis*).

Survey Date: 16/08/1994


West Runton
Wood Hill
East Run
IRB Sta
(summer only)
B Sta
Hotel
CROMER
Foulness
Old Hall
Mickle Hill
East Runton
Cemy
Hall
Stone Hill
PW &NC Path
The Roman Camp
The Valleys
Barn Plantation
Wr Twr
ROUGHTON ROAD STA
Great Wood
Felbrigg
Roundwood Hill
Common Plantn
Crossdale Street
Cumulus
Heath Fm
Northrepps Hall
Northrepps
Cottage Wood
The Warren
Motel
Hotel
Over
CH
MS

County Wildlife Site
(Ref No: 1107)

Site Name: Kelling Hard **Parish: Weybourne/Kelling**

Grid Reference: TG 098438 **Area: 2.6 ha**

Site Description:

This site comprises a mosaic of unimproved, slightly calcareous and neutral grassland, common reed (*Phragmites australis*) dominated swamp vegetation, and marshy grassland. A coastal influence is evident in all communities, although particularly noticeable in a short, sparse sward present where topsoil has been removed. It once formed part of the disused Weybourne Military Camp, and it lies immediately inland from the shingle sea defences

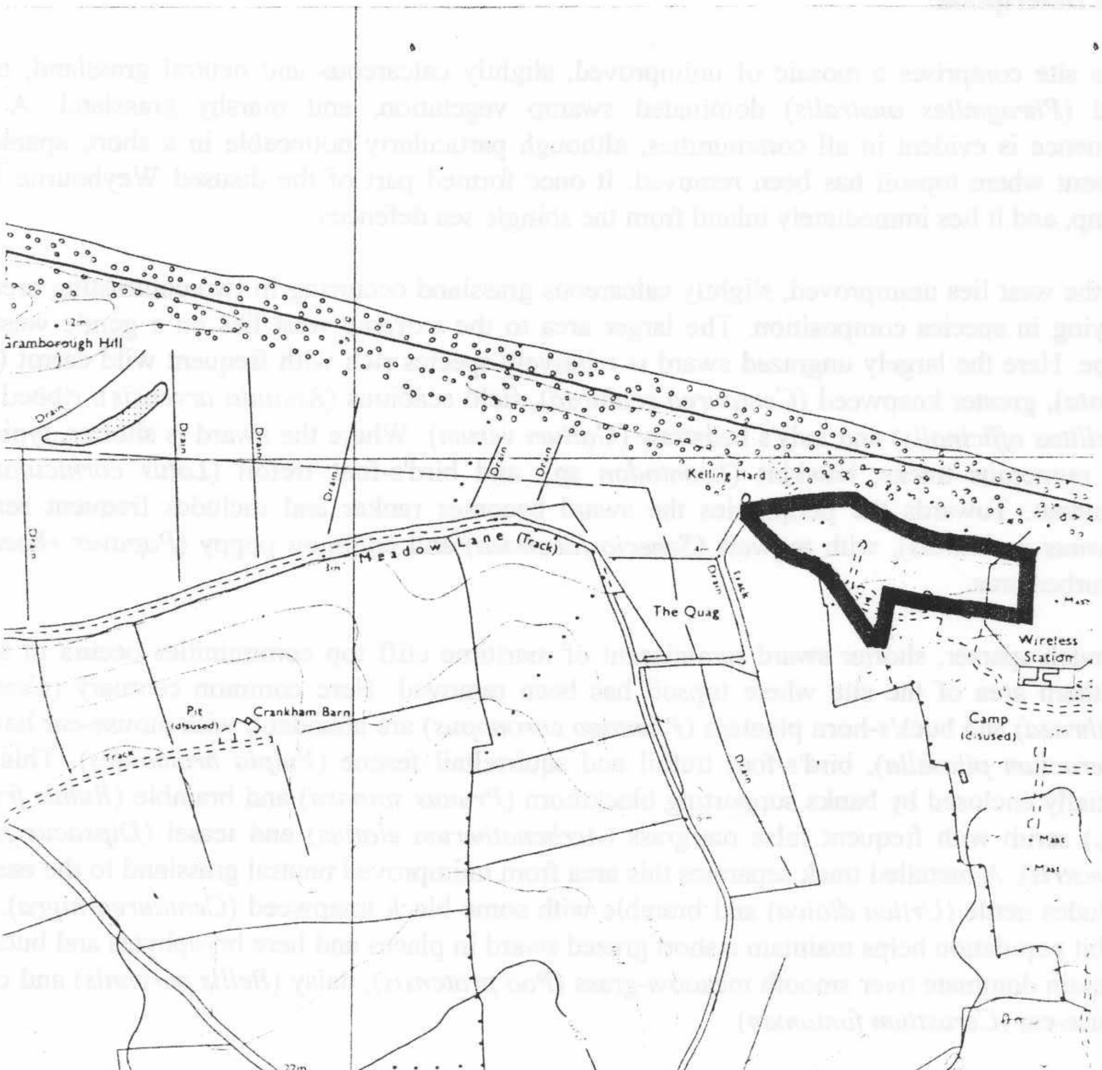
To the west lies unimproved, slightly calcareous grassland occurring in two contrasting areas, each varying in species composition. The larger area to the extreme west lies on a gentle west facing slope. Here the largely ungrazed sward is relatively species rich with frequent wild carrot (*Daucus carota*), greater knapweed (*Centaurea scabiosa*), field scabious (*Knautia arvensis*), ribbed melilot (*Mellitus officinalis*) and lady's bedstraw (*Galium verum*). Where the sward is shorter, typically on the numerous tracks, hawkbit (*Leontodon* sp.) and bird's-foot trefoil (*Lotus corniculatus*) are abundant. Towards the peripheries the sward becomes ranker and includes frequent sea couch (*Elymus pycanthus*), with ragwort (*Senecio jacobaea*) and common poppy (*Papaver rhoeas*) in a disturbed area.

A much sparser, shorter sward reminiscent of maritime cliff top communities occurs in a central southern area of the site where topsoil has been removed. Here common centuary (*Centaurium erythraea*) and buck's-horn plantain (*Plantago coronopus*) are abundant, with mouse-ear hawkweed (*Hieracium pilosella*), bird's-foot trefoil and squirreltail fescue (*Vulpia bromoides*). This area is partially enclosed by banks supporting blackthorn (*Prunus spinosa*) and bramble (*Rubus fruticosus* agg.) scrub with frequent false oat-grass (*Arrhenatherum elatius*) and teasel (*Dipsacus fullonum sylvestris*). A metalled track separates this area from unimproved neutral grassland to the east which includes nettle (*Urtica dioica*) and bramble with some black knapweed (*Centaurea nigra*). A high rabbit population helps maintain a short grazed sward in places and here bryophytes and buck's-horn plantain dominate over smooth meadow-grass (*Poa pratensis*), daisy (*Bellis perennis*) and common mouse-ear (*Cerastium fontanum*).

In the north-east, the sandy soil becomes more clayey, with a high water level. Here a small patch of common reed dominated vegetation occurs with false-fox sedge (*Carex otrubae*). The presence of sea arrowgrass (*Triglochin maritimum*) suggests a saline influence. A small stand of flag iris (*Iris pseudacorus*) occurs in the adjacent gateway.

The reed is surrounded by an area of marshy grassland. Here common fleabane (*Pulicaria dysenterica*), silverweed (*Potentilla anserina*) and spear thistle (*Cirsium vulgare*) are the only frequent herbaceous species present in a grassy sward which includes velvet bent (*Agrostis canina*), creeping bent (*Agrostis stolonifera*) and red fescue (*Festuca rubra*), together with large patches of hard rush (*Juncus inflexus*) and jointed rush (*Juncus articulatus*).

Survey Date: 01/08/1994



Gramborough Hill
Drain
Kelling Hard
Meadow Lane (Track)
The Quag
Mast
Wireless Station
Camp (disused)
Pit (disused)
Crankham Barn
22m

Appendix C Area of Outstanding Natural Beauty: Map

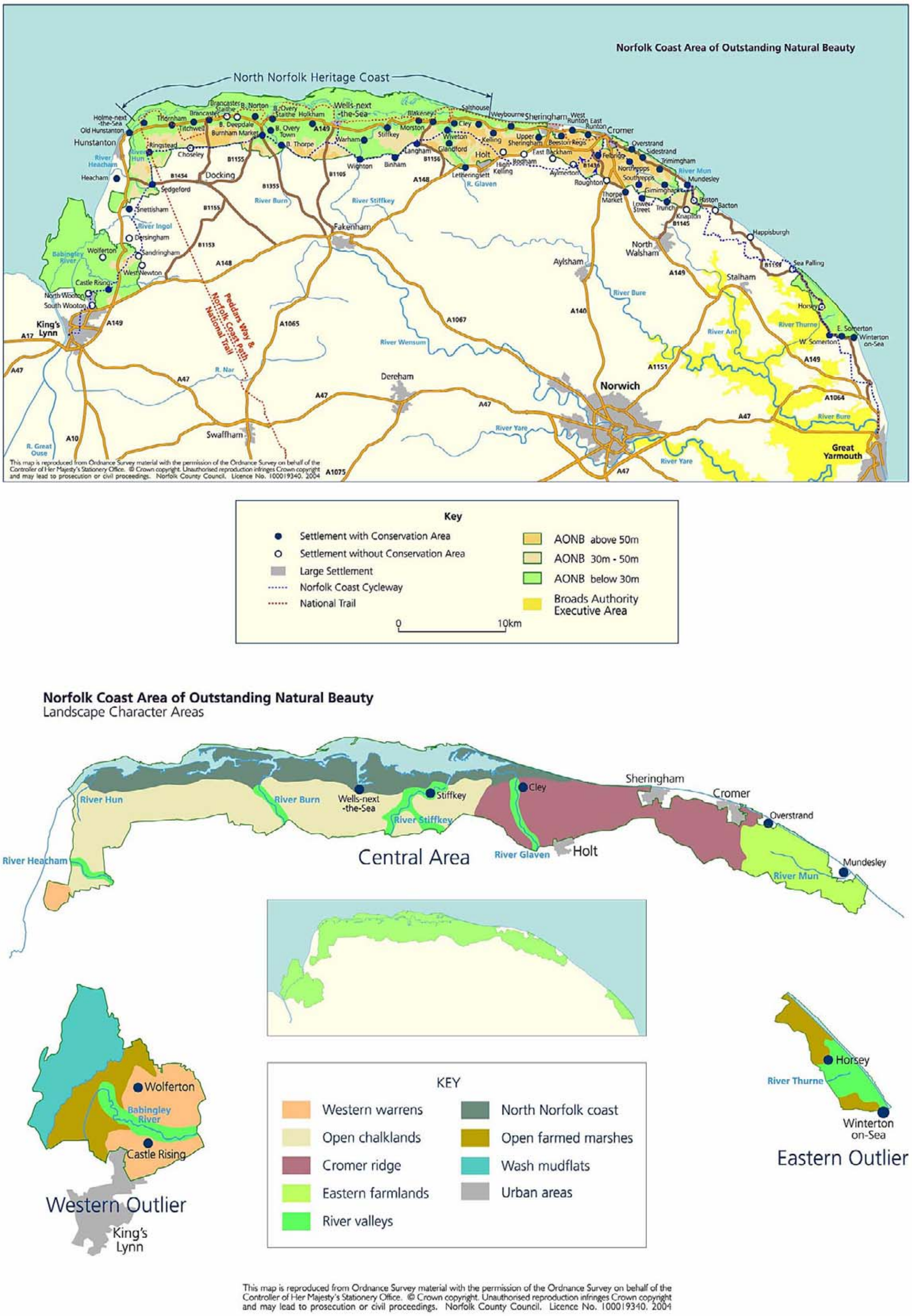


Figure C.1 Map of the Norfolk Coast AONB (NNDC website)

Appendix D Summary of North Norfolk Transport Strategy

The Norfolk Coast Transport Strategy - A Brief Summary

The Norfolk Coast Transport Strategy is being implemented by Norfolk County Council. The final Transport Strategy was agreed by the Planning and Transportation Committee of NCC in June 1998 after public consultation. The Strategy relates to the Norfolk Coast Area of Outstanding Natural Beauty (AONB), but includes a wider strategy area extending south to the A148 (between King's Lynn and Holt) and west to the A149 (between North Walsham and Potter Heigham).

The AONB, and particularly the beaches, villages and nature reserves along the coast road (the A149 and B1159) are a major focus of tourism during peak holiday periods. The resultant traffic pressures on narrow roads, and parking pressure at tourist 'honeypots', causes congestion and a progressive erosion of the landscape quality the AONB was set up to protect.

The aim of the Strategy is *"To identify a realistic and sustainable approach to the future management of traffic in the Norfolk Coast AONB which benefits the environment and local residents, and meets the need of tourism and other businesses."*

The Transport Strategy policies cover the following:

POLICY 1: the principles for completion of the County Route Hierarchy review, including a special status for the coast road

POLICY 2: investigation of a speed management zone for the core of the AONB between Hunstanton and Sheringham

POLICY 3: the treatment of minor country lanes as Quiet Lanes giving priority to walkers, cyclists and horseriders

POLICY 4: village traffic management schemes

POLICY 5: a speed reduction campaign and information exercise

POLICY 6: tourist public transport improvements, including the development of the Coastliner bus as a spine route

POLICY 7: commercial park and ride services based on existing tourist attractions

POLICY 8: the transport needs of residents

POLICY 9: seeking a reduction of car parking in the most environmentally sensitive parts of the coastline

POLICY 10: improved parking management in busy villages

POLICY 11: management of vehicular access to unsurfaced roads

POLICY 12: improved accessibility within the AONB for disabled people

POLICY 13: improved access to the countryside close to the adjoining towns

POLICY 14: the environmental improvement of town centres

POLICY 15: new tourism opportunities in walking, cycling and horseriding

POLICY 16: minimisation of the visually intrusive aspects of traffic management

POLICY 17: the potential for locally distinctive signs

Copies of the Transport Strategy are available from Norfolk County Council, Department of Planning and Transportation, Martineau Lane, Norwich. NR1 2SG.

REPRESENTATIVES INVOLVED IN DEVELOPMENT OF THE DRAFT NORFOLK COAST AONB MANAGEMENT STRATEGY

Country Landowners Association	Tony Blount
Countryside Commission	Tim De-Keyzer, Sarah Skinner, David Vose
East of England Tourist Board	Gillian Artis, Neil Warren
English Nature	Peter Lambley, Andy Millar
Environment Agency	Louise Bond
Farming and Rural Conservation Agency	Ed Blane
Forestry Authority	Barry Martin
Great Yarmouth Borough Council (Planning)	Edward Gilder
King's Lynn & West Norfolk Borough Council	Jeff Clarke, Mike Houldsworth, Chris Pearce, Tony Porter (Planning); Mike George (Economic Development); Tess Wright (Tourism)
National Farmers Union	Philip Edmonds, Rachel Juster, Robert Stevens
National Trust	Richard Hill
Norfolk Coast Project	Graeme Hayes, Heidi Mahon, Rachel Penny, Tim Venes
Norfolk County Council	Steve Harris, Graham King (Countryside); Ian Walters (Economic Development); Gerry Barnes, Graeme Cresswell (Forestry); Chris Mitchell (Highway Maintenance); Judith Cantell (Landscape); Gavin Smith (Transport Planner)
Norfolk Farming & Wildlife Advisory Group	Richard MacMullen
Norfolk Landscape Archaeology	David Gurney
Norfolk Society	Ian Shepherd
Norfolk Wildlife Trust	Peter Doktor
North Norfolk District Council	Ian Thompson (Planning); Steve Blatch (Economic Development)
Parishes Representatives	Roger Garrad, Keith Harrison, Peter Russell, Godfrey Sayers, Mike Seville
Royal Society for the Protection of Birds	Ian Robinson, John Sharpe
Rural Development Commission	Peter Gregson
West Norfolk Tourism Forum	Alister Borthwick

PEOPLE INVOLVED IN NORFOLK COAST PROJECT LAND & LIFE MEETINGS (from information supplied by University College London)

Aylmerton	L Brockdorff, Edward Henderson, Tessa Miallett, Mr Redmayne
Binham	D Baxter, Kay Evans
Blakeney	Morris Arthur, Mr D Brackney, Michael Lee, Kirsty Sanford
Brancaster	G Coleman, Mr Jones
Brancaster Staithe	Mr M Bucher
Burnham Market	Martin and Rita Cadman, Irene Ducker, Mrs M Harvey, Mr J Streeter, Mr R Tidd
Burnham Overy	Mr Lambert
Burnham Thorpe	John Musgrave
Choseley	Major & Mrs Peter Hutchinson
Cley-next-the-Sea	E M Butters, W J High-Caston, Robert Cooke, Mrs G E Davies, Frank Hawes, Richard Kelham, Mr P Kinsella, Miss A B Maw, Mr Millard, Mrs C Young
Cromer	P Burnett, Mrs Farmer, Mr R Linsay, Mr and Mrs Martindill, David Stow
East Runton	T Hall
Felbrigg	A E Richards, Mr T Styles
High Kelling	Mrs Bedford
Holme next the Sea	Susan Grey, Keir and Patricia Hughes, Ryan Hughes, Mr C Kell, D Swift, Mr and Mrs Walter
Horsey	Mrs J Keel, Robin Lang
Hunstanton	Rachel Blazeley, Andrew Smith
King's Lynn	Chris Gillett, Mr P Richardson
Knapton	Mr Heath
Langham	Mrs Harcourt
Letheringsett	R Chase, M David
Little Thornage	Melody Beeley
Mundesley	Mrs S A Reed
North Walsham	Heather Webster
Old Hunstanton	Lt Col J R Hamer, Mr and Mrs Plowright, Mrs S Plummer
Paston	Mr & Mrs Damen, Mr G Thomas
Ringstead	Mrs D Fielder
Roughton	Sarah Crouch
Salthouse	Mrs Hatcher, P H Pringle, Dorothy Thompson
Sea Palling	Mr & Mrs Irons
Sedgeford	Mr and Mrs Beech, Jean McGinty, Ms S Jackson, Mr J Tee
Sheringham	Miss M L Digby
Sidestrand	Queenie Tune-Thorogood
Stiffkey	Philip Gerrard
Thornham	Mr and Mrs Bovey, Mr H Greef, T & S Mather, Anna Potts, Mr J Smith
Trimingham	Mr Banks, Mr H Fantham, Mr E Slama
Trunch	Mr N Burton, Jean Hill
Upper Sheringham	Dorothy Butriss, Mrs J M Garrad
Wells-next-the-Sea	Dawn Boddy, John Coleridge, Mr & Mrs Scoles, Mr & Mrs Scott, Eric Swann, David Wickens, Mrs J Wood
West Newton	P Martini
West Runton	Margaret Craske, Mary Frew, P Goody, Mr and Mrs Mitchell
West Somerton	Thomas Haig
Weybourne	Mr C Harrison, Mrs P Kennett, Mr and Mrs Rayner
Wiveton	Mr F Crossley, Mr and Mrs Hoare

Nature Conservation Designations

The following table lists the various nature conservation designations which apply to land within the AONB. Some areas of land, most notably the coastal strip, may be included under more than one of these designations. The table is arranged in descending order of importance i.e. sites of global → European → national → local importance. However the strength of protection a site receives does not always increase in proportion with its accredited importance. For example the European sites have stronger protection under UK law than the globally important Ramsar sites.

Designation	Explanation	No. & names of sites within AONB	
Ramsar Site	The Convention on Wetlands of International Importance especially as Wildfowl Habitat was adopted at a meeting of countries held at Ramsar, Iran in 1971. The UK Government signed the convention in 1973 and became a contracting party in 1976 and in so doing accepted a commitment to promote both the conservation of particular sites and the wise use of wetlands within its territory.	2	The Wash North Norfolk Coast
Special Area of Conservation (SAC)	The UK Government has an obligation to designate and protect SACs under the European Commission Habitats Directive 1994. They are protected under the same Regulations as SPAs and are considered internationally important for species and habitats. Before being designated as a SAC any terrestrial site must already be an SSSI.	4	The Wash & North Norfolk Coast (marine) Norfolk Coast and Gibraltar Point Dunes (terrestrial) Dersingham Bog Winterton & Horsey Dunes
Special Protection Area (SPA)	The UK Government has an obligation to designate and protect SPAs under the European Commission Directive on Wild Birds 1979. These sites are considered to be internationally important for birds. All such sites must already be SSSIs, but SPA designation gives them enhanced protection under the planning system through the UK Habitat Regulations.	3	The Wash North Norfolk Coast Great Yarmouth and North Denes
National Nature Reserve (NNR)	Some of the best SSSIs are designated as NNRs by English Nature under the National Parks and Access to the Countryside Act 1949. They are managed with nature conservation as the primary objective, by English Nature or other approved conservation bodies.	5	Holme Dunes Scolt Head Island Holkham Blakeney Point Winterton Dunes
Site of Special Scientific Interest (SSSI)	Designated by English Nature under the Wildlife and Countryside Act 1981. Sites are protected legally under the Act but positive conservation management relies mainly on the co-operation of landowners.	27	including the North Norfolk Coast SSSI which covers 7700 hectares
Local Nature Reserve (LNR)	Designated by local authorities in consultation with English Nature, under the National Parks and Access to the Countryside Act 1949. The local authority agrees to ensure that the site is managed for wildlife.	1	Wiveton Downs
County Wildlife Site (CWS)	A non statutory designation. Local authorities have adopted County Wildlife Sites into the planning process and the Norfolk Structure Plan and District Local Plans contain policies to protect them.	85	

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EX 4985

Kelling to Cromer Strategy Study
Hydrodynamics

Report EX 4985
Release 2.0
November 2006

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Summary

Kelling to Cromer Strategy Study

Hydrodynamics Part II:

Technical support information

Report EX 4985
November 2006

This report addresses the sea conditions required within the Kelling to Cromer strategy study. Existing information on waves, tidal levels and tidal currents was collated, wave and tidal models were established and run, and results are presented for a number of locations within the study area.

These results provide the hydraulic loading conditions needed for calculations performed elsewhere within the strategy study, in terms of:

- tables and roses of wave climate and extremes;
- tables of extreme sea levels;
- maps and tables of tidal currents;
- tables of extreme combinations of waves and water levels.

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1. Introduction

This report is concerned with the hydraulic loading that changes the shoreline, namely the waves, tidal currents, and tidal levels. An accurate estimate of these processes is an important factor both in quantifying beach behaviour and in assessing the types of coastal management or defence scheme that may be feasible.

Current data were obtained from published sources and from the tidal flow model used during this study. Results were produced through the tide throughout the two strategy study areas and further offshore. Illustrative results are given in this report as maps of tidal currents at particular states of the tide, and tabulations and plots through the tide for particular locations.

A wave model was set up for the area, and predictions were made for one offshore and eleven nearshore locations in the study area. Illustrative results are provided for the following three locations: Kelling, Sheringham and Cromer.

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 joint probability extremes of waves and water levels were also produced for the three locations.

Results in addition to those shown in this report were made available for other calculations elsewhere in the study as necessary.

This report was prepared in 2004 and the information contained is correct to that time. For the current issue, minor revisions have been undertaken to include the recent Defra guidance on sea level rise due to climate change.

2. Tidal Levels

The tidal level at any instant in time will be the summation of an ‘astronomical’ tidal level and a ‘residual’ level caused by meteorological effects. While astronomical tidal level is accurately forecasted in published tide tables, the residual components (i.e. atmospheric pressure, winds, and temperature) are not easily predicted. In summer, the ‘residuals’ are usually small and so the predicted tidal levels are close to those observed. In winter, however, deep atmospheric depressions and strong winds can radically alter the propagation of the tides. The most important effect occurs when a ‘storm surge’ is created. A storm surge is a wave-like disturbance of the sea surface that typically travels southwards down the North Sea increasing in amplitude as it travels into the narrower area between East Anglia and the European mainland. If a large storm surge coincides with a high astronomical tidal level, then the resulting ‘total’ water level can cause great problems to coastal defences, and occasionally leads to disastrous flooding of low-lying areas, for example in 1953 and 1978. This chapter therefore considers both the astronomical tides and the residuals / surges, before deriving estimates of exceptional high total water levels, with contributions from both.

2.1 ASTRONOMICAL TIDES

The propagation of tides in the southern North Sea, and hence along the coastline of North Norfolk, is far from straightforward. Put simply, the tide off the East Anglian coastline travels as an anti-clockwise gyre or eddy centred close to Great Yarmouth. The rise and fall of the tide is small close to the centre of this gyre, increasing further from the centre. Hence, on a mean spring tide at Great Yarmouth or Lowestoft, the vertical difference between high and low water level (the tidal range), is only 1.9m, increasing to 6.5m at Hunstanton (see Figure 2.1). At Cromer, the mean spring tide range is about 4.4m, increasing slightly moving westward through the study area.

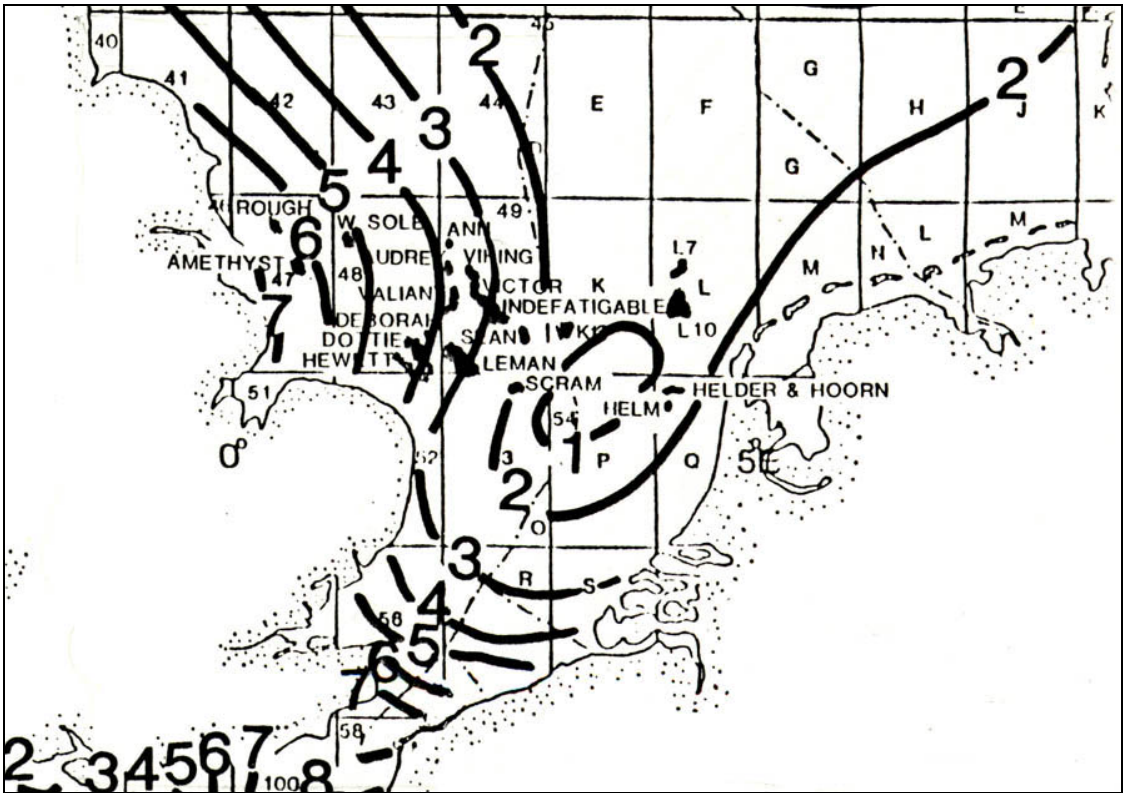


Figure 2.1 Tidal level variation off the East Anglian coastline (MHWS in mCD)

The variations in tidal levels at Cromer are particularly well understood because of the presence of an A-Class tidal gauge on the Pier. To the nearest 0.10m, the normal astronomical tidal levels (i.e. unaffected by atmospheric effects) are as follows:

		mCD	mODN
Mean High Water Springs	(MHWS)	5.2	2.45
Mean High Water Neaps	(MHWN)	4.1	1.35
Mean Sea Level	(MSL)	2.8	0.05
Mean Low Water Neaps	(MLWN)	2.1	-0.65
Mean Low Water Springs	(MLWS)	0.8	-1.95

Levels in the first column above are given relative to Admiralty Chart Datum at Cromer, which is set 2.75m below Ordnance Datum Newlyn (ODN).

Corresponding figures for Blakeney, the next position west of Cromer for which values are given in the Admiralty Tide Tables, are:

	mCD	mODN
MHWS	3.4	2.6
MHWN	2.0	1.2
MSL	---	---
MLWN	---	---
MLWS	---	---

Sheringham lies about four tenths of the distance between Cromer and Blakeney, and Kelling about seven tenths of the distance. Tidal range data were therefore estimated as follows:

	Kelling mODN	Sheringham mODN	Cromer mODN
MHWS	2.55	2.51	2.45
MHWN	1.25	1.29	1.35
MSL	0.05	0.05	0.05
MLWN	-0.65	-0.65	-0.65
MLWS	-1.95	-1.95	-1.95

2.2 SURGES AND RESIDUALS

North Sea surges have been studied by a variety of authors (Hunt 1972, Keers 1966, and Corkan 1948). Some of this work is briefly summarised here.

North Sea surges tend to originate off the north-west coast of Scotland, and propagate into the North Sea in the form of a progressive long wave. Coriolis force guides the surges southwards down the eastern coast of the UK and around the North Sea in an anticlockwise direction. The speed of propagation of the surge is similar to that of the astronomical tidal wave.

The meteorological conditions that produce surges in the North Sea are varied. The most severe surges are generally of the type described below.

Large low-pressure systems tracking north-eastwards from the Atlantic Ocean, between Iceland and the British Isles, generate strong south westerly winds. These winds cause a small positive surge on the north-west coast of Scotland, as water 'piles up', and a small negative surge on the east coast of the UK, as water is pushed towards Norway.

As the depressions move further north-eastwards, the wind veers and starts to blow from the north. These northerly winds further enhance the surge, which by now will have propagated across the north coast of Scotland and into the north-west North Sea. This surge travels down the eastern coast of Britain being constantly reinforced by strong northerly winds, and reaches a maximum in the south western corner of the North Sea (see Figure 2.2). In the study area, the maximum surge elevation expected once in 50 years is between 2.50 and 2.75m.

As surges propagate into the shallower water in the southern North Sea, surge tide interaction can become a prominent feature. That is to say the extent of the surge can be amplified or restricted depending on the astronomical tidal level at the time.

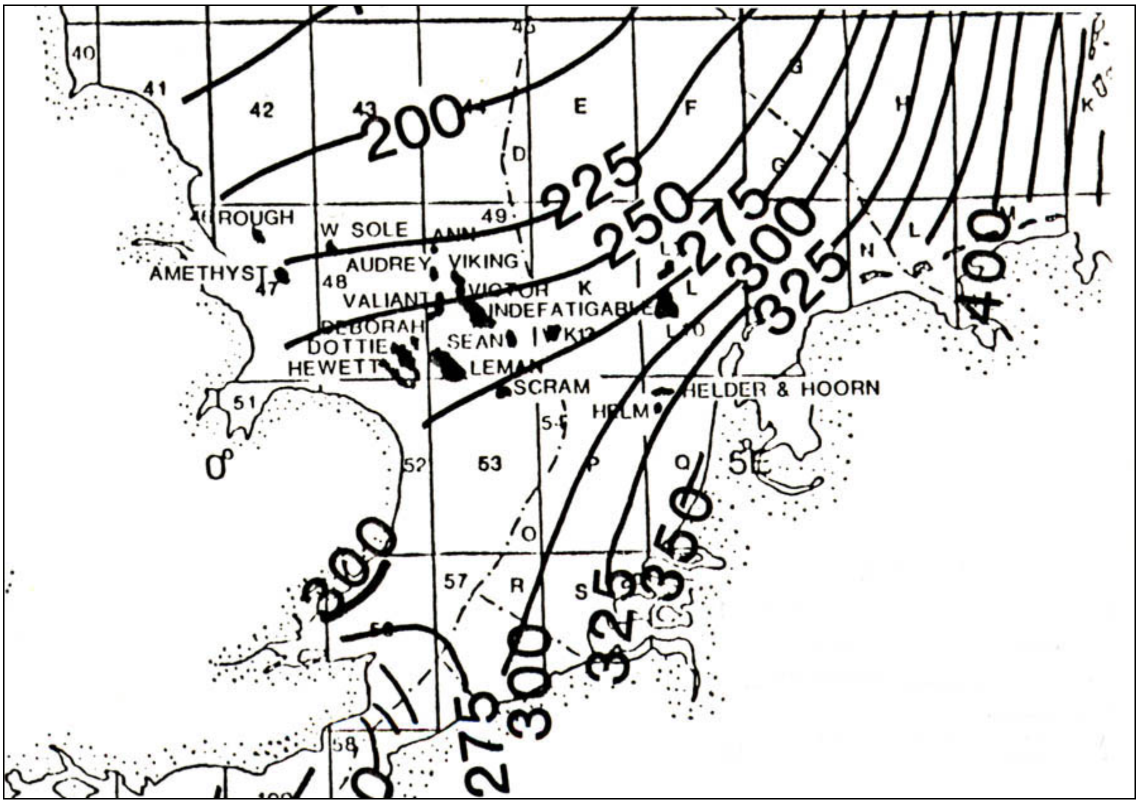


Figure 2.2 Tidal surge levels - expected maximum elevation once in 50 years (cm)

2.3 TOTAL WATER LEVELS

Extreme water levels (tide + surge) around the UK have been studied by a variety of authors over a number of years (Graff 1981, Flather 1987, and Dixon & Tawn 1994, 1995, 1997). Dixon and Tawn (1997) use the most advanced methods and their work is generally regarded as containing the most accurate information. The results have thus been adopted for use in this study.

Dixon and Tawn (1997) provide estimates of 1-year water levels, together with tabulated values that are added to the 1-year level to obtain higher return period estimates. Results for the A-Class tide gauge sites are detailed, together with each grid point on POL's surge model (spacing 12km) around the coast of the UK. Statistical fitting procedures have been used to obtain spatially smoothed results. The relevant results for Cromer are reproduced in Table 2.1. Dixon and Tawn (1997) recommend that, where the 1-year water level at the location of interest is known with greater confidence (for example, from local gauge measurements) than the estimate provided, then the local estimate should be used. The A-Class tide gauge at Cromer has been analysed to provide this 1-year total water level and the extreme values then estimated following the recommendations made by Dixon and Tawn. Extreme levels at Kelling and Sheringham are taken 0.10 and 0.06m higher than at Cromer, respectively, based on differences between MHWS at the three locations. Results of this analysis are given in Table 2.2, giving present-day extreme water levels for Kelling, Sheringham and Cromer, in mODN.

Table 2.1 Water level extrapolation at Cromer (Dixon and Tawn, 1997)

Return period (years)	10	25	50	100	250	500
Addition to one year level	0.53	0.74	0.87	1.08	1.28	1.41

Table 2.2 Extreme (present-day) water levels for Kelling, Sheringham and Cromer (mODN)

Return period (years)	1	10	25	50	100	250	500
Kelling	3.27	3.80	4.01	4.14	4.35	4.55	4.68
Sheringham	3.23	3.76	3.97	4.10	4.31	4.51	4.64
Cromer	3.17	3.70	3.91	4.04	4.25	4.45	4.58

2.4 ALLOWANCE FOR CLIMATE CHANGE

2.4.1 Past climate change estimates

Dixon and Tawn (1997) indicate a rate of sea level rise in the recent past of 1.7mm/yr for this area, approximately equal to the global average value. Wave predictions done in previous HR Wallingford studies off Norfolk and Lincolnshire show significant variability in wave height from year to year, but no significant overall trend. A tentative prediction of future wave conditions for the same area, based on the output of a global meteorological model of present and future wind conditions, does not indicate that a significant change should be expected. Thus, the nationally accepted figure for future sea level rise has been used in this study, and attempts to represent future change in wave conditions are regarded as a sensitivity test rather than a prediction.

2.4.2 Future climate change allowances

The above discussion of tidal levels is based on present-day information and measurements. Because of continuing climate changes, particularly the increase in temperature of the world's oceans, mean sea level is increasing. Predictions from various numerical simulations of the world's atmosphere in the coming few decades, and other sources, seem to be agreed that the present rate of increase in mean sea level will accelerate. Since this will occur over the expected lifetime of a coastal defence structure, it is necessary to anticipate higher tidal levels in any consideration or design of such defences.

Table 4.4 of MAFF (1999) recommends an appropriate precautionary allowance for future mean sea level rise of 6mm/yr for the Anglian 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. In this instance, there is some additional information from a Defra-funded study at HR Wallingford into the future vulnerability of sea defences. In calculations for Mablethorpe, HR Wallingford (2001a) allowed future winds, waves, surges, beach profiles, and tidal ranges to change in addition to mean sea level. This study showed that the 'normal practice' is a fair approximation of the overall change in vulnerability.

To apply the allowance of 6mm/yr, all the predicted present-day water levels are raised by 6mm times the number of years ahead being considered. For example, at the end of a 50-year design life, all levels would be assumed 300mm higher. Note that this has a dramatic effect on the predicted return period of the total water levels presented in Table 2.2 above. At present, the annual chance of the water level rising to over 4.0m ODN at Cromer is only approximately 2%. However, by 2050, this probability will have increased to approximately 10%.

Updated guidance on climate change impacts has recently been published by Defra (October 2006) with new estimations for sea level rise. Table 2.3 below summarises this advice for the area.

Table 2.3 Net sea level rise allowances (Defra, 2006)

Area	Net sea-level rise (mm per year)			
	1990-2025	2025-2055	2055-2085	2085-2115
East of England, East Midlands, London, SE England	4.0	8.5	12.0	15.0

3. Tidal Currents

Strong tidal currents accompany the rapid spatial changes in tidal range along the coastline of North Norfolk. An initial appraisal of such currents can be gained from the information published on the Admiralty Charts (106, 108) for this coastline. Details on measured current speeds and directions are provided at two locations in and around the study area. These details are reproduced in the following Tables 3.1 and 3.2. Position B is about 14km directly offshore of Mundesley, inshore of the north-western end of Haisborough Sand. Position A is 15km offshore from Sheringham. Using the opposite convention for winds (i.e. direction to which the current is flowing), the directions are given in degrees relative to True North. Thus, just before high water, the current (direction approximately 120-150°N depending on the location) is travelling approximately from the north-west to the south-east.

Table 3.1 Tidal streams – Offshore from Mundesley (from Admiralty Chart 106)

Position B	52° 59.0′ N	1° 35.0′ E	
Time relative to HW at Immingham	Direction	Speed (knots)	
		Spring	Neap
-6hr	327	1.7	1.0
-5hr	327	2.6	1.5
-4hr	327	2.7	1.6
-3hr	327	1.9	1.1
-2hr	327	0.7	0.5
-1hr	147	0.6	0.3
HW	147	1.6	0.9
+1hr	147	2.4	1.4
+2hr	147	2.4	1.5
+3hr	147	1.9	1.2
+4 hr	147	1.1	0.6
+5hr	327	0.1	0.1
+6hr	327	1.6	0.7

Table 3.2 Tidal streams – Offshore from Sheringham (from Admiralty Chart 106)

Position A	53° 05.4′ N	1° 13.2′ E	
Time relative to HW at Immingham	Direction	Speed (knots)	
		Spring	Neap
-6hr	300	1.9	1.0
-5hr	296	2.4	1.2
-4hr	289	2.4	1.2
-3hr	281	1.6	0.8
-2hr	248	0.4	0.2
-1hr	131	0.7	0.4
HW	120	1.6	0.8
+1hr	115	2.1	1.1
+2hr	111	2.1	1.1
+3hr	109	1.6	0.8
+4 hr	087	0.6	0.3
+5hr	326	0.6	0.3
+6hr	301	1.6	0.8

Tables 3.1 and 3.2 provide information on the variation of tidal current velocities throughout both a mean Spring and a mean Neap tide, with speeds given in knots (1 knot ≈ 0.51m/s or 1.16mph). Unfortunately, the time-base for these tables is relative to high water at Immingham. High water at Cromer occurs approximately 30-50 minutes later than at Immingham. Once this adjustment is made, the tables indicate that minimum current speeds (slack water) occur roughly half-way between high and low water. The currents are remarkably rectilinear off Mundesley (probably an effect of the Haisborough Sand) while further north and west there is some variation in current direction with an anticlockwise circulation during the tidal cycle. However, the use of information on tidal currents measured well offshore, and presented using timings relative to Immingham, is not an ideal approach for the study of coastal processes at the coastline of the study area.

For a more detailed appraisal of tidal currents close to this shoreline, therefore, we have used a numerical model. HR has developed a regional tidal flow model of the southern North Sea using the finite element based model TELEMAC (HR Wallingford, 1998). TELEMAC, developed by LNH Paris, uses a completely unstructured grid enabling the detailed simulation of a particular area of interest while using larger model elements to keep any imposed boundary conditions distant.

For the southern North Sea regional model, the model boundaries were from Scarborough to Den Helder in the north, with southern boundaries within the English Channel. Imposed tidal levels generated from tidal harmonics drove the model at these boundaries. The finest model resolution has been concentrated around the UK coast with a grid size of 1.5km around the study area.

Since its establishment, the regional model has been widely used, to include strategic studies of sediment transport in the southern North Sea by HR Wallingford (2001b). In this study, HR Wallingford included comparisons of various versions of the model with tidal currents synthesised from harmonics in the area. This model can provide predictions of the rise and fall of the tide, and the simultaneous tidal currents, at any location. Figure 3.1 shows a portion of seabed as represented in this model. On this figure, the coastline extends from approximately Blakeney Point to the west to Happisburgh to the east. The seabed contours are shown relative to ODN and extend offshore to beyond the 20m contour.

The inset figures show the tidal rise and fall (solid line) and the tidal current speed at Points K, S and C about one kilometre offshore from Kelling, Sheringham and Cromer, respectively, on about the -7mOD contour. It is clear from this that the times of greatest current speed coincide reasonably closely with the times of high and low water. To be more precise, maximum flood currents (i.e. going to the east) occur about one hour later than high water, and maximum ebb flows about one hour after low water.

Figures 3.2 to 3.5 are snapshots of tidal currents during the simulation of a series of spring tides beginning 21 March 2000, in the form of arrows whose length indicates the current speed and orientation indicates the current direction. The tidal currents can be seen to be generally coastline parallel with some directional changes caused by the offshore sandbanks, which are a feature of the area. Offshore, near the locations of the Admiralty measurements from Charts 106 and 108, the model results agree well, in both speed and direction, with the results presented in the tables above. Current speeds are slightly lower closer inshore because of the increased frictional resistance of the seabed. However, they are predicted to be about 0.8m/s (1.5kt) at high water, slightly slower at about 0.6m/s (1.2kt) at low tide. (Note that, at low tide, water depths close to the shore are less than at high tide, and this further increases the frictional resistance). These current speeds, on their own, are capable of mobilising and transporting large quantities of seabed sediments up to the size of small gravel. The added effects of breaking waves, which disturb and agitate much larger gravel and shingle particles, means that tidal currents along this coast strongly affect beach sediment transport.

A particular feature of this part of the Norfolk coastline is that the strongest tidal currents will occur at about the time of high water during an exceptionally large tide. While this occurs regularly during Spring tides, it will also occur during storm surges, which will increase the total water level and add to the eastward flowing currents. On such occasions, winds are normally from the north or north-west, and will therefore create large waves along the Cromer frontage as well as affecting the tides.

Such a combination of events will occur several times during a winter, and will have a strong effect on beaches, producing sediment transport both along the shore and offshore, with a flattening of the beach profile. Such events are referred to by local fishermen as ‘scouring tides’, and this is an appropriate if unusual terminology. Such strong currents close to the shoreline will interact strongly with groynes or breakwaters, and this issue needs to be borne in mind when considering the design of such structures.

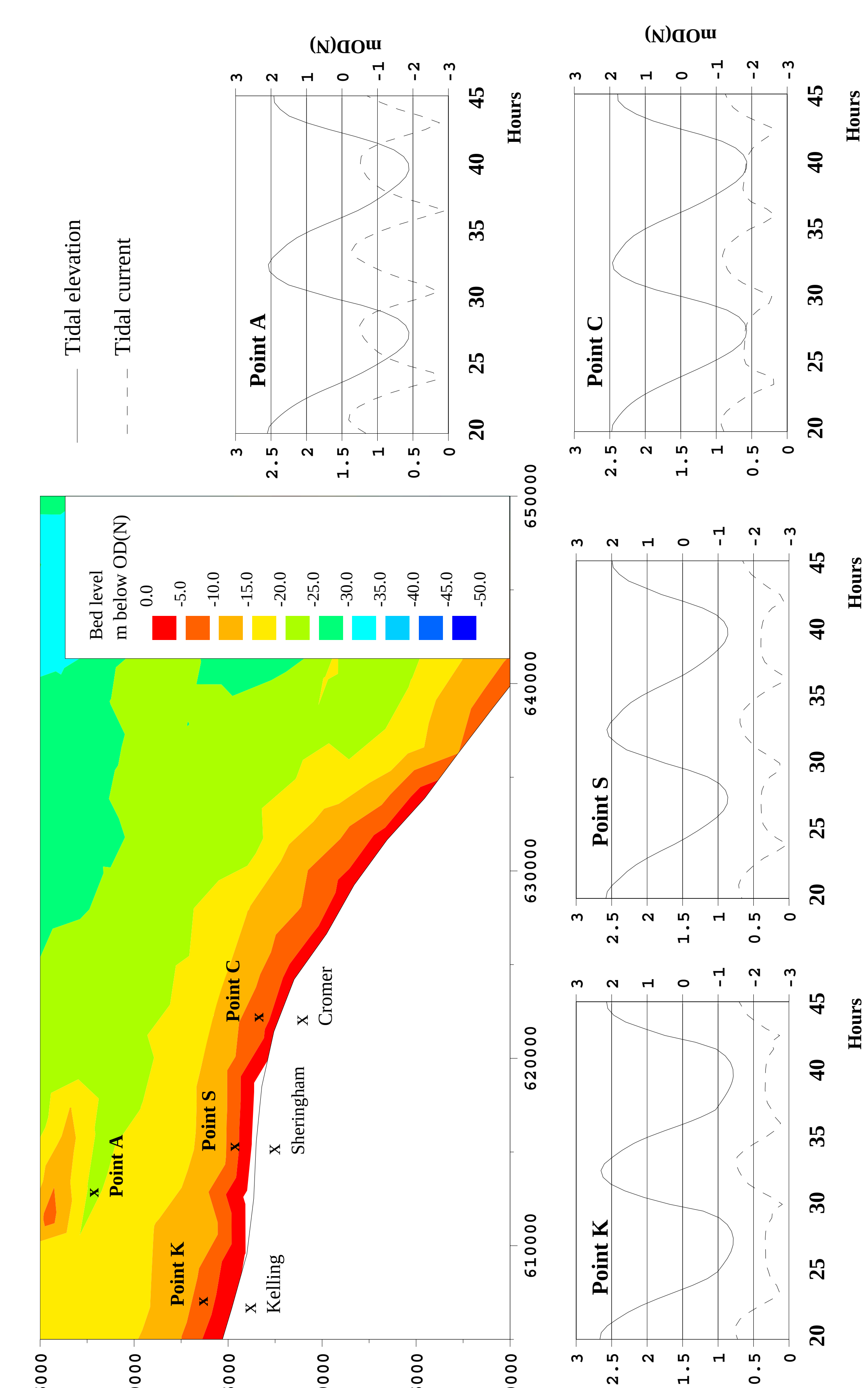


Figure 3.1 Seabed bathymetry between Kelling and Happisburgh

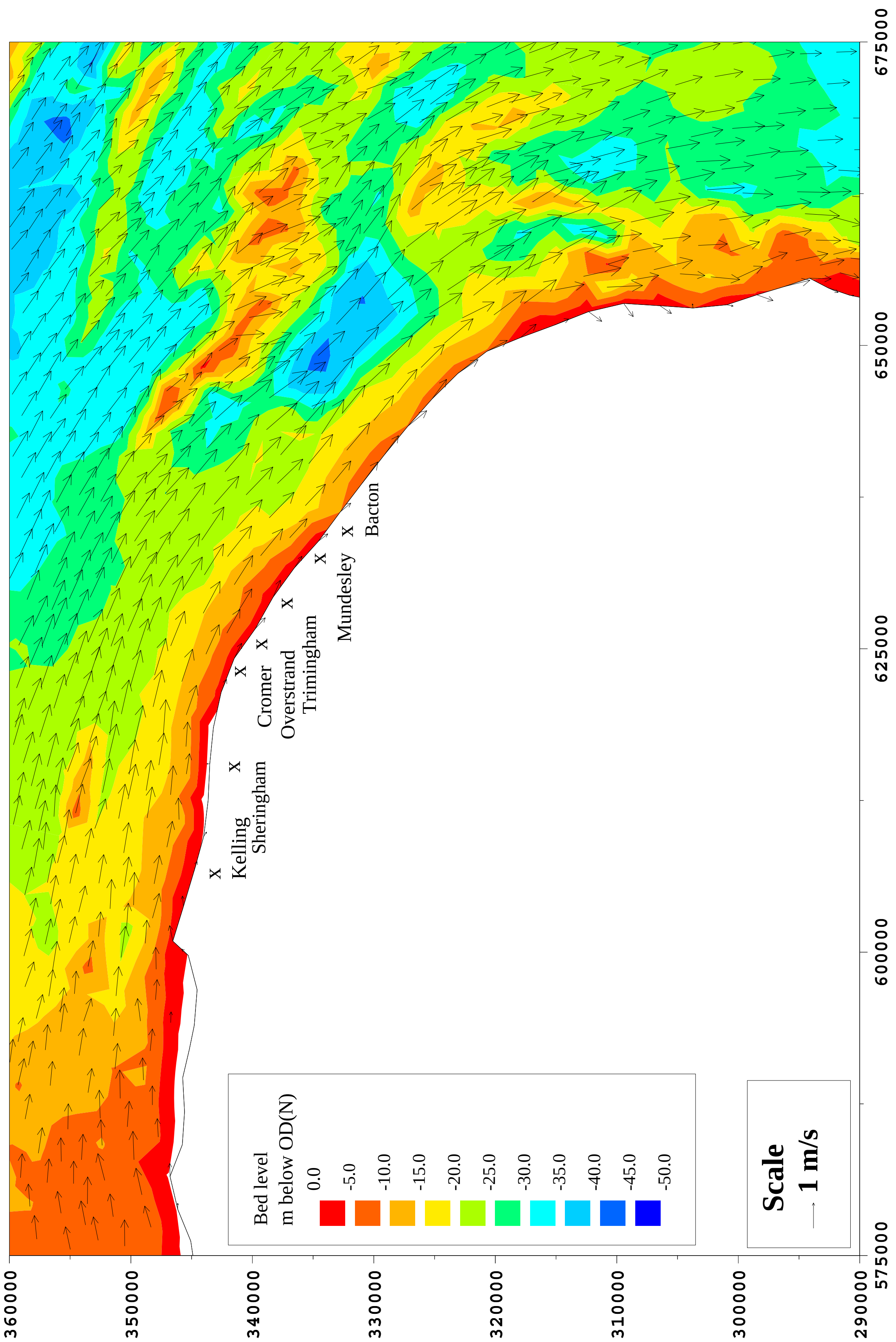


Figure 3.2 Ebb tidal currents on a spring tide

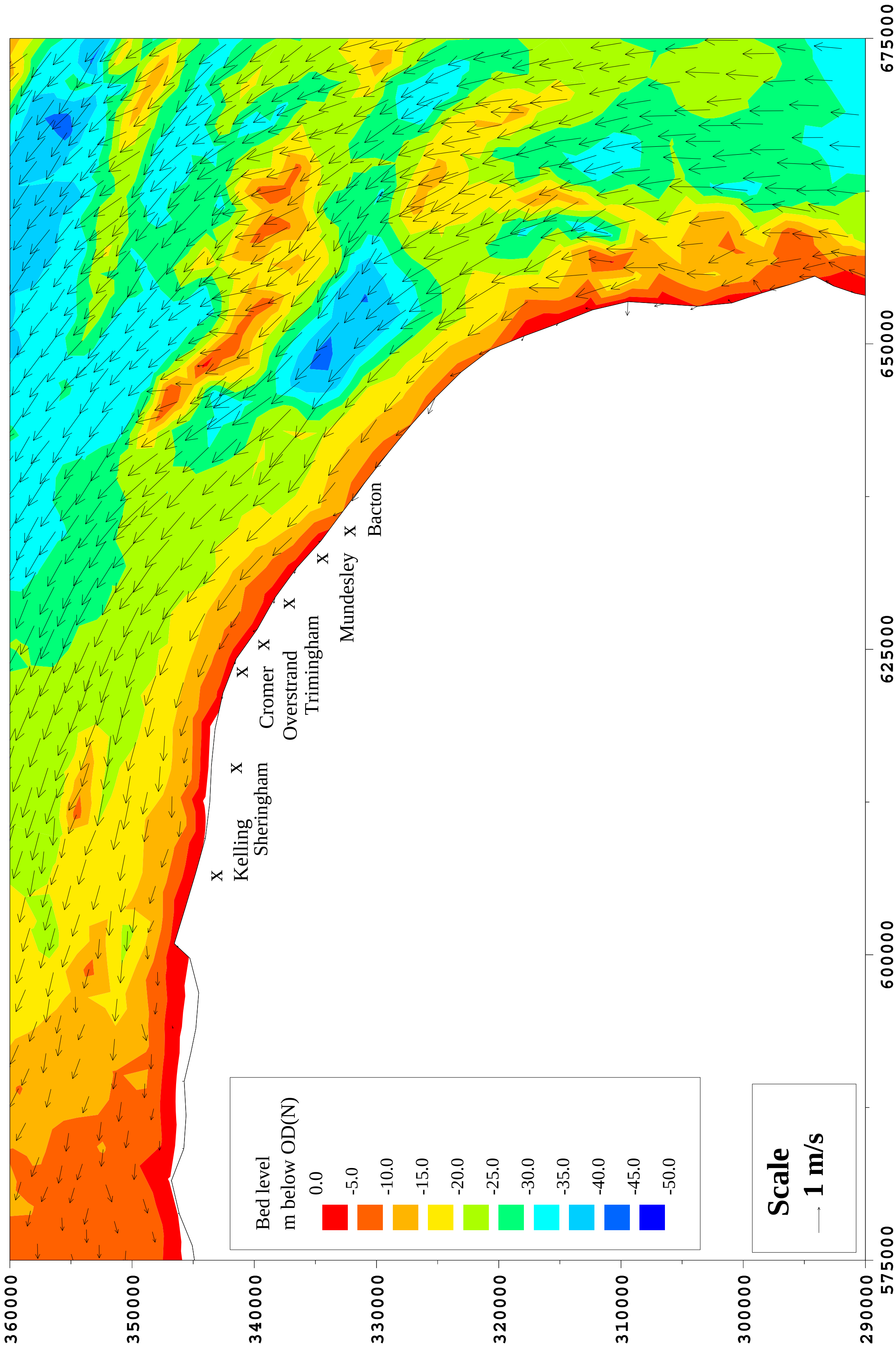


Figure 3.3 Flow tidal currents on a spring tide

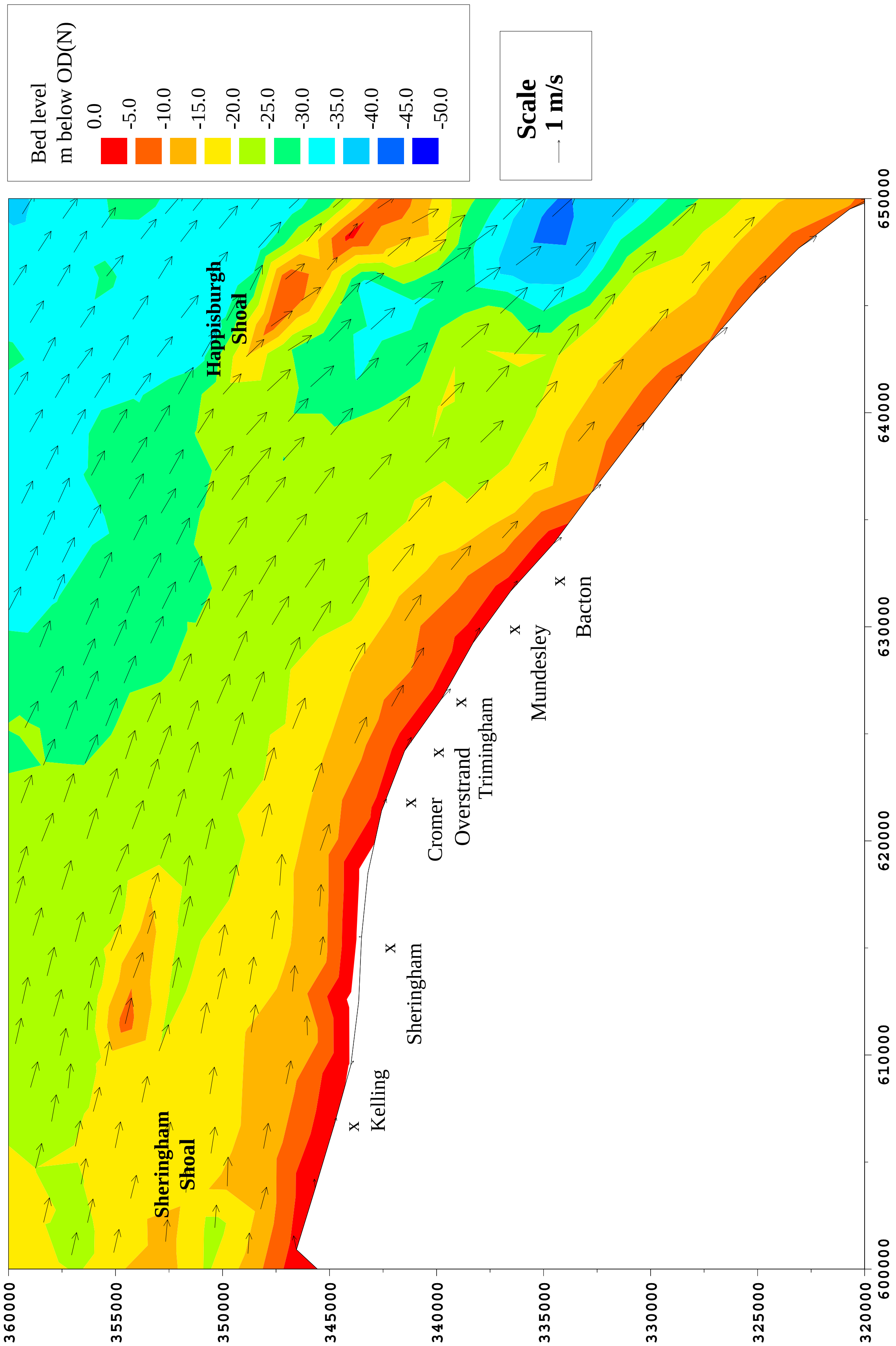


Figure 3.4 Ebb tidal currents on a spring tide (local area)

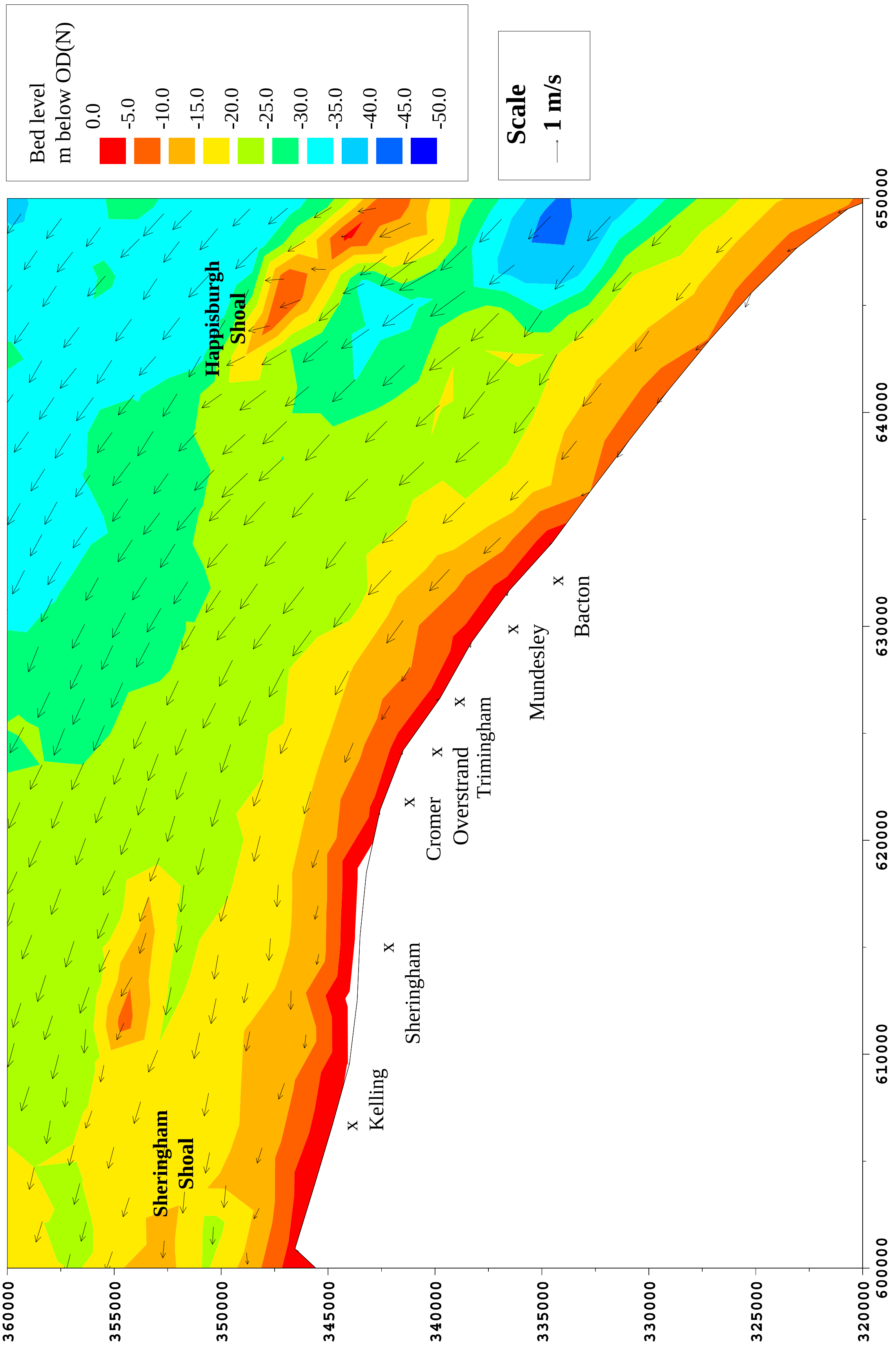


Figure 3.5 Flow tidal currents on a spring tide (local area)

4. Wave Conditions

4.1 INTRODUCTION

The major force for changes in the coastline of North Norfolk and of its beaches is wave action. Along the study area, the coastline is exposed to waves generated within the North Sea from all directions between approximately 300°N and 90°N. However, waves are predominately from between North (0°N) and 70°N, since the fetch lengths for this sector all exceed 500km (see Figure 4.2). For this study, it is necessary to obtain information on wave conditions close to the coastline in order to predict longshore sediment transport rates, and the future evolution of the shoreline. Such predictions will also provide estimates of the largest waves likely to occur, and these will be useful in the design of any coastal structures in the development of a defence scheme, following the completion of this strategy study. Wave conditions were predicted both offshore and at eleven nearshore points on the -3.25mOD contour (see Figure 4.1). Full results for Kelling, Sheringham and Cromer are provided in this report.

4.2 PREDICTING OFFSHORE WAVE CONDITIONS

As an initial step in predicting 'nearshore' wave conditions, it is necessary to predict 'offshore' wave conditions, i.e. in deep water ignoring the effects of the changing water depth closer to the coast. For this study, offshore wave conditions were predicted using a numerical model named HINDWAVE. This model simulates the growth of waves under the action of winds and requires, as input data, information on the area over which waves are created and on wind conditions measured close to the study frontage. This modelling approach has been used several times previously for studies of the coastline of East Anglia, for example for the detailed study of the coastal defences at Sheringham, in 1994 (HR Wallingford, 1994).

The model has been verified by comparison with long-term visually observed wave climate data off the North Norfolk coast, at Smith's Knoll light vessel, as part of the Anglian Coastal Management Study carried out for the NRA in 1988. HR Wallingford (1988) provides a comparison between the HINDWAVE and Smith's Knoll wave climates for this study. In this instance, the model input was taken from sequential land-based wind data from Gorleston (near Great Yarmouth). However, the wind speeds were appropriately increased to represent over-water conditions and extended in duration using synthetic wind data from an UK Met Office weather model.

The wave modelling for the present study used the same HINDWAVE model, but with a somewhat improved user interface. Again, sequential wind data from Gorleston was used, with the same adjustments to the wind speeds as used in the original 1988 study. However, the wind data available from this site now covers a longer period, i.e. from 1978 to 1994, extended to 2001 using weather model data allowing us to produce corresponding offshore wave conditions for a period of 23 years.

4.3 ALLOWANCE FOR THE EFFECTS OF HAISBOROUGH SAND

A second validation of the results of the HINDWAVE model, using wave measurements made well offshore from Cromer, was also undertaken during the 1988 study. In view of the results obtained, this validation exercise was re-visited during a subsequent research study in 1989. This second study showed the benefits of making some allowance for wave attenuation over the offshore banks. Predictions with no allowance for banks tended to be too high, whilst the refined predictions were significantly better. HR Wallingford (1989) gives a comparison between the wave measurements off Cromer, the 'standard' HINDWAVE predictions and the modified, 'shallow water' HINDWAVE results.

This earlier work therefore indicated that the standard HINDWAVE model would be likely to over-estimate wave conditions unless the effects of Haisborough Sand were taken into account. The first step in the wave prediction process in the recent study was therefore to adjust the standard HINDWAVE prediction for a location offshore of Cromer to account for the dissipation of wave energy over this sandbank. This is particularly important for waves approaching from the eastern sector.

At low tide especially, the water depths over this bank will cause significant wave breaking, and hence a reduction in wave heights from the seawards to the landwards side of the bank. This effect will vary in intensity along the length of the bank, depending on its crest height.

For the present study, however, the main emphasis is on the prediction of waves at times of high tidal level, when the beaches and cliffs will be most strongly affected by wave action. This is also the situation when coastal defence structures will be most at risk from damage by waves. We are only interested in calculating a 'representative' wave climate in this strategic study, rather than very detailed, location-specific conditions for the design of a structure. Such more complicated and costly calculations would be needed at the 'scheme appraisal' stage for any proposed coastal defence, as part of the detailed design calculations needed at that time.

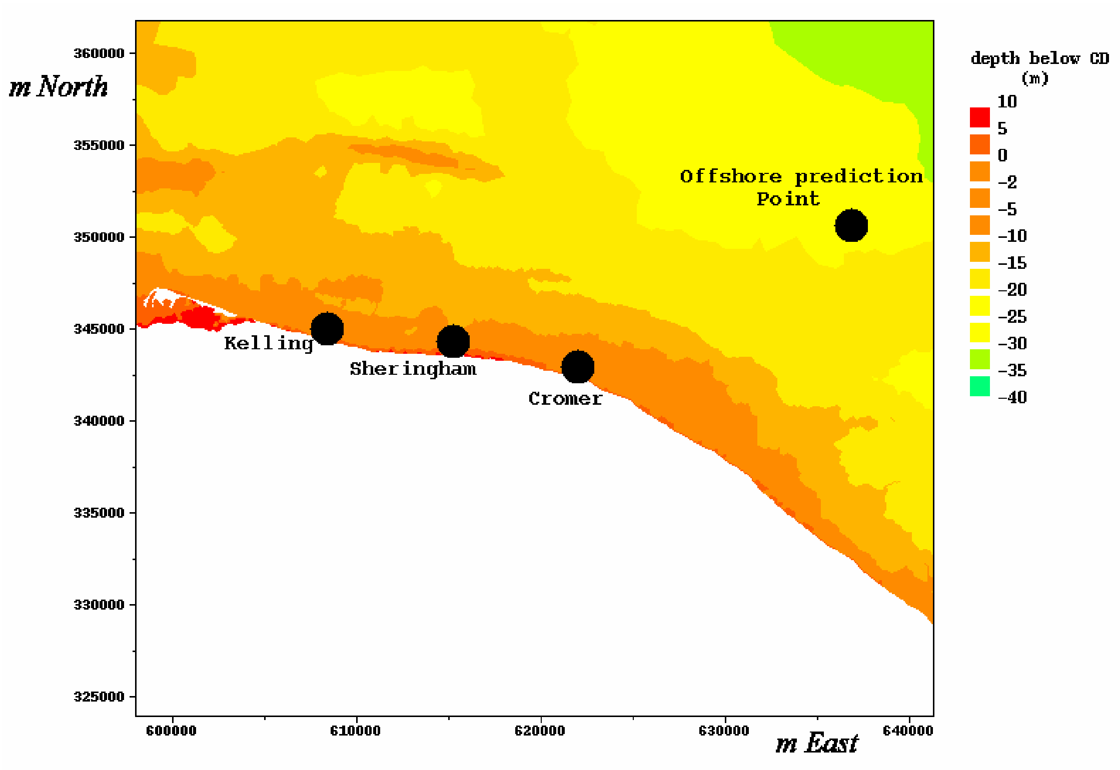
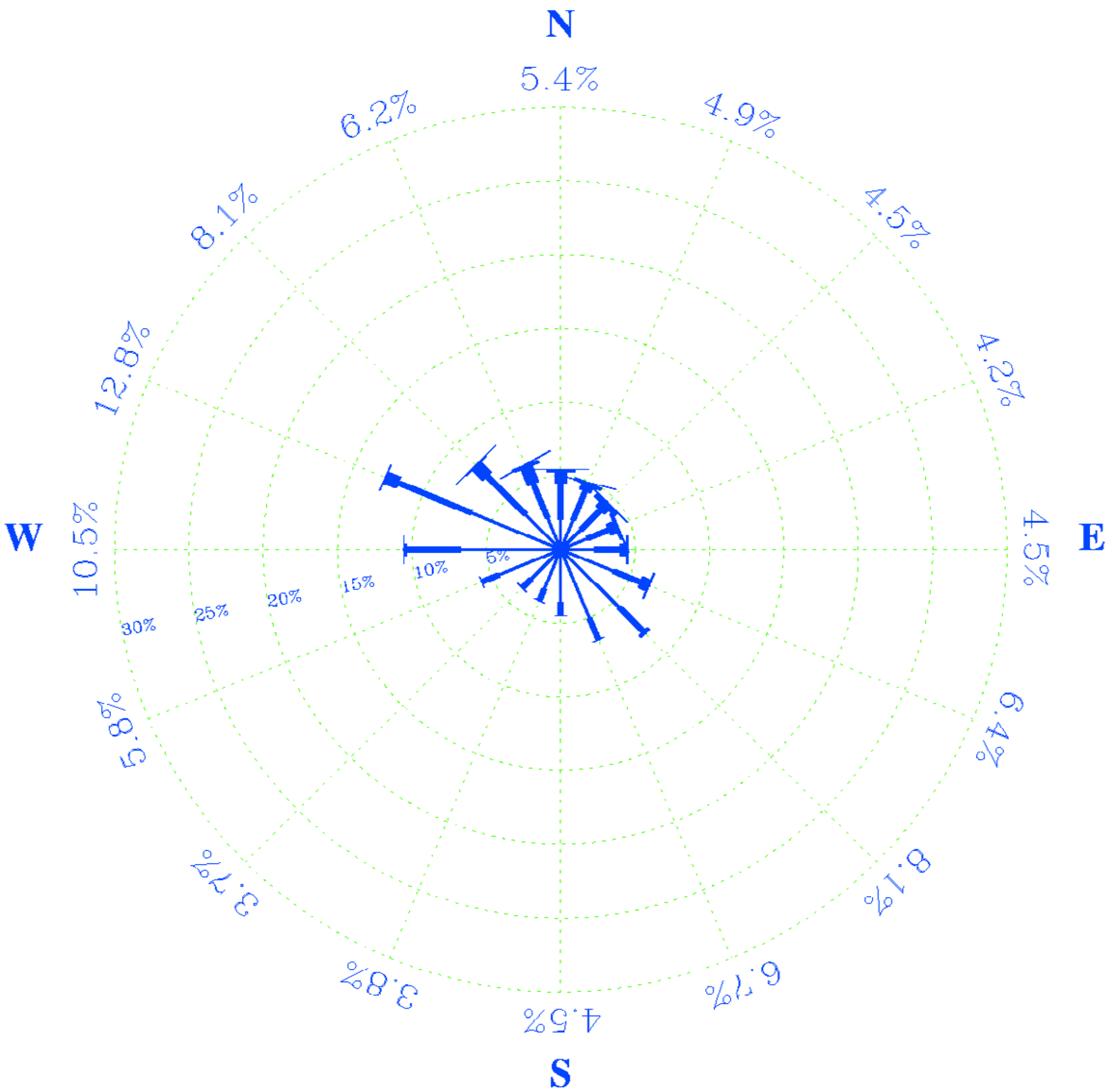


Figure 4.1 Offshore and nearshore wave prediction points

Figure 4.2 Fetch lengths for the generation of waves at Cromer

Because of this, a simplified approach was taken to account for the effects of Haisborough Sand on the offshore wave conditions. This simplification involved calculating the depth-limited maximum wave height over its crest and hence limiting the maximum wave heights that can occur on its landwards side. The results from the two-stage prediction of offshore waves, described above, are in the format of wave conditions, i.e. height, period, and direction, for each hour of the 23 years for wind data. While this amount of information is too substantial to present in this report, it is retained in electronic format for potential use in the future. For the purposes of this report, only a summary of the wave information is presented. One straightforward and visually appealing method of summarising the data is to use a wave rose as shown in Figure 4.3. This gives information on the frequency of occurrence and height of waves approaching the shore location from different directions.

It can be seen that the largest waves of all are likely to arrive from the north and north-east (337, 000, 022 and 045°N), but the most frequent wave directions are from the north-west (270, 292 and 315°N). Alternative methods of summarising this offshore wave data are provided in Tables 4.1 and 4.2, which provide information on the probability of wave height against direction, and wave height against wave period, respectively.



Wave Height (m)

less than 1.00
1.00 - 2.00
2.00 - 3.00
3.00 - 4.00
greater than 4.00

Data analysed from:

1/ 1/ 78 to 31/03/ 2001

Figure 4.3 Wave rose showing offshore wave conditions

Table 4.1 Annual offshore wave climate – Wave height against mean wave period occurrence table *

H_s (m)	Mean wave period T_m (seconds)									
	0–1	1-2	2-3	3-4	4-5	5–6	6-7	7-8	8-9	9-10
0–1	0	314	27860	24945	0	0	0	0	0	0
1-2	0	0	1	13477	15751	2834	0	0	0	0
2-3	0	0	0	8	1578	4520	0	0	0	0
3-4	0	0	0	0	16	510	682	0	0	0
4-5	0	0	0	0	0	26	131	0	0	0
5-6	0	0	0	0	0	4	1	0	0	0
All H_s	0	314	27861	38430	17345	7894	814	0	0	0

Table 4.2 Annual offshore wave climate –Wave height against wave direction occurrence table *

	Mean wave direction (degrees North)											
H_s (m)	345-015	015-045	045-075	075-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345
0–1	2570	2545	2470	2927	5142	6475	4527	3502	4669	8162	6971	3158
1-2	2886	2511	2120	2114	2399	2514	1325	1188	1401	4182	5769	3551
2-3	952	529	641	593	578	92	15	18	23	188	1011	1464
3-4	199	258	301	149	42	0	0	0	0	7	65	187
4-5	20	42	62	8	1	0	0	0	0	0	5	19
5-6	5	0	0	0	0	0	0	0	0	0	0	0
All H_s	6732	5885	5594	5791	8161	9081	5867	4708	6093	12539	13821	8379

* Based on HINDWAVE predictions for 1 January 1978 to 31 March 2001, with data expressed in parts per hundred thousand; total number of wave predictions is 203784.

4.4 NEARSHORE WAVE CONDITIONS

Having predicted wave conditions in relatively deep water offshore, it was then necessary to calculate how these wave conditions alter as they travel towards the shoreline. As the water depths become shallower, so the direction and height of the waves alters as a result of refraction and shoaling. Because of the irregular nature of the seabed contours, it was necessary in this study to carry out a further numerical modelling exercise to predict nearshore wave conditions.

This modelling exercise involved creating a digital representation of the seabed offshore of Norfolk, using a combination of information from Admiralty charts, and the recent (2000) survey of the nearshore seabed. This latter survey was commissioned by North Norfolk DC as an early part of the strategic study of the defences at Cromer. The resulting bathymetric grid is depicted in Figure 4.4.

The offshore wave conditions were assumed to occur (uniformly) along the seaward boundary of this grid, and the grid itself formed the domain for a computational method for predicting wave transformation between the boundary and selected locations closer inshore. The method used for these predictions was the TELURAY model, which uses the concept of following wave 'rays' between the inshore locations and the seaward edge of the grid. Wave rays are lines perpendicular to the wave crests that run in the direction of wave propagation.

In brief, however, a matrix specifying the wave energy as a function of wave period and direction represents each hourly offshore wave condition. Using this matrix (and three matrices of identical size that summarise how wave rays travel between the inshore location and the edge of the bathymetric grid), the main parameters of the corresponding inshore wave conditions are predicted. The principal output is then the nearshore wave height, period and direction. Wave direction is particularly important, as this parameter is central for calculating the movement of beach sediment along the coast.

The wave transformation method used allows the (long) hourly sequence of offshore wave conditions to be converted into a corresponding sequence of nearshore wave conditions. Again, it is only necessary, in this report, to provide a summary of this substantial volume of results for three representative locations of interest, namely Kelling, Sheringham and Cromer. Figures 4.5-4.7 show wave roses, which can be compared directly with Figure 4.3 for the offshore wave conditions. Notice that there is less directional spread in the nearshore wave roses, because of the effects of wave refraction. Waves from 90°N have been substantially reduced in both height and frequency of occurrence compared to conditions offshore. Waves from the north-west sector (300-330°N) are predicted to occur much more frequently than for other directions, but the largest waves of all arrive from the North (030°N). Tables 4.3-4.8 present information on the nearshore wave conditions as probability tables in the same format used for the offshore waves (Tables 4.1 and 4.2).

The results of extremes analyses, based on fitting Weibull distributions to the overall wave height distributions given in Tables 4.4, 4.6 and 4.8, are given in Table 4.9. The corresponding wave periods, derived from the steepness ($2\pi H_s/gT_m^2$) of the highest few percent of waves in Tables 4.3, 4.5 and 4.7, are also listed in Table 4.9.

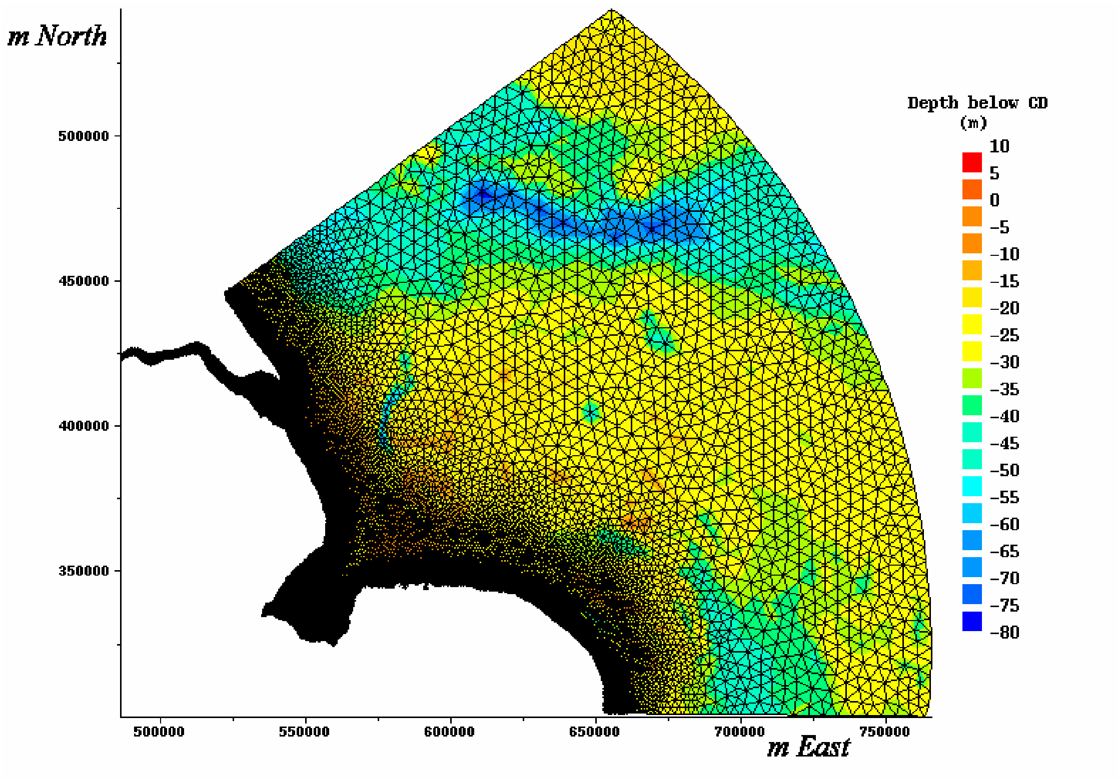


Figure 4.4 Bathymetric grid used for wave transformation modelling

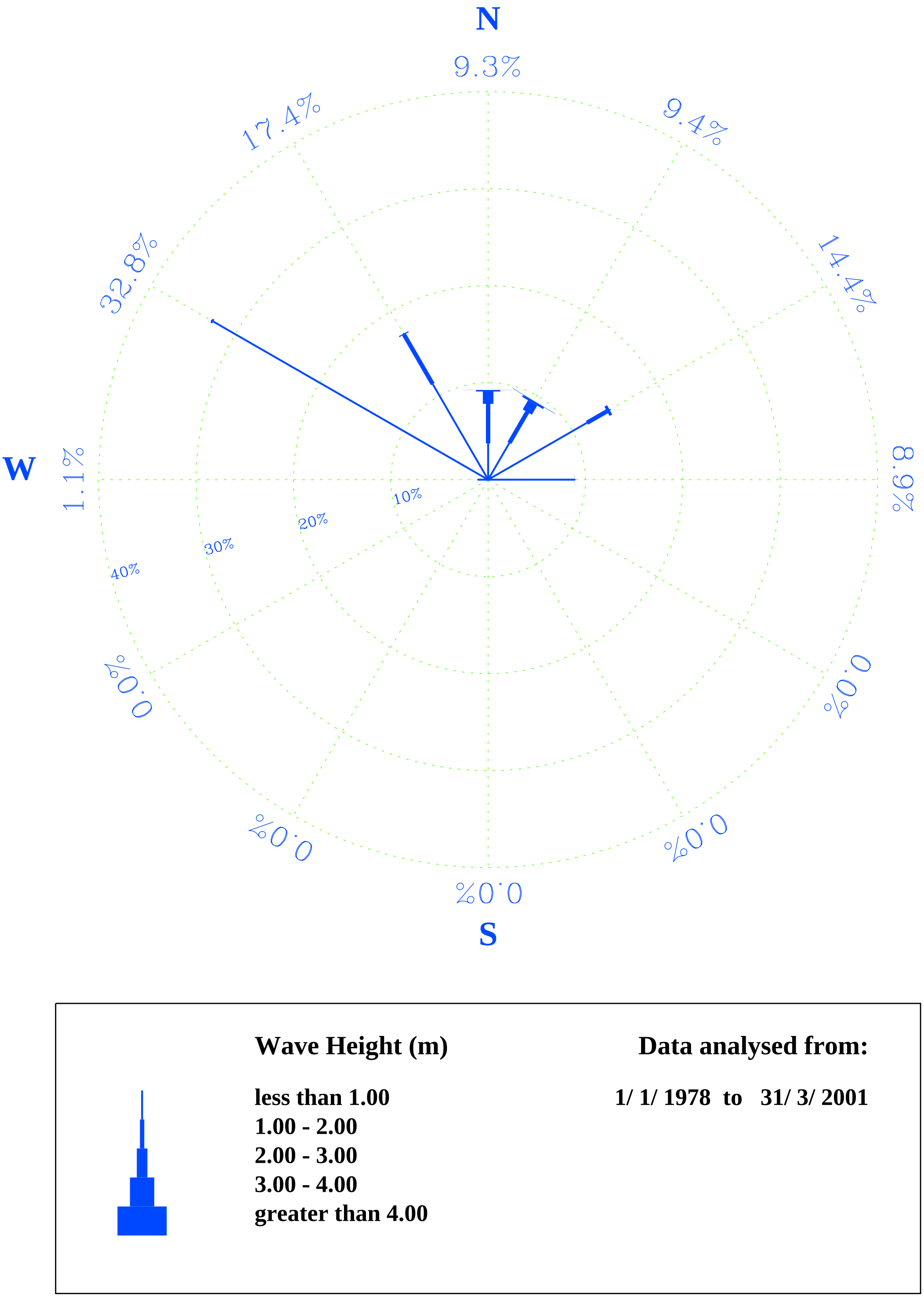


Figure 4.5 Wave rose showing inshore wave conditions – Kelling

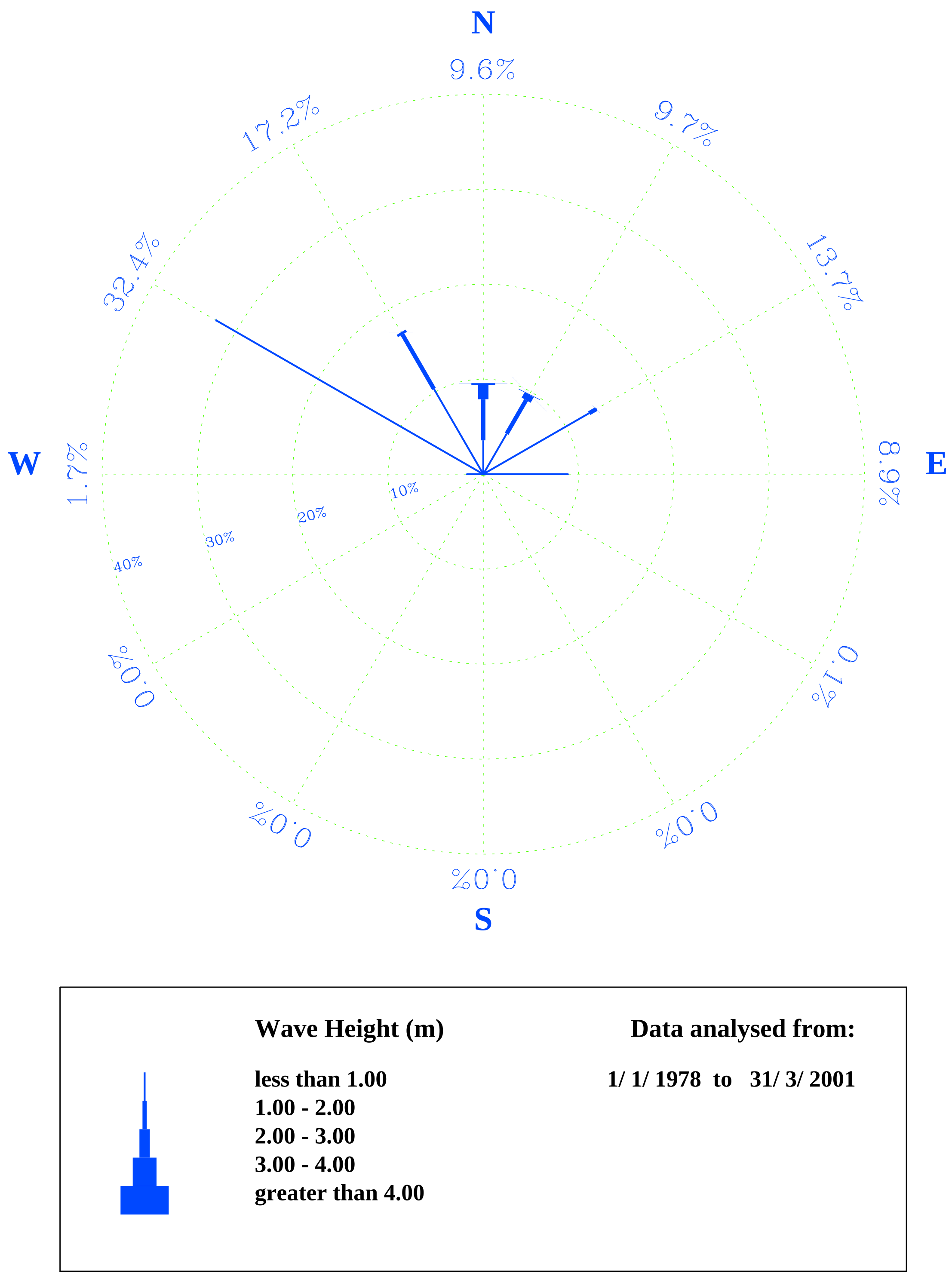


Figure 4.6 Wave rose showing inshore wave conditions – Sheringham

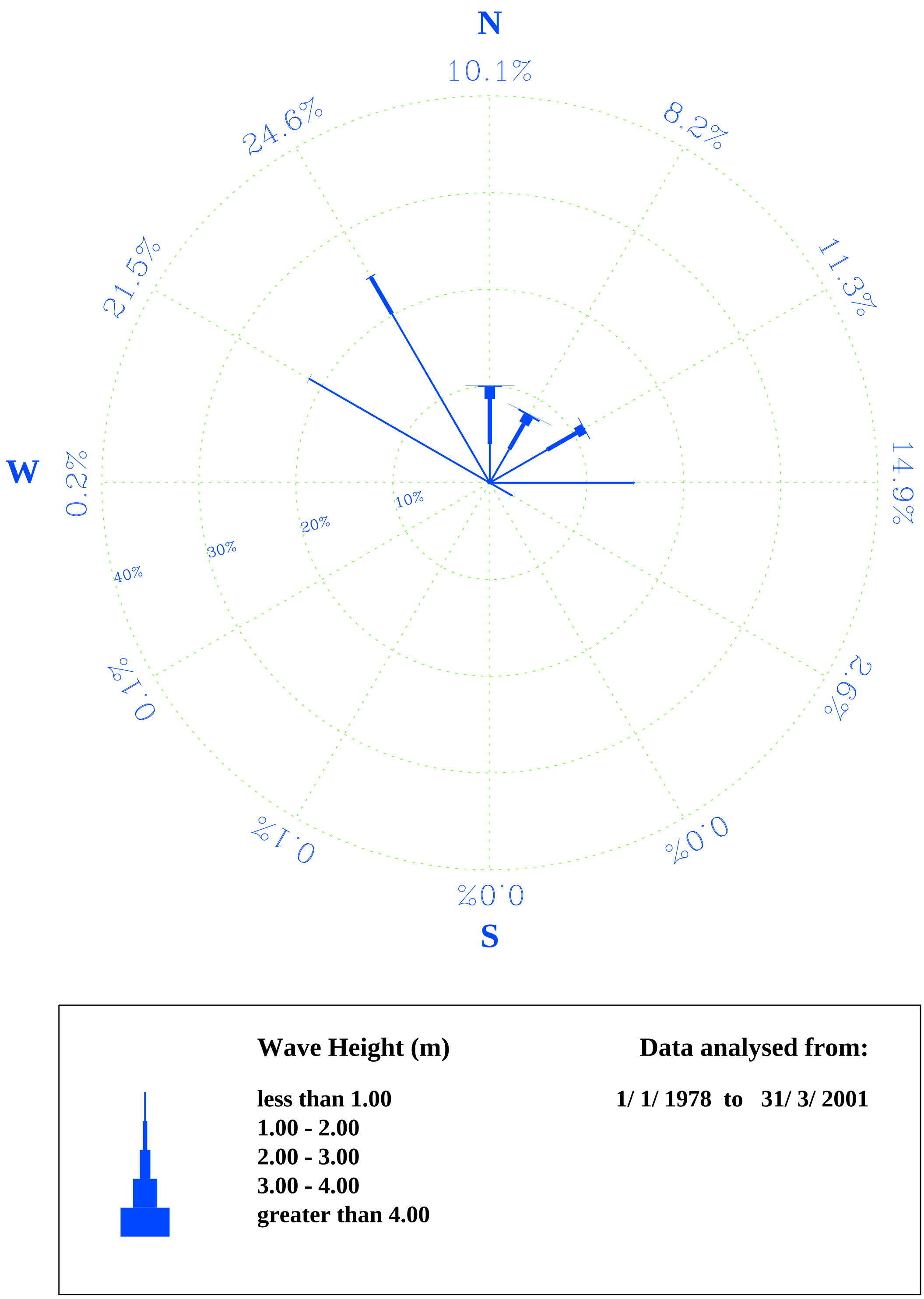


Figure 4.7 Wave rose showing inshore wave conditions – Cromer

Table 4.3 Annual inshore wave climate – Kelling – Wave height against mean wave period occurrence table *

	Mean wave period T_m (seconds)									
H_s (m)	0–1	1-2	2-3	3-4	4-5	5–6	6-7	7-8	8-9	9-10
0–1	0	563	23172	36298	11488	1749	508	24	0	0
1-2	0	0	1	766	11959	3488	32	0	0	0
2-3	0	0	0	0	88	2583	122	0	0	0
3-4	0	0	0	0	0	108	262	0	0	0
4-5	0	0	0	0	0	5	48	0	0	0
5-6	0	0	0	0	0	0	5	0	0	0
All H_s	0	563	23173	37064	23535	7933	977	24	0	0

Table 4.4 Annual inshore wave climate – Kelling – Wave height against wave direction occurrence table *

	Mean wave direction (degrees North)											
H_s (m)	345-015	015-045	045-075	075-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345
0–1	3737	4362	11726	8855	48	17	6	7	12	1057	32603	11371
1-2	4083	3687	2367	0	0	0	0	0	0	8	207	5894
2-3	1270	1088	314	9	0	0	0	0	0	0	3	110
3-4	151	214	5	0	0	0	0	0	0	0	0	0
4-5	15	36	0	0	0	0	0	0	0	0	2	0
5-6	0	5	0	0	0	0	0	0	0	0	0	0
All H_s	9256	9392	14412	8864	48	17	6	7	12	1065	32815	17375

* Based on HINDWAVE predictions for 1 January 1978 to 31 March 2001, with data expressed in parts per hundred thousand; total number of wave predictions is 203784.

Table 4.5 Annual inshore wave climate – Sheringham – Wave height against mean wave period occurrence table *

	Mean wave period T_m (seconds)									
H_s (m)	0–1	1-2	2-3	3-4	4-5	5–6	6-7	7-8	8-9	9-10
0–1	0	520	23701	39881	10006	649	6	0	0	0
1-2	0	0	1	747	12764	2394	0	0	0	0
2-3	0	0	0	0	130	2293	0	0	0	0
3-4	0	0	0	0	0	144	125	0	0	0
4-5	0	0	0	0	0	5	32	0	0	0
All H_s	0	520	23702	40628	22900	5485	163	0	0	0

Table 4.6 Annual inshore wave climate – Sheringham – Wave height against wave direction occurrence table *

	Mean wave direction (degrees North)											
H_s (m)	345-015	015-045	045-075	075-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345
0–1	3551	4906	12832	8887	95	26	7	0	0	1721	32389	10351
1-2	4332	4086	856	0	0	0	0	0	0	0	12	6620
2-3	1480	662	4	0	0	0	0	0	0	0	0	276
3-4	204	60	0	0	0	0	0	0	0	0	0	5
4-5	25	11	2	0	0	0	0	0	0	0	0	0
All H_s	9592	9725	13694	8887	95	26	7	0	0	1721	32401	17252

* Based on HINDWAVE predictions for 1 January 1978 to 31 March 2001, with data expressed in parts per hundred thousand; total number of wave predictions is 203784.

Table 4.7 Annual inshore wave climate – Cromer – Wave height against mean wave period occurrence table *

	Mean wave period T_m (seconds)									
H_s (m)	0–1	1-2	2-3	3-4	4-5	5–6	6-7	7-8	8-9	9-10
0–1	0	545	27675	35468	8588	1600	389	18	0	0
1-2	0	0	0	662	10292	4514	100	0	0	0
2-3	0	0	0	0	100	2968	178	0	0	0
3-4	0	0	0	0	0	80	326	0	0	0
4-5	0	0	0	0	0	4	46	0	0	0
5-6	0	0	0	0	0	0	2	0	0	0
All H_s	0	545	27675	36130	18980	9166	1041	18	0	0

Table 4.8 Annual inshore wave climate – Cromer – Wave height against wave direction occurrence table *

	Mean wave direction (degrees North)											
H_s (m)	345-015	015-045	045-075	075-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345
0–1	4000	4001	6818	14825	2613	50	31	56	54	204	21470	20161
1-2	4628	3023	3504	60	0	0	0	0	0	0	0	4353
2-3	1280	937	868	7	7	0	0	0	0	8	24	114
3-4	132	194	79	0	0	0	0	0	0	0	0	1
4-5	21	29	0	0	0	0	0	0	0	0	0	0
5-6	2	0	0	0	0	0	0	0	0	0	0	0
All H_s	10063	8184	11269	14892	2620	50	31	56	54	212	21494	24629

* Based on HINDWAVE predictions for 1 January 1978 to 31 March 2001, with data expressed in parts per hundred thousand; total number of wave predictions is 203784.

Table 4.9 Extreme wave conditions for Kelling, Sheringham and Cromer

Return period (years)	Significant wave height (m) and mean wave period (s)					
	Kelling		Sheringham		Cromer	
	H_s	T_m	H_s	T_m	H_s	T_m
0.1	3.1	6.0	3.0	5.9	3.1	6.0
1	4.2	6.9	4.0	6.7	4.2	6.9
5	4.9	7.5	4.7	7.4	4.9	7.5
10	5.2	7.8	5.0	7.6	5.2	7.8
20	5.5	8.0	5.3	7.8	5.5	8.0
50	5.9	8.3	5.7	8.1	5.8	8.2
100	6.2	8.5	6.0	8.3	6.1	8.4
200	6.4	8.7	6.3	8.6	6.4	8.7
500	6.8	8.9	6.7	8.9	6.8	8.9
1000	7.1	9.1	7.0	9.0	7.1	9.1

5. Joint Probability of Large Waves and High Water Levels

Flood risk and potential for damage to coastal structures tends to be associated with times when waves occur in conjunction with unusually high water levels. The joint probability of the simultaneous occurrence of large waves and high water levels is therefore of interest.

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

Section 3.5.3 of CIRIA (1996) provides a method of combining extreme water level predictions with extreme wave predictions in order to derive overall extreme sea conditions with given joint return periods. The necessary ‘correlation factor’ to be used in CIRIA (1996) was estimated from the results of a more rigorous analysis undertaken previously for nearby Dowsing. The results are listed in Tables 5.1-5.3 for Kelling, Sheringham and Cromer, respectively.

Table 5.1 Combinations of large waves and high water levels at Kelling with given joint return periods

Joint return period (years)	Water levels		Wave conditions		
	Return period (years)	Actual level (mOD)	Return period (years)	H_s (m)	T_m (s)
1	0.03	2.69	1	4.2	6.9
	0.05	2.81	0.6	3.9	6.6
	0.1	2.85	0.3	3.6	6.4
	0.2	3.05	0.15	3.3	6.1
	0.5	3.17	0.06	2.9	5.8
	1	3.27	0.03	2.6	5.5
10	0.08	2.91	10	5.2	7.8
	0.2	3.05	4	4.8	7.4
	0.5	3.17	1.6	4.4	7.1
	1	3.27	0.8	4.1	6.8
	2	3.44	0.4	3.7	6.5
	5	3.63	0.16	3.3	6.1
	10	3.80	0.08	3.0	5.9
100	0.2	3.05	100	6.2	8.5
	0.5	3.17	40	5.8	8.2
	1	3.27	20	5.5	8.0
	2	3.44	10	5.2	7.8
	5	3.63	4	4.8	7.4
	10	3.80	2	4.5	7.2
	20	3.95	1	4.2	6.9
	50	4.14	0.4	3.7	6.5
	100	4.35	0.2	3.4	6.2
1000	0.5	3.17	1000	7.1	9.1
	1	3.27	500	6.8	8.9
	2	3.44	250	6.5	8.7
	5	3.63	100	6.2	8.5
	10	3.80	50	5.9	8.3
	20	3.95	25	5.6	8.1
	50	4.14	10	5.2	7.8
	100	4.35	5	4.9	7.5
	200	4.50	2.5	4.6	7.2
	500	4.68	1	4.2	6.9
	1000	4.86	0.5	3.8	6.6

Note 1: Consider *every* combination as a potential worst case for any given return period. Each one is expected to be equalled or exceeded once, on average, in each return period.
Note 2: Allow for future sea level rise, after 2002, where appropriate, with reference to the Defra (2006) guidance.
Note 3: To convert from OD to CD at Cromer, add 2.75m to water levels.
Note 4: Check for local wave height depth limitation where appropriate

Table 5.2 Combinations of large waves and high water levels at Sheringham with given joint return periods

Joint return period (years)	Water levels: Return period (years)	Water levels: Actual level (mOD)	Wave conditions: Return period (years)	Wave conditions: H_s (m)	Wave conditions: T_m (s)
1	0.03	2.65	1	4.0	6.7
	0.05	2.77	0.6	3.7	6.5
	0.1	2.91	0.3	3.4	6.3
	0.2	3.01	0.15	3.2	6.1
	0.5	3.13	0.06	2.9	5.8
	1	3.23	0.03	2.6	5.5
10	0.08	2.87	10	5.0	7.6
	0.2	3.01	4	4.6	7.3
	0.5	3.13	1.6	4.2	6.9
	1	3.23	0.8	3.9	6.6
	2	3.40	0.4	3.5	6.4
	5	3.59	0.16	3.2	6.1
	10	3.76	0.08	3.0	5.9
100	0.2	3.01	100	6.0	8.3
	0.5	3.13	40	5.6	8.0
	1	3.23	20	5.3	7.8
	2	3.40	10	5.0	7.6
	5	3.59	4	4.6	7.3
	10	3.76	2	4.3	7.0
	20	3.91	1	4.0	6.7
	50	4.10	0.4	3.5	6.4
	100	4.31	0.2	3.3	6.2
1000	0.5	3.13	1000	7.0	9.0
	1	3.23	500	6.7	8.9
	2	3.40	250	6.4	8.6
	5	3.59	100	6.0	8.3
	10	3.76	50	5.7	8.1
	20	3.91	25	5.4	7.9
	50	4.10	10	5.0	7.6
	100	4.31	5	4.7	7.4
	200	4.46	2.5	4.4	7.1
	500	4.64	1	4.0	6.7
	1000	4.82	0.5	3.6	6.5

Note 1: Consider *every* combination as a potential worst case for any given return period. Each one is expected to be equalled or exceeded once, on average, in each return period.
Note 2: Allow for future sea level rise, after 2002, where appropriate, with reference to the Defra (2006) guidance.

Note 3: To convert from OD to CD at Cromer, add 2.75m to water levels.
Note 4: Check for local wave height depth limitation where appropriate

Table 5.3 Combinations of large waves and high water levels at Cromer with given joint return periods

Joint return period (years)	Water levels: Return period (years)	Water levels: Actual level (mOD)	Wave conditions: Return period (years)	Wave conditions: H_s (m)	Wave conditions: T_m (s)
1	0.03	2.58	1	4.2	6.9
	0.05	2.71	0.6	3.9	6.6
	0.1	2.85	0.3	3.6	6.4
	0.2	2.95	0.15	3.3	6.1
	0.5	3.07	0.06	2.9	5.8
	1	3.17	0.03	2.6	5.5
10	0.08	2.82	10	5.2	7.8
	0.2	2.95	4	4.8	7.4
	0.5	3.07	1.6	4.4	7.1
	1	3.17	0.8	4.1	6.8
	2	3.34	0.4	3.7	6.5
	5	3.53	0.16	3.3	6.1
	10	3.70	0.08	3.0	5.9
100	0.2	2.95	100	6.1	8.4
	0.5	3.07	40	5.7	8.1
	1	3.17	20	5.5	8.0
	2	3.34	10	5.2	7.8
	5	3.53	4	4.8	7.4
	10	3.70	2	4.5	7.2
	20	3.86	1	4.2	6.9
	50	4.03	0.4	3.7	6.5
	100	4.25	0.2	3.4	6.2
1000	0.5	3.07	1000	7.1	9.1
	1	3.17	500	6.8	8.9
	2	3.34	250	6.5	8.7
	5	3.53	100	6.1	8.4
	10	3.70	50	5.8	8.2
	20	3.86	25	5.6	8.1
	50	4.03	10	5.2	7.8
	100	4.25	5	4.9	7.5
	200	4.40	2.5	4.6	7.2
	500	4.58	1	4.2	6.9
	1000	4.74	0.5	3.8	6.6

Note 1: Consider *every* combination as a potential worst case for any given return period. Each one is expected to be equalled or exceeded once, on average, in each return period.
Note 2: Allow for future sea level rise, after 2002, where appropriate, with reference to the Defra (2006) guidance.

Note 3: To convert from OD to CD at Cromer, add 2.75m to water levels.
Note 4: Check for local wave height depth limitation where appropriate.

6. References

CIRIA (1996). Beach management manual. CIRIA Report 153.

Corkan, R. H. (1948). Storm Surges in the North Sea. H.O. Misc. No. 15072, Vols. 1 and 2, Washington.

Defra (2006). Flood and Coastal Defence Appraisal Guidance – FCDPAG3 Economic Appraisal. Supplementary Note to Operating Authorities – Climate Change Impacts. October 2006.

Dixon, M. J. and Tawn, J. A. (1994). Estimates of extreme sea conditions: extreme sea levels at the UK A-class sites: site by site analyses. Internal Document 65, Proudman Oceanographic Laboratory, Bidston.

Dixon, M. J. and Tawn, J. A. (1995). Estimates of extreme sea conditions: extreme sea levels at the UK A-class sites: optimal site by site analyses and spatial analyses of the East Coast. Internal Document 72, Proudman Oceanographic Laboratory, Bidston.

Dixon, M. J. and Tawn, J. A. (1997). Estimates of extreme sea conditions: spatial analyses of the UK coast. Internal Document 112, Proudman Oceanographic Laboratory, Bidston.

Flather, R. A. (1987). Estimates of extreme conditions of surge and tide using a numerical model of the North West European continental shelf. Estuarine Coastal Shelf Science, **24**, 69-93.

Graff, (1981). An investigation of the frequency distributions of annual sea-level maxima at ports around Great Britain. Estuarine Coastal Shelf Science, **12**, 389-449.

HR Wallingford (1988). Coastal Defence Management Study for the Anglian Region: Offshore Wave Climate. HR Report EX 1665, January 1988.

HR Wallingford (1989). An assessment of two wave prediction models: HINDWAVE and BRISWAVE. HR Report SR 218, October 1989.

HR Wallingford (1994). Sheringham Coast Protection Scheme 902. Stage 2 – Beach recharge and control structures. HR Report EX 2888, January 1994.

HR Wallingford (1998). Outer Thames Regional Model, HR Report EX 4159, December 1998.

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

HR Wallingford (2001b). Southern North Sea Sediment Transport Study Phase 2 Inception Report. HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier. HR Report TR 117, January 2001.

Hunt, R. D. (1972). North Sea Storm Surges, Marine Observer, July 1972.

Keers, J. F. (1966). The meteorological conditions leading to storm surges in the North Sea. Met Mag, London, 95, pp. 261-272.

MAFF (1999). Flood and coastal defence project appraisal guidance: FCDPAG3: Economic appraisal. MAFF Publication PB 4650.

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EX 4985

Kelling to Cromer Strategy Study
Littoral sediment processes

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Summary

Kelling to Cromer Strategy Study

Littoral sediment processes: Technical support information

Report EX 4985
November 2006

The littoral sediment processes in the region between Kelling and Cromer on the North Norfolk coast have been investigated through observations and modelling. The potential net longshore sediment transport has been modelled, and beach volume changes have been derived from repeated surveys of set profiles.

Furthermore, results of previous studies, including regional and national level research as well as adjacent Coastal Strategy Studies, have been reviewed and incorporated into the analysis where appropriate.

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Appendix A Beach volume changes – Kelling, Sheringham, East Runton and Cromer
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1. Introduction

This report is concerned with the littoral sediment processes that change the shoreline, namely the interaction between the cliffs, beaches, and seabed with the hydrodynamic 'loadings' as described in the hydrodynamics interim report. The principal aim of the study of these 'littoral processes' is to explain and then later quantify the potential recession of the cliffs in response to natural forces and to possible changes in the coastal defences. The following simplified flowchart sets out the main littoral processes and their interrelationship.

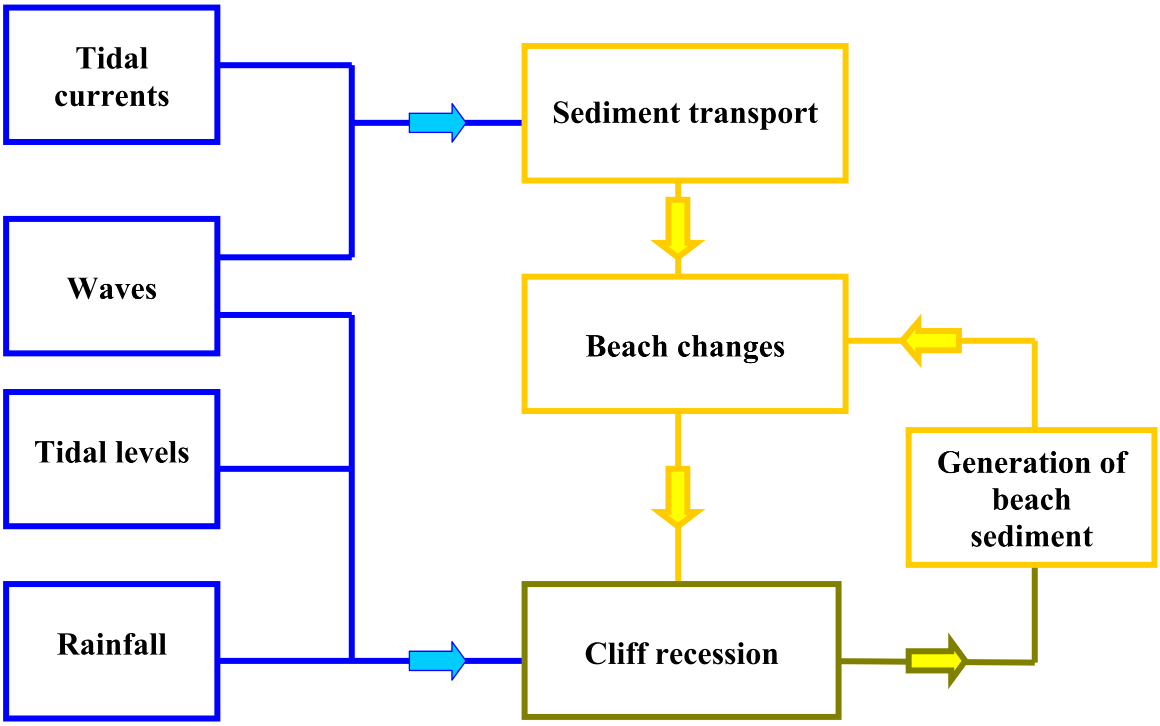

Figure 1.1 Simplified flowchart of littoral processes

This 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 main processes causing the 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.

Prior to the construction of coastal defences in the study area, the rate of cliff recession due to all these causes was approximately 0.3m to 0.75m/year (Cambers 1976). However, there have been substantial variations in this rate along the coast and in response to varying weather conditions, variations in the glacigenic sediments in the cliff material and the frequency of wave attack on the cliff base. Clayton and Coventry

(1986) investigated the recession rate between Kelling and Cromer between 1885 and 1985 and found that it reached a maximum rate of 1.00m/year

The construction of coastal defences, especially seawalls, altered these natural processes. While a reduction in natural cliff recession rates was achieved in some areas (typically at the sites of greatest human development of the cliff-top land), this generated increased recession on undefended sections. This increased recession occurred on the downdrift side of the coastal defences 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, tended to trap beach sand travelling along the coast, typically from the west to the east.

Both of these effects reduced the amount of sand arriving on the beaches in front of the cliffs immediately downdrift of the defences, a phenomenon known as 'drift starvation.' Because the sediment drift on the unprotected coast was now not supplied by sufficient sand from the defended frontage, the beaches (and shortly afterwards the cliffs) eroded to make up the deficit in the sediment budget. Such problems often resulted in the construction of more coastal defences, typically groynes and sometimes seawalls or revetments, further along the coast. Such construction reduced the direct wave attack on the cliff faces and reduced the changes in the plan shape of beaches caused by variations in the longshore drift.

In contrast to this, a positive effect on beaches updrift was observed, in which beach material tended to accumulate since it could only travel past the groynes and seawalls more slowly. Even this effect, however, can have disadvantages since it may reduce cliff erosion and hence the supply of extra beach material.

Other littoral processes, however, have continued including the erosion of the nearshore seabed and the increase in mean sea level. Previous studies have commented on the significant quantities of beach sediment that are lost offshore from the North Norfolk coastline, although without explaining the mechanisms involved in detail.

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 any such dredging has taken place in recent years is offshore from Caister, about 50km distant to the SE. This dredging is too far away and in water too deep to affect waves, tidal currents or sediment transport processes in the Kelling/Cromer area.

The principal concern of this study is to predict the future changes in the beaches, of the coastal defences and subsequent recession of the cliffs along the frontage between Kelling and Cromer. This prediction exercise has assumed that the process that is most influential in causing beach changes will be the variation in longshore drift rates along the study frontage. The assessment of longshore drift rates is therefore described in some detail in Section 2 of this report.
This report was prepared in 2004 and the information contained is correct to that time. For the current issue, minor revisions have been undertaken but there are no significant changes.

2. Wave-driven longshore sediment transport

2.1 INTRODUCTION

Long-term beach changes are usually dominated by changes in the beach plan shape. These types of change are related to the transport of sediment along a coastline, the 'longshore drift'. Where this volumetric rate of transport varies along a stretch of shoreline, then the beach plan shape alters in response. The importance of this mechanism to beach evolution, and hence to coastal defences, is emphasised by the following quotation from an eminent coastal engineer in the USA, C J Galvin (1990) who wrote:

'... all examples of shore erosion on non-subsiding sandy coasts are traceable to man-made or natural interruptions of longshore sediment transport'.

While this somewhat overstates the case, in many situations (including this study frontage) the cause of rapid beach erosion (or accretion) is similar to that described by Galvin.

Along most coastlines of the world, longshore sediment transport (or longshore drift) is predominantly caused by waves that break obliquely to the shoreline. This is also the situation along the North Norfolk coast, where the prevalence of waves from the north-west creates a net drift, i.e. from Sheringham towards Great Yarmouth. Unusually, strong nearshore tidal currents also affect the longshore drift on this coastline. Further discussion of the modifying effects of tides on the longshore drift is presented in Section 3.

Researchers at the University of East Anglia made early estimates of the net annual longshore drift rate along the coastline of Norfolk in the 1970s. As normal in such studies, the longshore drift rate was calculated by a simple formula that estimates the instantaneous rate of sediment transport caused by any wave condition. By repeated use of this formula for the whole wave climate, as predicted for a chosen location at the coast, the total volume of longshore drift at that location was estimated. While this approach is still widely used, it is important to realise that the longshore drift rates calculated by this numerical method are subject to a considerable degree of uncertainty unless a site-specific validation can be carried out. In addition, estimates made using information on waves over one period can vary dramatically from subsequent estimates made using wave information for a different period.

Despite many studies estimating drift rates along the North Norfolk coast having been carried out, there is no way of physically measuring the rates of sand transport along the coastline. Any drift rates quoted must therefore be treated as rather uncertain estimates rather than absolute values.

The net longshore drift rate in the vicinity of Sheringham and Cromer has been estimated several times in the past, with a wide range of predictions. These have been made assuming that the coastline was still in a natural state, i.e. with no groynes or other coastal defences that affect the transport of beach sediment. One of the earliest estimates, of about 97,000 m^3/year *from east to west* between Sheringham and Cromer was made by the University of East Anglia (Vincent, 1979). However, HR Wallingford (1994, 2001) visited Sheringham and Cromer and noted very clear indications of a *nett west to east* drift at both (although the observations at Sheringham were for shingle, not sand). Clayton et al. (1983) also noted evidence of drift from west to east at Cromer.

Onyett and Simmonds (1983) calculated drift rates of 160,000m^3/year to the west between Sheringham and Cromer, but a nett drift rate of 400,000m^3/year to the east at Cromer.

In interpreting the results of their studies of the drift regime for the whole of the coastline of East Anglia, the UEA team indicated that there was a "drift divide" to the west of Cromer, with the longshore drift moving westwards to the west of the town, and eastwards from the eastern end of its seafront. Beaches in the vicinity of a drift divide can be expected to rapidly erode, especially in a location where there is no supply of fresh sediment, e.g. from eroding cliffs. However, Clayton (1977) estimated that the North Norfolk cliffs are eroding at a rate of about 400,000m^3/year of sand, so there is a supply of sediment to the beaches.

Recent studies and site visits have provided evidence that the present-day drift divide lies to the west of Sheringham, and that between Sheringham and Cromer the drift appears to be from west to east. Note also that the "drift divide" or null point in the mean nett annual sediment transport rate is purely a statistical phenomenon. Sediment travels in both directions past this null point and in some years the nett annual drift direction will be to the east and in other years it will be to the west. However, on average, the nett transport rate is about zero at the null point. The position of the null point will vary in time, on a yearly and a decadal scale and it may be different for shingle and sand.

The results of the modelled longshore drift of shingle above the 0mCD contour at Sheringham (HR Wallingford 1994) indicates a nett transport potential towards the east that increases further east. Moreover, the amount of shingle on the frontage reduced towards the east and was explained in terms of increasing sediment transport potential towards the east. The results also suggested that the drift null point was to the west of Sheringham. However, the location of the drift divide may be different for shingle and sand and will vary in time was the wave climate exhibits inter-annual variability. Onyett (1982) has shown that decadal averages of nett longshore transport rates at Sheringham have different directions.

2.2 MODELLING OF LONGSHORE DRIFT RATES

In order to study the future (and recent past) evolution of the coastline between Kelling and Cromer in this study, a further calculation of net longshore drift rates along the 'natural' coastline was made. These calculations used the long-term wave conditions summarised in the hydrodynamics report. 24 years of offshore wave data (from 1st January 1978 to 31st March 2001) were used to predict wave conditions for nine nearshore wave prediction points. These points (a to k) were located on the -3.25m contour along the frontage between Kelling and Cromer (shown in Section 4 of the hydrodynamics report which illustrates three of these nearshore wave prediction points). Estimates of drift were made based on the wave conditions using the standard CERC formula, a simple empirical method that relates the total longshore sediment transport at any time to the height and the direction (relative to the beach normal) of waves at breaking. This is the same technique as used by previous researchers, and therefore allows a straightforward comparison with the results of the earlier studies mentioned above. These calculations were made for four locations along the coastline, Kelling, Weybourne, West Sheringham and West Cromer.

The beaches along the coastline between Kelling and Cromer are largely comprised of shingle (>90% shingle at Kelling) with an increasing amount of sand further east (>90% sand at West Cromer). This mixture of beach sediments complicates the calculation of drift rates, especially in the absence of any direct measurements of the sediment transport.

However, the sand (West Cromer) and shingle beaches have been modelled separately and the results combined. This procedure produced the results shown in Figure 2.1, which plots the mean annual potential drift rate averaged over 23 years. Figure 2.1 shows an upper and a lower limit for the mean potential longshore drift rate, as the calculation of drift rates is extremely sensitive to beach angle. As expected, these results indicate that the open-beach drift rate generally increases from west to east along the study area, thus implying the likelihood of beach erosion along the frontage. It also clearly shows the potential for a reversal in longshore drift direction.

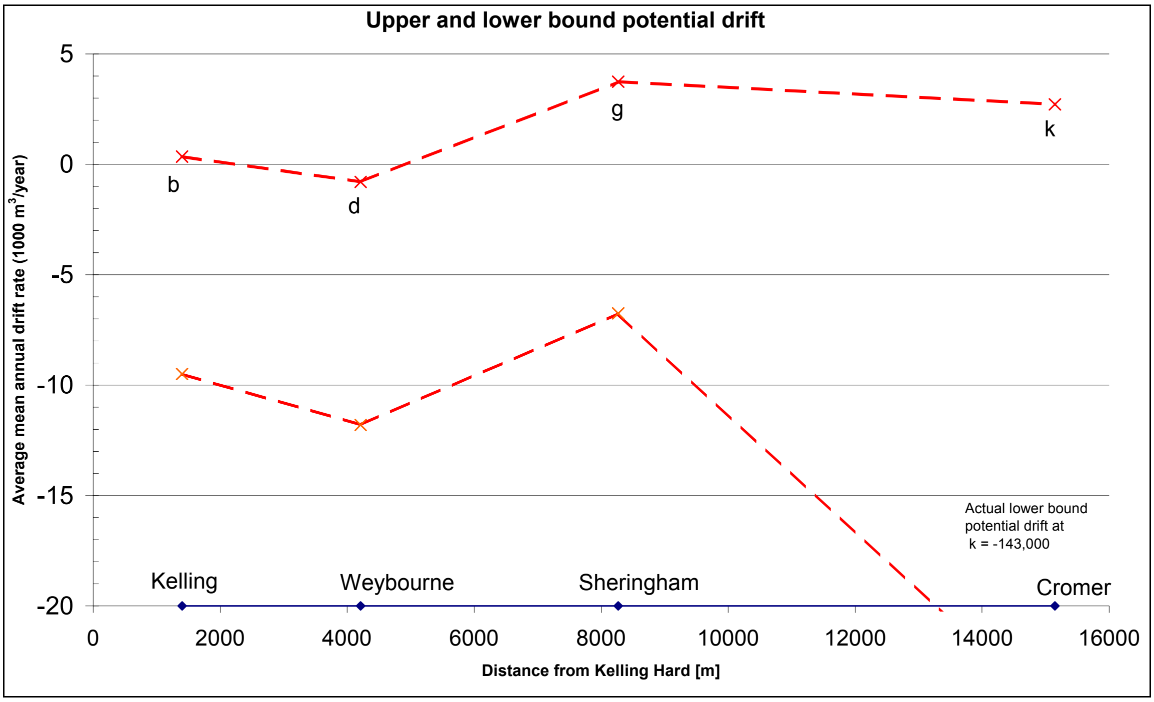

Figure 2.1 Average mean annual potential drift along the study area

The estimated net drift rates from the calculations are summarised in Figure 2.2, which illustrates the predicted net longshore transport rate for each year between 1978 and 2001 at each location. The graph includes the net longshore transport rates for point K (West Cromer) which is a sandy beach and the values are an order of magnitude higher than the shingle beaches and have therefore been plotted against a secondary y-axis. It is noticeable that during the 23 years, the annual drift varies with an eastward transport in some years, westwards in others. Although there is a predominant westward transport, in 1978-79, 1985-87, 1989, 1996, and 1997, the average annual longshore transport is in an easterly direction at all locations. It should also be noted that the average annual longshore drift rate at point G (West Sheringham) is very low (1500 m^3/yr easterly) indicating the possible location of the drift divide. Figure 2.2 also illustrates the difficulty in comparing results from different periods as averaging the results over different periods yields different net potential transport rates.

As mentioned previously, there are substantial uncertainties in these theoretical calculations. One of the most important of these potential sources of error is whether there is sufficient sediment to "satisfy" this calculated drift rate. The source of sand on the beaches of this coastline is largely from the eroding cliffs of North Norfolk, while the shingle is probably largely derived from the chalk exposed on the nearshore seabed. Further inaccuracies will result from the numerical modelling of the waves and the neglect of tidal currents (see next section). However, at present based on the evidence from site appraisals and the drift calculations, the net longshore drift rate along this coastline is undoubtedly (at present) eastwards.

The increase in drift rates on moving east from Sheringham is fundamentally important to understanding the evolution of the coastline in the study area. It implies the drift rate out of the eastern end of the frontage (towards Cromer) is likely to be higher than the rate of sediment arriving at the western end (i.e. from Sheringham). This difference in volume leads to beach erosion, and then cliff recession. This is therefore a purely natural phenomenon, caused by the gradual changes in orientation of the Norfolk coastline and the character of the waves generated in the North Sea. The rather sharp change in beach orientation in the vicinity of Cromer Pier can be expected to locally emphasise the increase in drift rates from west to east along this part of the coast.

The seawalls at Sheringham and Cromer now effectively prevent any additional sediment being added from those frontages to the beaches, to compensate for this deficit in volume, leading to an underlying trend for erosion. The traditional solution to this problem has been to interfere with the longshore drift by installing groynes. The installation of groynes, even if they are only partly effective at altering the natural drift rates, will provoke changes in the beach plan shape. Such plan shape changes typically result in accretion on the western faces, with a comparable danger of erosion to the east. However, if the existing groynes along the frontages at Sheringham were to be removed (or allowed to fall into disrepair), the spatial variation in the longshore drift would rapidly remove the beaches there.

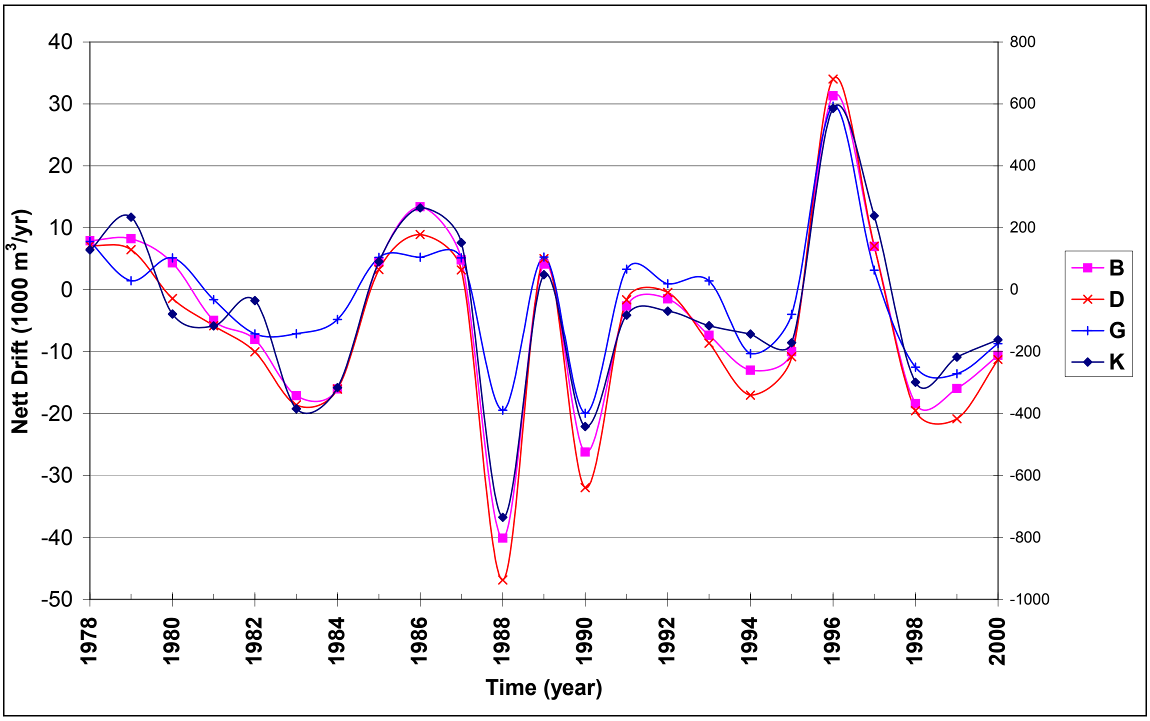

Figure 2.2 Estimated annual net potential longshore drift rates 1978 to 2001

3. Effect of tidal currents on longshore drift

It is not usual to consider the effects of tidal currents on the transport of beach sediments, except perhaps near the mouth of an estuary or tidal inlet. This is partly due to the fact that much of the research into longshore drift has been carried out on coastlines with virtually no tidal currents (e.g. in the western USA). In the UK, where tidal ranges are much larger and tidal currents stronger, it might be thought that a different approach would be needed. However, on most coasts, the times of high (or low) water and slack water (i.e. no tidal current) are close to one another. As a result, tidal currents on the upper part of a beach (close to the high water mark) are small, and at lower levels (i.e. mid-tide) the effects of the tidal currents are similar and opposite during the flood and ebb. Under these circumstances, the net effect of tidal currents on the longshore drift is very small compared to the effect of waves.

In the present study area, the tidal currents can be seen to be generally parallel to the coastline with some directional changes caused by the offshore sandbanks. Current speeds are lower closer inshore because of the increased frictional resistance of the seabed. However, they are predicted to be about 0.8m/s (1.5kt) at high water and slightly slower at about 0.6m/s (1.2kt) at low tide (when water depths close to the shore are less than at high tide, further increasing the frictional resistance). These current speeds, on their own, are capable of mobilising and transporting large quantities of seabed sediments up to the size of small gravel. The added effects of breaking waves, which disturb and agitate much larger gravel and shingle particles, means that tidal currents along this coast strongly affect beach sediment transport.

As discussed in the accompanying report on hydrodynamics, a particular feature of this part of the Norfolk coastline is that the strongest tidal currents will occur at about the time of high water during an exceptionally large tide. While this occurs regularly during Spring tides, it will also occur during storm surges, which will increase the total water level and add to the eastward flowing currents. On such occasions, winds are normally from the north or north-west, and will therefore create large waves along the study frontage as well as affecting the tides.

Such a combination of events will occur several times during a winter, and will have a strong effect on beaches, producing sediment transport both along the shore and offshore, with a flattening of the beach profile. Such events are referred to by local fishermen as ‘scouring tides’, and this is an appropriate if unusual terminology. Such strong currents close to the shoreline will interact strongly with groynes or breakwaters, and this issue needs to be borne in mind when considering the design of such structures.

However, with reference to the aspects of the tidal currents mentioned above, sediment on the upper portion of the inter-tidal zone will only experience tidal currents flowing to the east and south. This is because, at low water (when the ebb tide current is in the opposite direction), the upper part of the inter-tidal zone will be dry. Therefore, the tidal flows may have a significant impact on the transport of beach sediments, particularly through alteration of the behaviour of groynes or other coastal defences.

Using the BEACHPLAN numerical model of longshore drift, the previous Cromer Coastal Strategy Study (HR Wallingford 2002a) demonstrated that, without tidal currents, there would be an eastward (negative) transport of sand over the whole beach profile. This study also noted that the volume of sediment transported is low at the top of the beach because this area is only affected by waves around the time of high water.

Furthermore, the water depth and wave heights at the top of the beach are relatively small even at the time of high water. Thus, the drift rate is highest at a point where the beach level is about 0.5m below Ordnance Datum (i.e. just below the mean tidal level).

By modelling the additional effect of the tidal currents it was clear that these currents have had two effects. Firstly, on the lower part of the beach profile, the predicted sediment transport for this wave condition is reduced or reversed (i.e. with a net transport to the north-west). This is an expression of the ebb tidal flow around the time of low water. At this time, waves are agitating the sand and although they also try to produce a south-east flowing current it is shown that this is countered by the stronger tidal flows.

The second effect was that the peak south-east drift on the upper part of the beach profile is increased (in the order of 7.5%) by the effects of the flood tide near the time of high water. An inaccuracy in the longshore drift calculations of this magnitude, through the neglecting of tidal currents, could be considered acceptable in the light of the general accuracy of sediment transport calculations. However, a possible implication of this is that the downdrift effects of a groyne system may be greater than anticipated at design stage.

Closer to the location of the wave-induced drift divide, e.g. at Sheringham, the net eastward bias in the tidally-induced sediment transport on the upper intertidal may be proportionally more important.

4. Beach volume changes

A beach may be defined as 'a deposit of non-cohesive material (e.g. sand, gravel) situated on the interface between dry land and the sea … and actively "worked" by present-day hydrodynamic processes (i.e. waves, tides and currents) and sometimes by winds' (CIRIA 1996). The upper and lower limits of the beach can be taken as the beach crest (at the normal limit of wave induced run-up) and the seaward limit of sediment motion respectively. The beach volume thus includes all the potentially mobile material between the beach crest and the lower limit of wave action. Beach morphology is influenced not only by wave energy, but also by:

- Material added to the beach from slumping and mud flows from cliffs
- Aeolian processes
- The reworking of beach sediments by anthropogenic factors, such as vehicular disruption/digging

Beach profile changes occur over a variety of timescales, which vary from a single tide or storm through to seasonal variations and long term trends lasting thousands of years. Most beaches exhibit a seasonal variation in profile variability and volume in response to changing wave energies. During the summer months most beaches build up to produce a high beach with a berm above the high tide mark, and in the winter, higher waves comb down the beach moving sand down to, and below the low water mark. The higher rainfall and increased wave attack at the base of the cliffs experienced during the winter months are likely to result in a higher incidence of slumping and mudflows from the cliffs, thus in the short term increasing the beach volume.

The volume of the true beach material is very difficult to obtain and therefore, a measure of beach volume is found by calculating the volume of a geometrically developed beach prism, including all material (whether true beach sediment or not). The volume is calculated as volume per unit width (cross sectional area) of a shore-normal beach profile. This profile is constrained by horizontal planes at the lower limit of wave action, a vertical plane at the landward limit of the beach system (such as the beach crest, cliff toe, or seawall), and the beach surface.

North Norfolk District Council has provided surveys of the beach surface along 13 shore normal profiles, from Weybourne to Cromer, see Figure 4.1 below. The surveys were carried out in the summer and winter months from January 1992 to January 2003 so that the seasonal variations in beach morphology can be examined. Furthermore, offshore bathymetric surveys have been carried out at five year intervals, and calculations presented here are based on the 1991 and 2003 surveys. In this study six beach profile locations at West Weybourne (N2B5), Dead Mans Hill (N2A1), West Sheringham (N2A3), East Sheringham (N2A5), East Runton (N3E1) and West Cromer (N3E3) have been selected for further analysis and are illustrated in Appendix A.

In some cases it is difficult to determine the volume of beach material accurately due to the erratic nature of the boundary between slumped material at the cliff toe and the beach sediments. This boundary is taken as the upper limit of the beach. The lower limit of the beach sediments is defined as the location where there is an apparent break of slope in the extended beach profile that includes the bathymetric data.

The surveyed beach slope on the upper beach and foreshore was assumed to be representative of the entire beach slope. Thus, the mean slope (represented by a linear trend line defining the slope of the beach identified by the surveys) was extended to cover the entire active beach, down to the lower limit of wave action (with the break of slope defining the lower limit of the active beach).

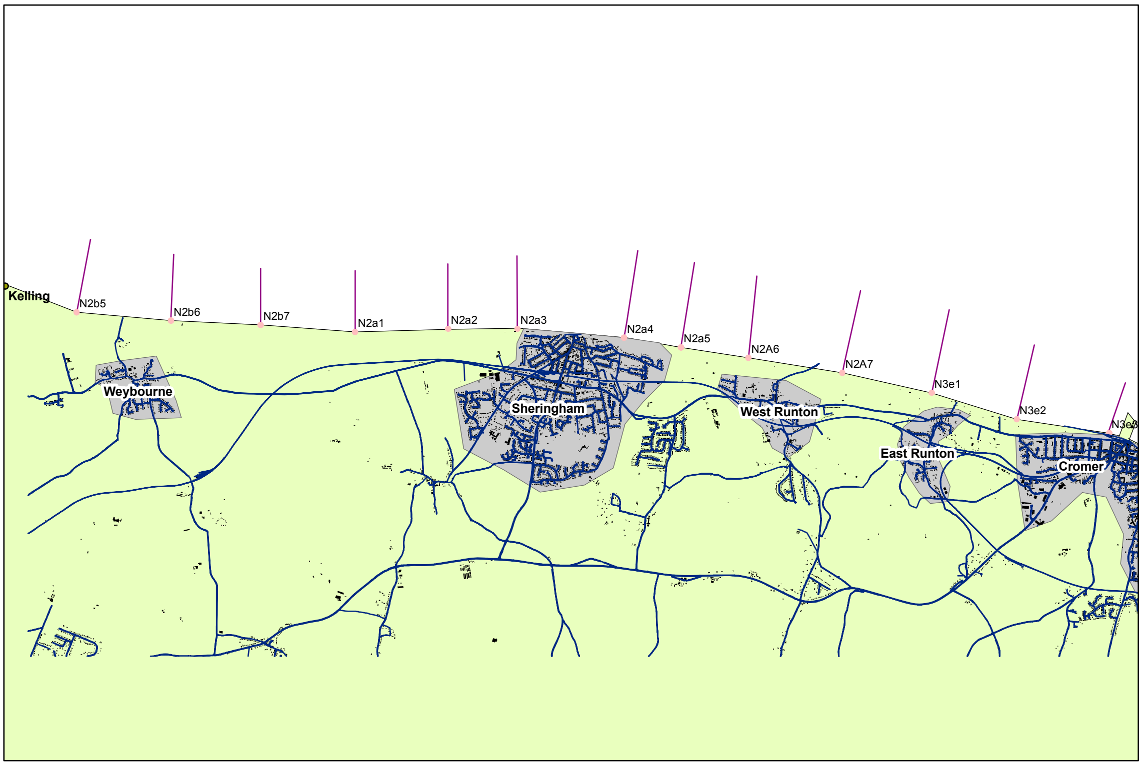

Figure 4.1 Beach profile locations

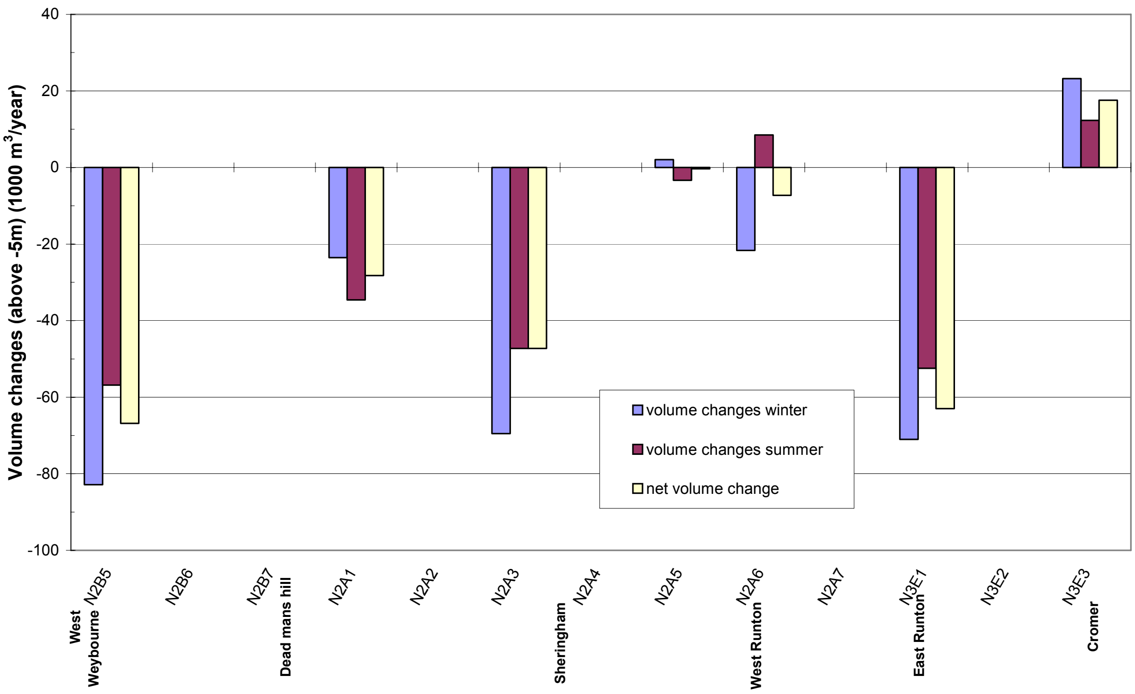

Figure 4.2 Beach volume changes in the study area

BDAS (Beach Data Analysis System, described in Appendix B) was used to calculate the mean profile and the change in levels at seven locations along the frontage, over the monitoring period, thereby providing an indication of the direction and magnitude of beach movement, as shown in Appendix A. The area under the mean profile line down to a constant lower limit (-5m ODN), and between the landward and seaward boundary is representative of the beach prism. This area was extracted in BDAS and then multiplied by the length of coastline to provide a volume in cubic metres. It is assumed that each profile is representative of a length of coastline extending half the way to the adjacent profiles to the east and west. In other words, the profile is multiplied by the sum of half the distance between the two stations immediately to the east and west. The volume changes in thousands of cubic metres per year are illustrated in Figure 4.2.

It is difficult to identify seasonal trends within this data set since the surveys were completed once in the summer and once in the winter on an annual basis. Changes to the beach profile may therefore not be indicative of long-term changes, but may reflect short-term changes following a single storm event, or be exaggerated due to a severe episode of cliff landsliding. Therefore it is not possible to identify a long-term seasonal trend with any degree of confidence.

Figure 4.2 presents the results of the analysis of change in the beach profiles and indicates a general pattern of beach volume losses between West Weybourne and Cromer, with an average annual loss of around 90,000m^3/year along the entire frontage. The East Anglian Coastal Research Programme carried out a continuous time series of beach profiling between 1974 and 1980 (Onyett and Simmonds 1983; Clayton et al 1983), and the Anglian Region NRA study in the early 1990s also completed similar beach profile measurements. Both studies revealed an overall net decrease in beach volume over the period 1974 to 1980. Furthermore, erosion of the glacial till sediments beneath the beach was found to result in erosion of the base of the beach. The results in this study indicate that this general trend is continuing.

The graph also indicates overall volume gains at West Cromer (N3E3) as might be expected updrift of the defences at Cromer. These trends are also reflected in earlier work in the East Anglian Coastal Research Programme, where accumulation was observed at West Cromer. There is no net volume change at East Sheringham (N2A5 and N2A6) downdrift of Sheringham as a result of the palisades installed along this section of coastline, further east again the downdrift effects of these defences are evident at profile N3E1.

5. Cliff recession mechanisms and potential sediment yields

The littoral processes discussed above, and particularly the effects of longshore drift, are fundamentally important to the evolution of the beaches in the study area. While the recession of the cliff is of greatest concern to the residents and property owners, these two processes are closely linked. Where beach levels are low, or the beach has disappeared entirely, waves and tides can act directly on the seawalls and, by overtopping, on the cliff face as well. Should the seawalls deteriorate and fail (e.g. as a result of undermining following removal of the beaches at its toe and lowering of the shore platform) then the rate of cliff top recession will increase. Conversely, a high healthy beach will prevent direct wave attack on the seawalls and the cliff face and hence greatly reduce the rate of recession of the cliff top edge. However, even the complete protection of the base of the cliffs will not completely halt cliff top recession because of erosion and weathering of the cliff face as well as the dangers of slumping or land-sliding caused by ground water flows from the land as shown in Figure 5.1.

Figure 5.1 Landsliding on the coast, Dead Mans Hill area (view westward)

The consideration of the possible reactivation of cliff recession following the deterioration and failure of coastal defences is a complex issue. This and the overall cliff recession rate are considered in greater detail in the accompanying reports on cliff processes and cliff modelling.

6. Interaction with adjacent Coastal Management Units

A summary of the geographic boundaries of the study area and the preferred policy options identified in the Shoreline Management Plan (Halcrow 1996 and Mouchel 1996) is provided in Figure 6.1. Having discussed the most important littoral processes, it is appropriate to briefly comment on the interactions between the study frontage and the adjacent sections of the coast.

To the east of the study frontage at Cromer, there is a stated policy to 'Hold the Line' (i.e. to continue to hold the line of the existing defences), and this strategy is also the preferred option along the Sheringham frontage. Between Kelling and Sheringham the policy is not to further intervene in the protection of the coastline (i.e. 'Do Nothing'). Similarly, between Sheringham and Cromer and to the east of Kelling the stated policy in the Shoreline Management Plan is of 'Managed Retreat' (i.e. setting the present coastal defences further landwards and accepting some cliff recession).

Considering the management unit to the west (i.e. updrift) of the study frontage first, the managed retreat policy will continue to allow sediment to reach the study frontage. Likewise the policy of not to further intervene in the protection of the coastline (i.e. 'Do Nothing') between Kelling and Sheringham will not adversely effect the coastal processes updrift (i.e. further west of Kelling).

Turning now to the management unit downdrift (i.e. east of the study frontage), then the managed retreat policy between Sheringham and Cromer will tend to allow more beach sediment to reach the downdrift frontage at Cromer. Conversely, the policy of retaining the present line of defences at Cromer, if the present patterns of drift continue, will tend to encourage the formation of a wider beach along the eastern end of the Runton to Cromer frontage.

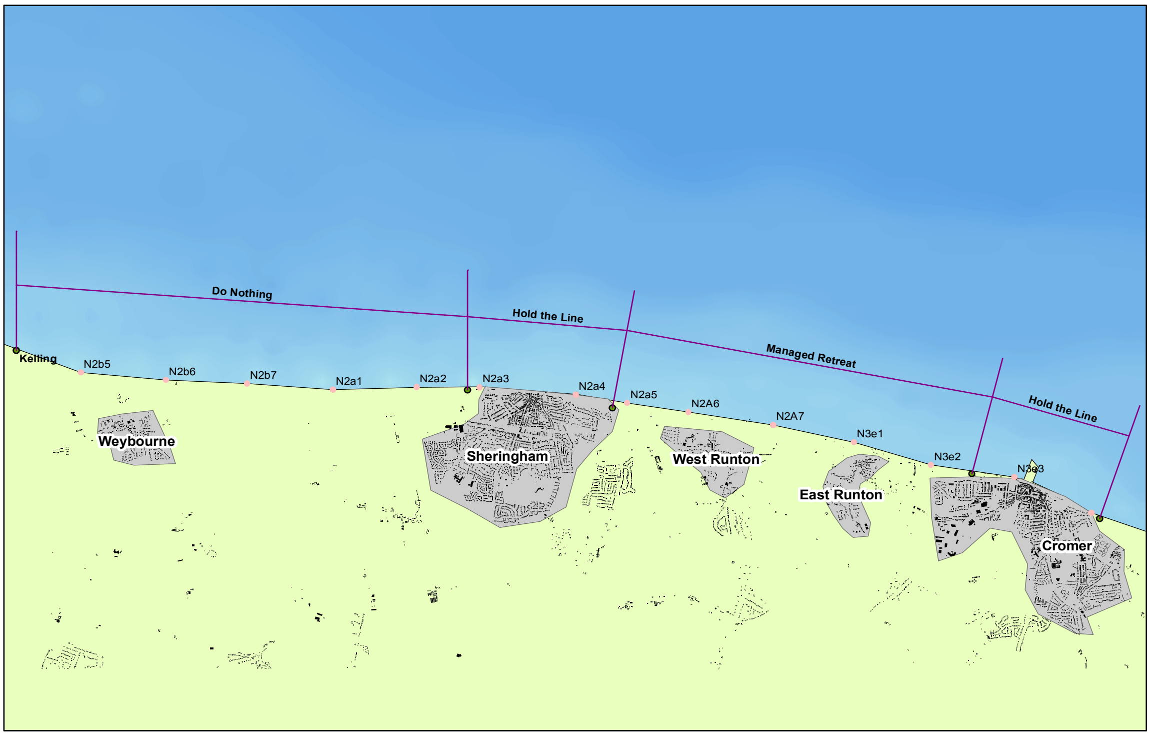

Figure 6.1 SMP policy options for the study area

7. References

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

CIRIA 1996 Beach management manual. Report 153. J.D Simm (editor)

Clayton K M 1977 East Anglian Coastal Research Programme, Report 5 – Beach Profiles: Form and Change.

Clayton K M 1989 Sediment input from the Norfolk cliffs, eastern England – a century of coast protection and its effect. Journal of Coastal Research, 5(3): 433-442.

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

Halcrow 1996 Sheringham to Lowestoft Shoreline Management Plan, Sediment Sub-cell 3B. Phase 2 – Shoreline Management Plan Strategy Document. May.

Halcrow 2002 Futurecoast. DEFRA.

HR Wallingford 2002a Cromer Coastal Strategy Study, Final Report EX 4363.

HR Wallingford 2002b Southern North Sea Sediment Transport Study, Phase 2: Sediment Transport Report. Report EX 4526. August.

Onyett D and Simmonds A 1983 East Anglian Coastal Research Programme Final Report 8: beach transport and longshore transport.

Vincent C E 1979 Longshore sand transport rates – a simple model for the East Anglian coastline, Coastal Engineering, 3, pp113-136.

Vincent C E, McCave I N, and Clayton K M 1983 The establishment of a sand budget for the East Anglian Coast and its implications for coastal stability. Shoreline Protection, Thomas Telford Ltd, London.

Appendices

Appendix A Beach volume changes – Kelling, Sheringham, East Runton and Cromer

Beach Analysis Results

Kelling to Cromer

November 2002

Kelling to Cromer

Stations N2B5, N2B6, N2B7, B2A1, N2A2, N2A3, N2A4, N2A5, N2A6, N2A7, N3E1, N3E2, N3E3.
Wave points B, C, D, E, F, G, H, I, J, K.

Kelling to Cromer

Station 1: N2B5

Chainages for calculation of the mean profile:
0-5-10-15-20-30-35-40-45-50-55-60-65-70-75-80-85
Values for the area calculation: 0\70\-5
Height changes per year: -0.070 m/yr
Length of active beach and width of present section: 930/1025
Volume changes in m^3/year: -66,000

Station 2: N2B6

Chainages for calculation of the mean profile:
Values for the area calculation:
Height changes per year:
Length of active beach and width of present section:
Volume changes in m^3/year:

Station 3: N2B7

Chainages for calculation of the mean profile:
Values for the area calculation:
Height changes per year:
Length of active beach and width of present section:
Volume changes in m^3/year:

Station 4: N2A1

Chainages for calculation of the mean profile:
0-5-10-15-20-25-30-35-40-45-50-55-60-65-70-75-80-85-90-100
Values for the area calculation: 15\60\-5
Height changes per year: -0.026 m/yr
Length of active beach and width of present section: 530\2032
Volume changes in m^3/year: -28,000

Station 5: N2A2

Chainages for calculation of the mean profile:
Values for the area calculation:
Height changes per year:
Length of active beach and width of present section:
Volume changes in m^3/year:

Station 6: N2A3

Chainages for calculation of the mean profile:
0-20-25-30-35-40-45-50-55-60-65-70-75-80-90-100-110-120-130-140
Values for the area calculation: 20\60\-5
Height changes per year: -0.021 m/yr.
Length of active beach and width of present section: 1170\1903
Volume changes in m^3/year: -47,000

Station 7: N2A4
Chainages for calculation of the mean profile:
Values for the area calculation:
Height changes per year:
Length of active beach and width of present section:
Volume changes in m^3/year:

Station 8: N2A5
Chainages for calculation of the mean profile:
0-10-20-25-30-35-40-45-50-55-60-65-70-75-80-90-100-110-120-130.000
Values for the area calculation: 25\100\-5
Height changes per year: 0.000 m/yr.
Length of active beach and width of present section: 960\1369
Volume changes in m^3/year: -350

Station 9: N2A6
Chainages for calculation of the mean profile:
15-20-25-30-35-40-45-50-55-60-65-70-75-80-90-100-110-120-130-140-150-160
Values for the area calculation: 25\100\-5
Height changes per year: -0.003m/yr
Length of active beach and width of present section: 855\1779
Volume changes in m^3/year: -7,000

Station 10: N2A7
Chainages for calculation of the mean profile:
Values for the area calculation:
Height changes per year:
Length of active beach and width of present section:
Volume changes in m^3/year:

Station 11: N3E1
Chainages for calculation of the mean profile:
0-20-40-50-60-70-75-80-85-90-95-100-105-110-120-130-140-150-160-170
Values for the area calculation: 60\120\-5
Height changes per year: -0.050 m/yr.
Length of active beach and width of present section: 650\1933
Volume changes in m^3/year: -62,000

Station 12: N3E2
Chainages for calculation of the mean profile:
Values for the area calculation:
Height changes per year:
Length of active beach and width of present section:
Volume changes in m^3/year:

Station 13: N3E3

Chainages for calculation of the mean profile:
0-10-20-30-40-50-55-60-65-70-75-80-85-90-95-100-105-110-115-120
Values for the area calculation: 20\110\-5
Height changes per year: 0.029 m/yr.
Length of active beach and width of present section: 620\989
Volume changes in m^3/year: 17,500

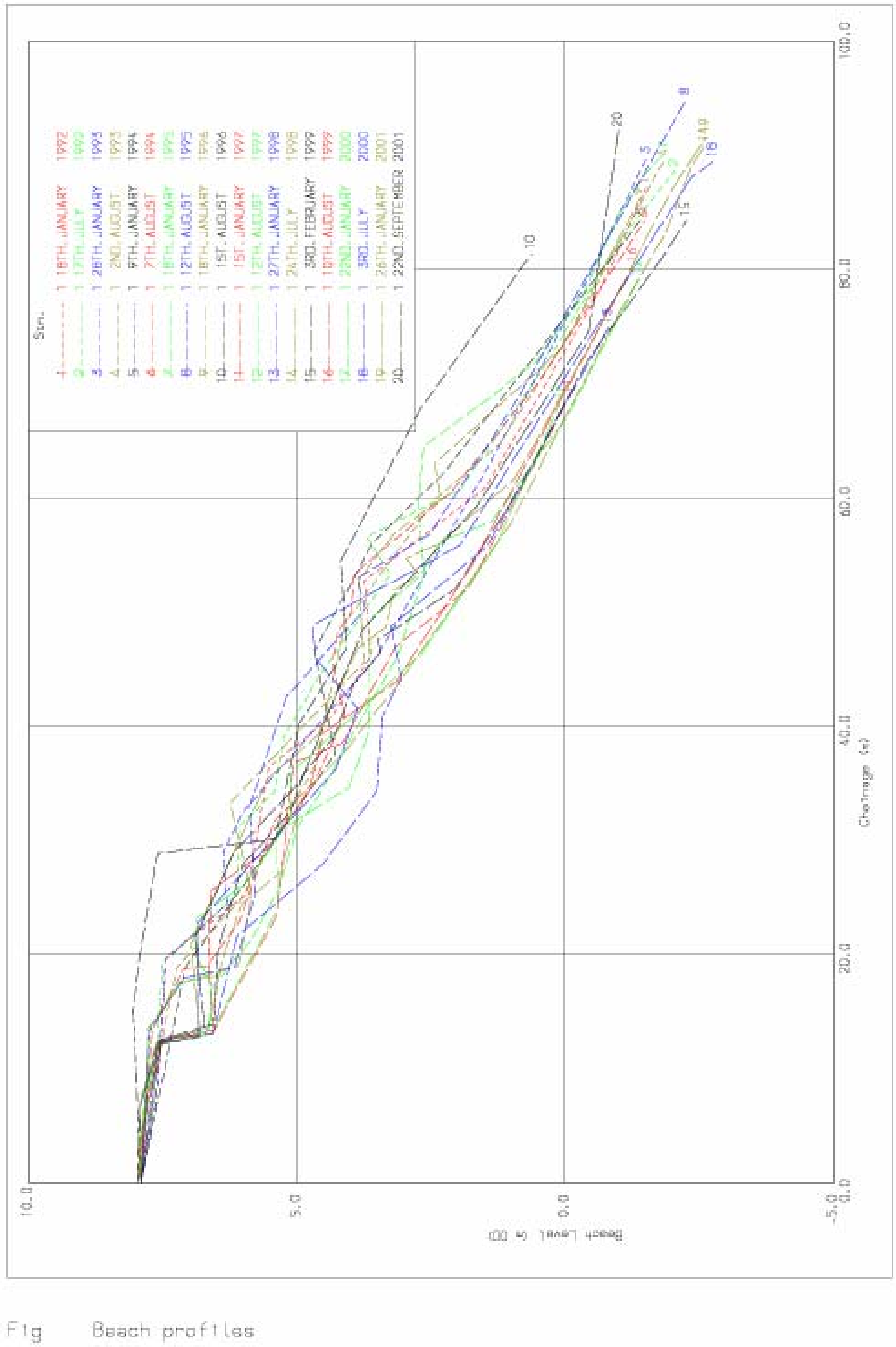

Figure A1 Beach Profiles Station 1 (N2B5)

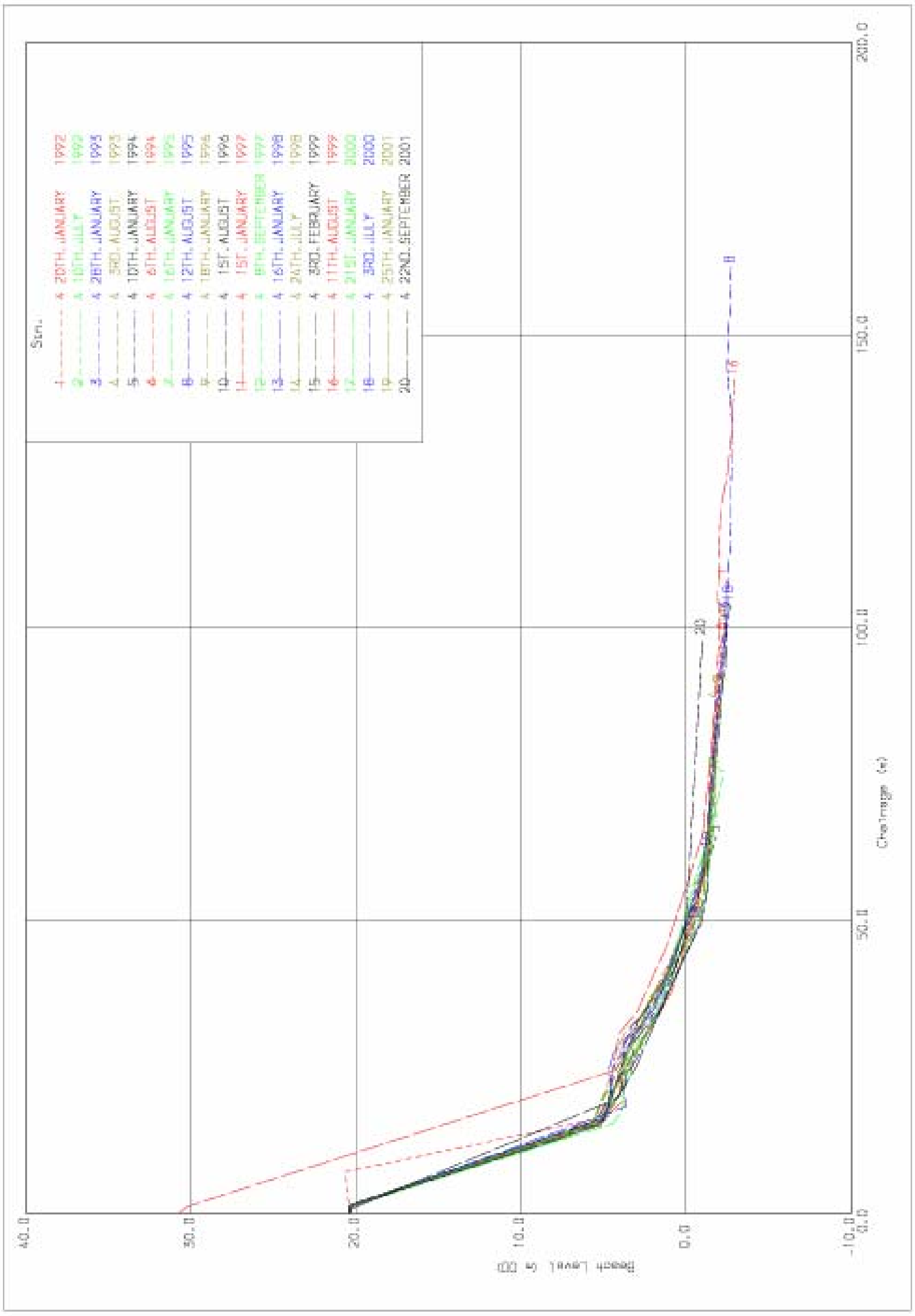

Fig 1

Figure A2 Beach Profiles Station 4 (N2A1)

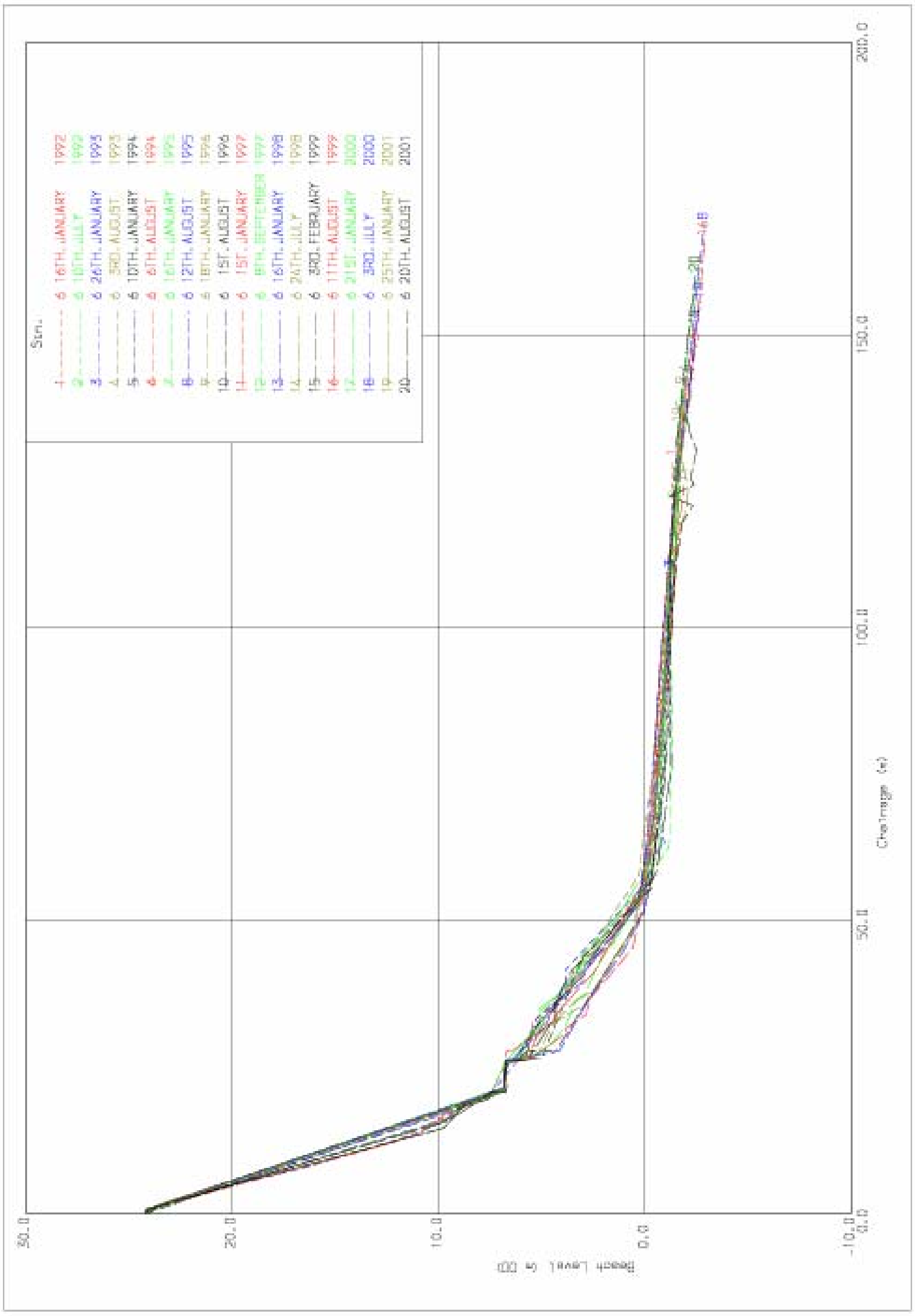

Fig beach profile

Figure A3 Beach Profiles Station 6 (N2A3)

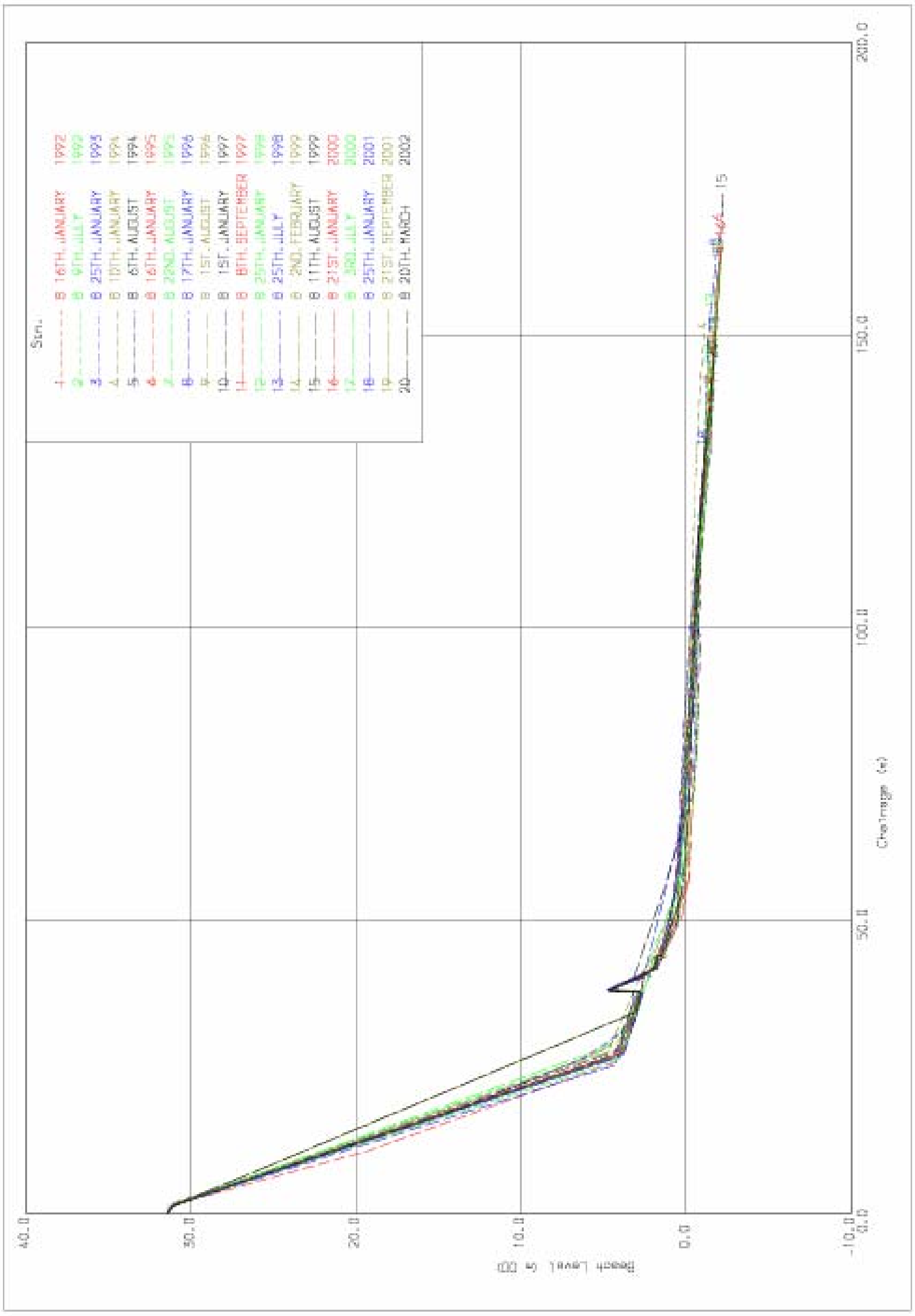

Fig 2

Figure A4 Beach Profiles Station 8 (N2A5)

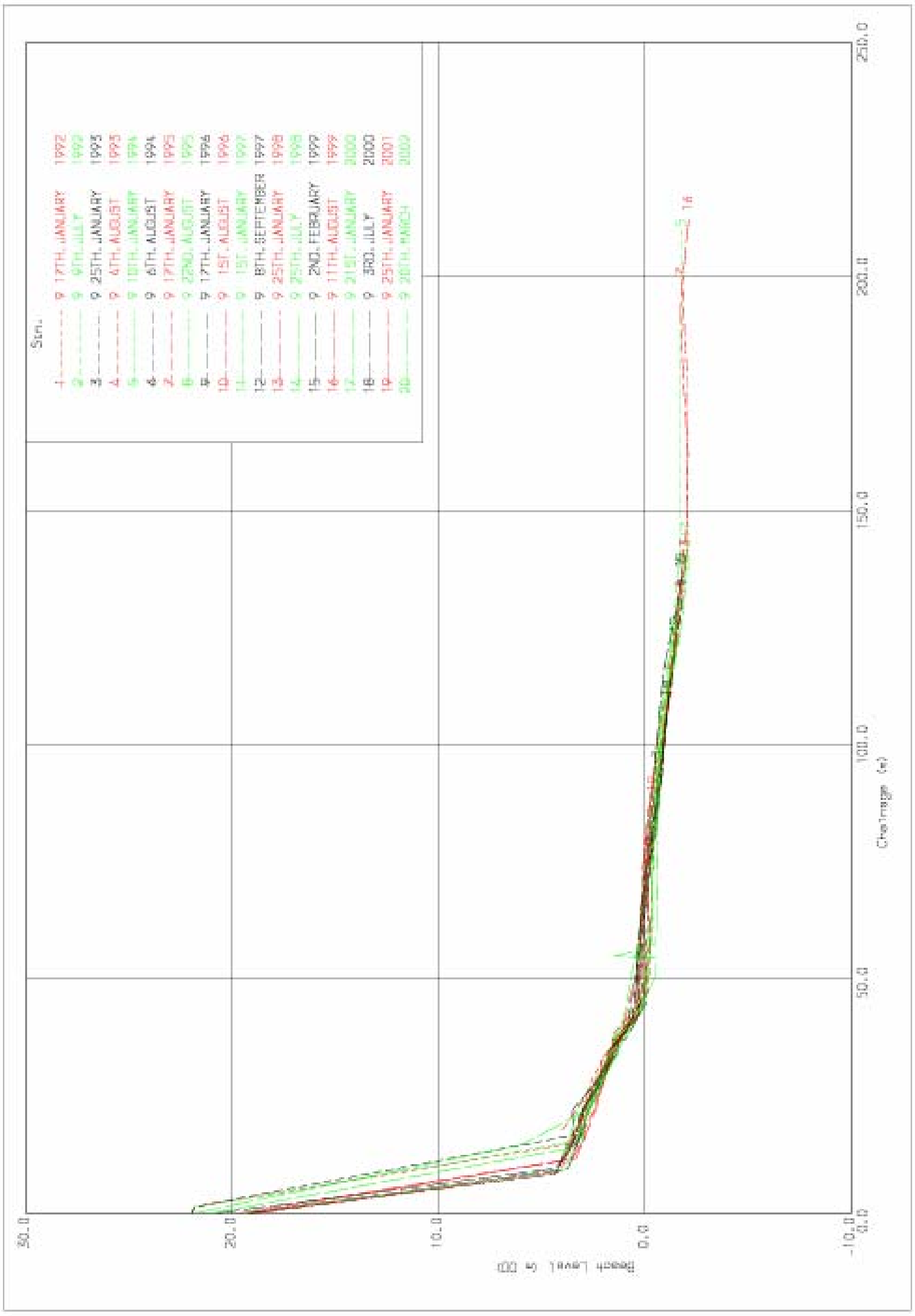

Fig 9 Station9 profiles

Figure A5 Beach Profiles Station 9 (N2A6)

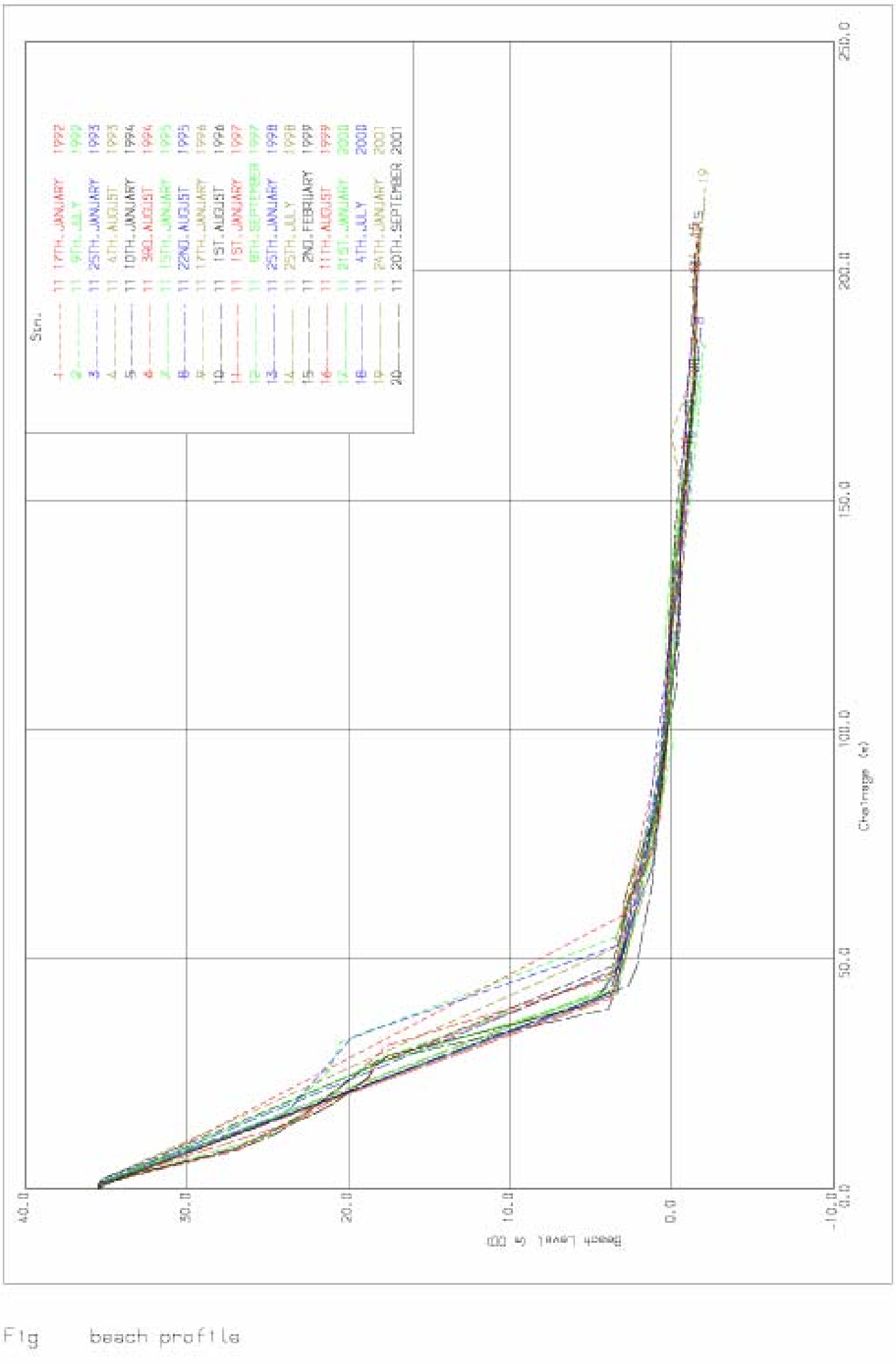

Figure A6 Beach Profiles Station 11 (N3E1)

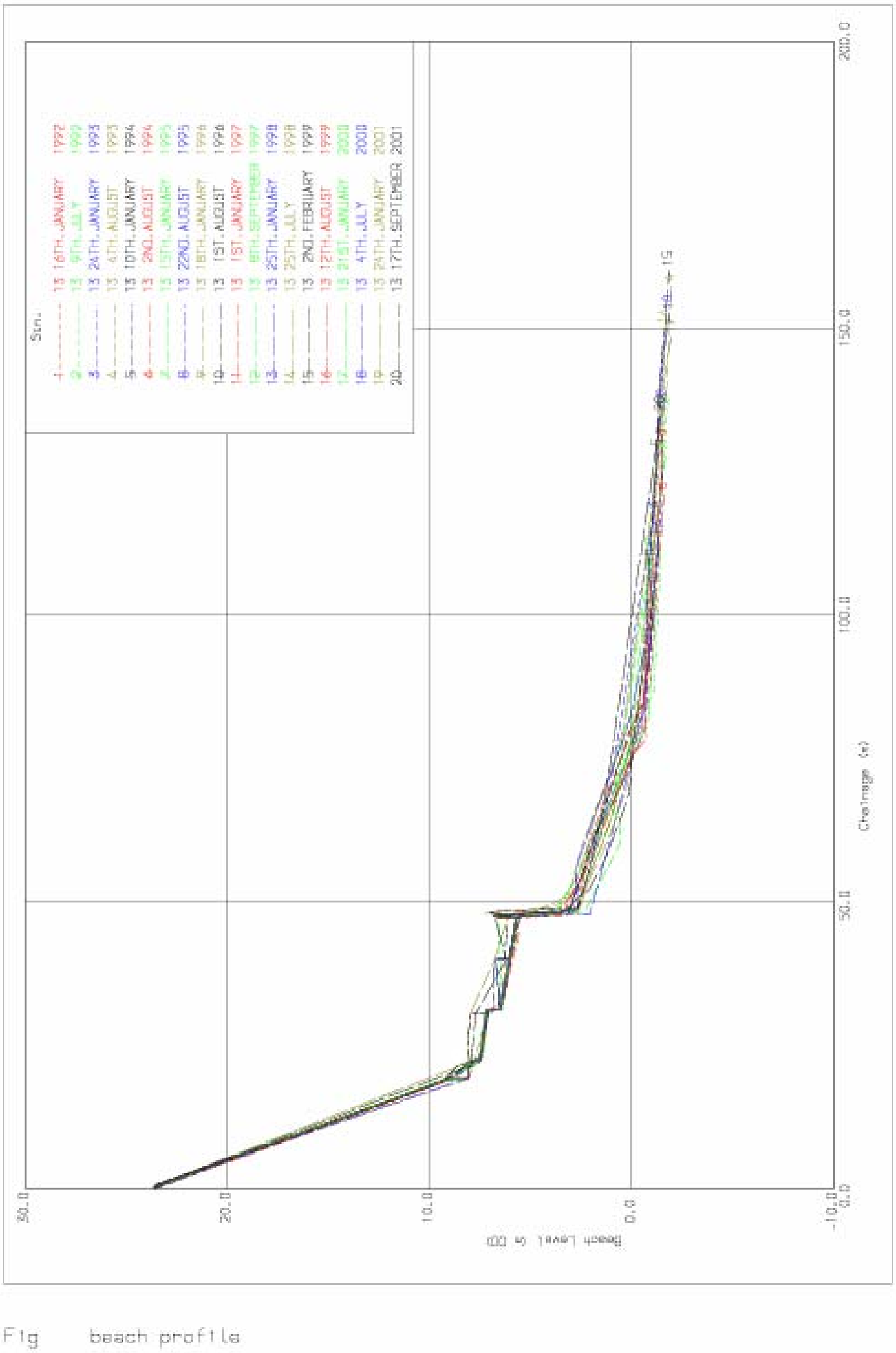

Figure A7 Beach Profiles Station 13 (N3E3)

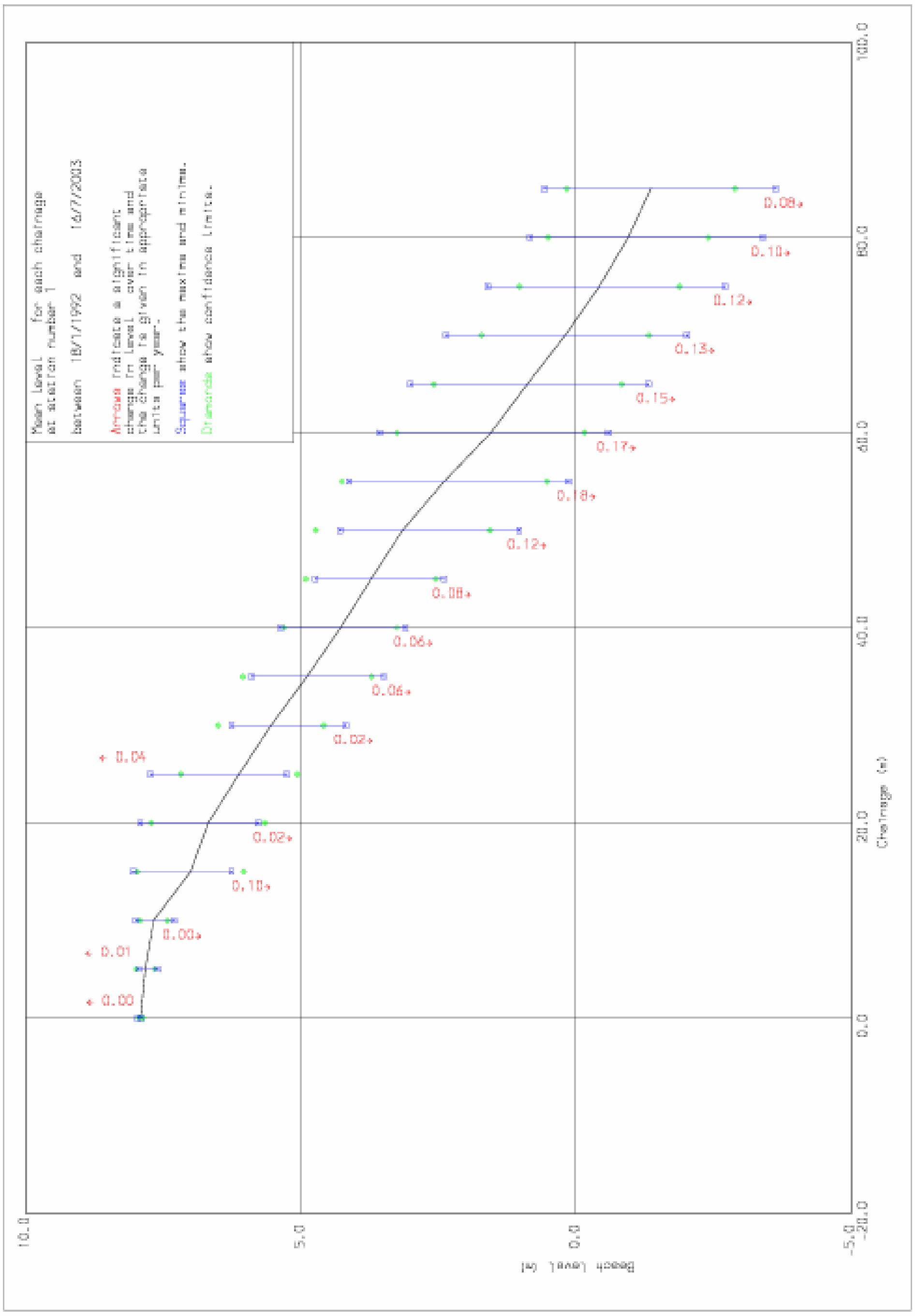

Fig Mean profile

Figure A8 Mean Beach Profile Station 1 (N2B5)

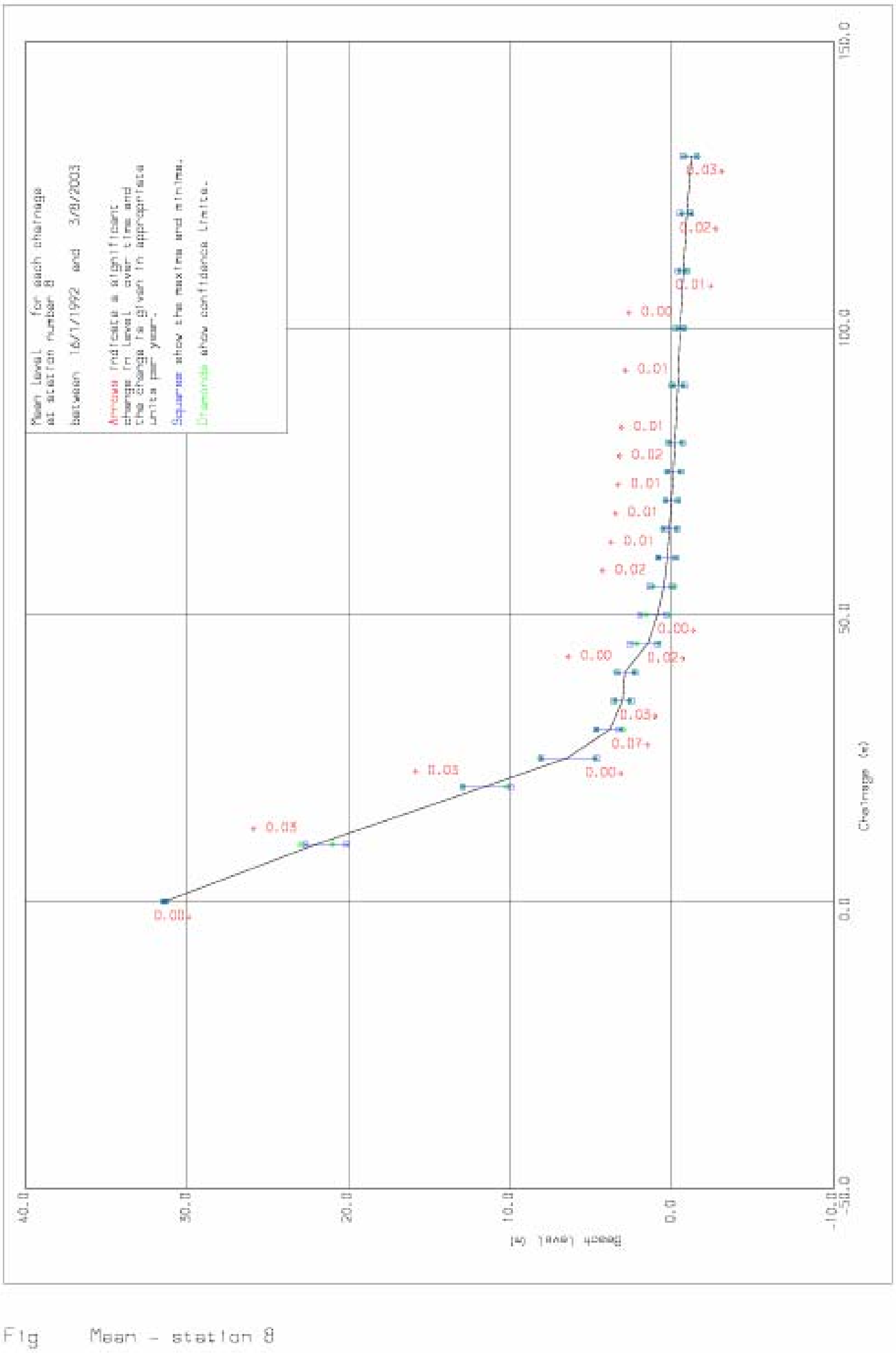

Figure A9Mean Beach Profile Station 4 (N2A1)

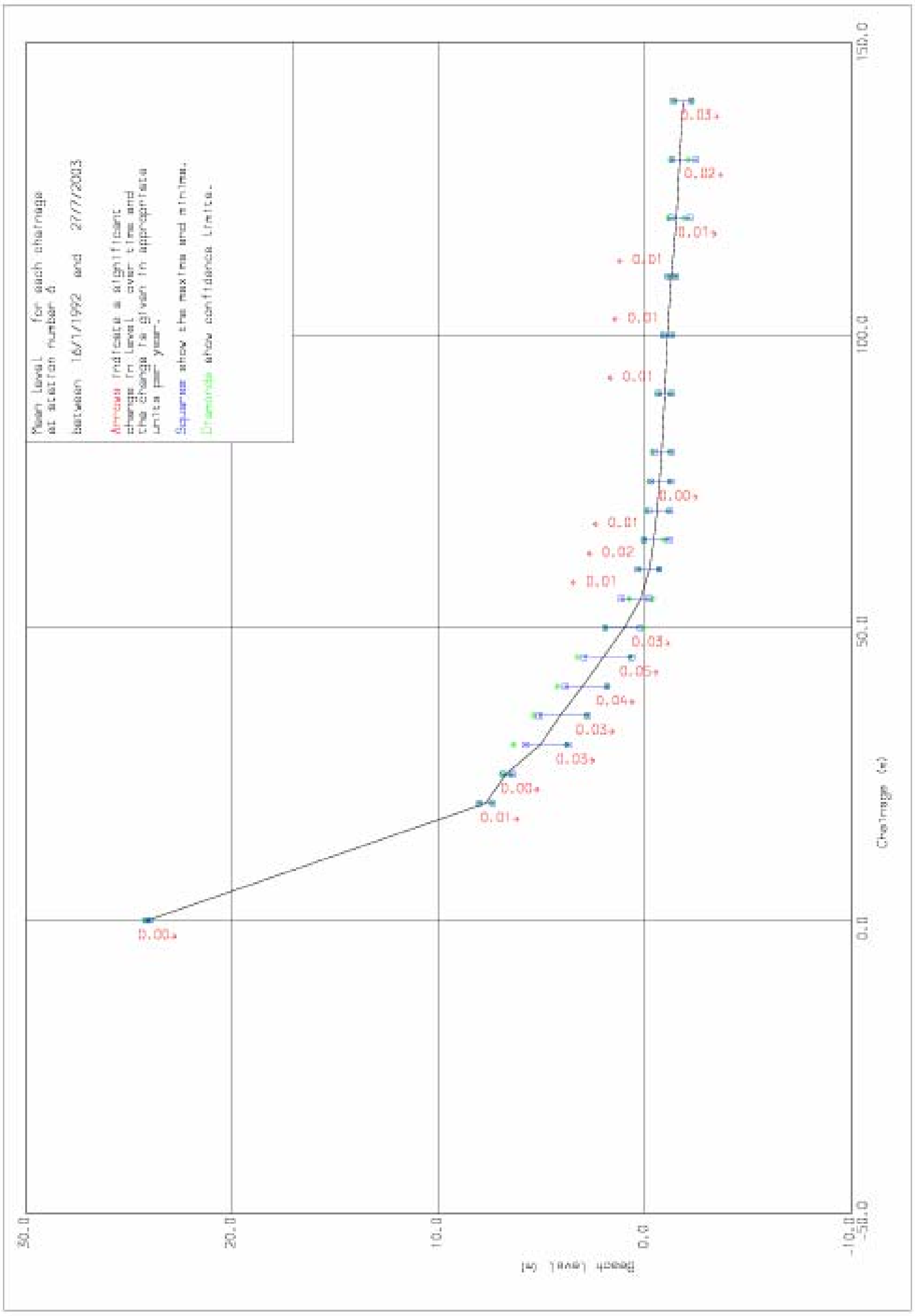

Fig Mean profile

Figure A10 Mean Beach Profile Station 6 (N2A3)

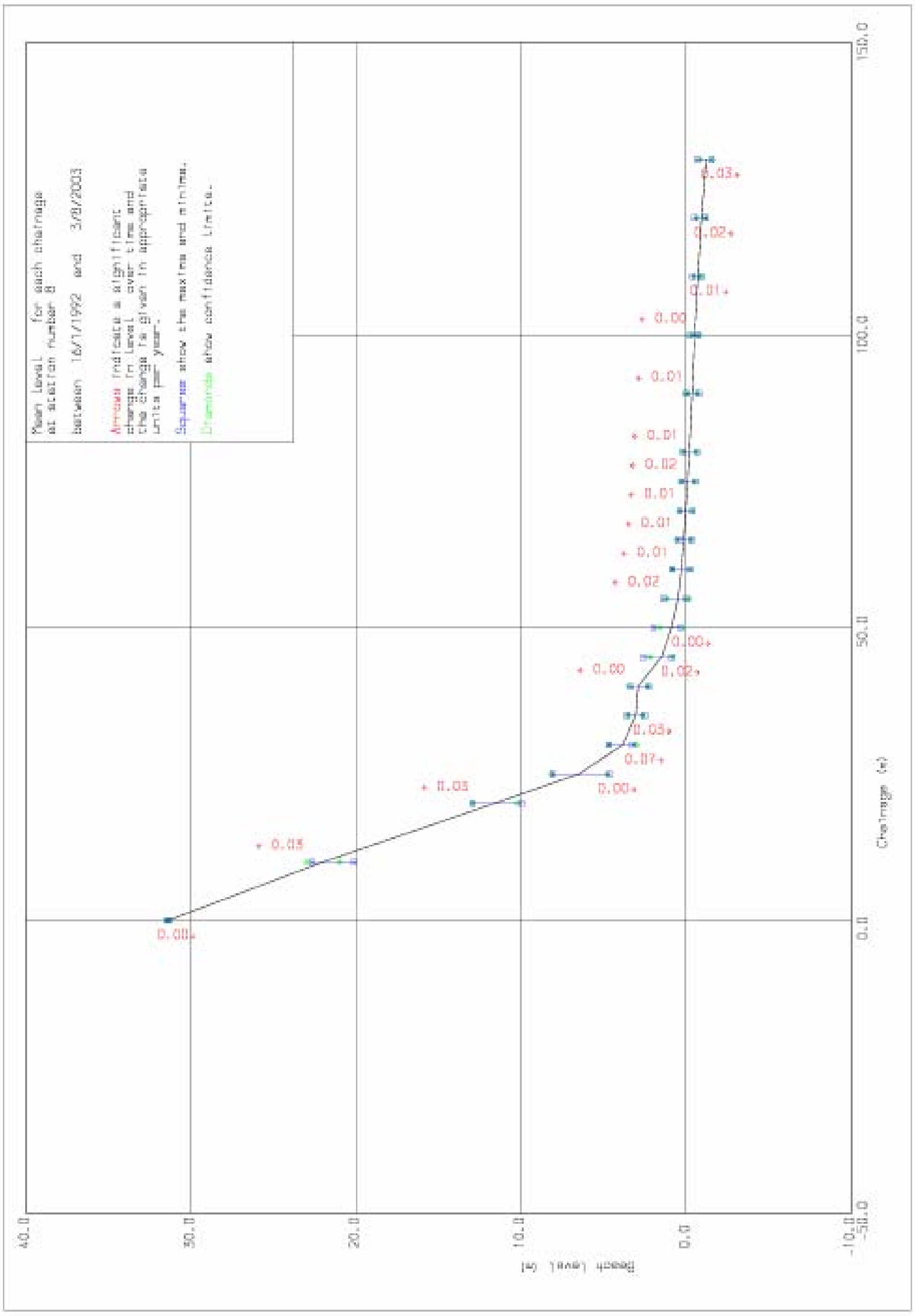

Fig Mean - station 8

Figure A11 Mean Beach Profile Station 8 (N2A5)

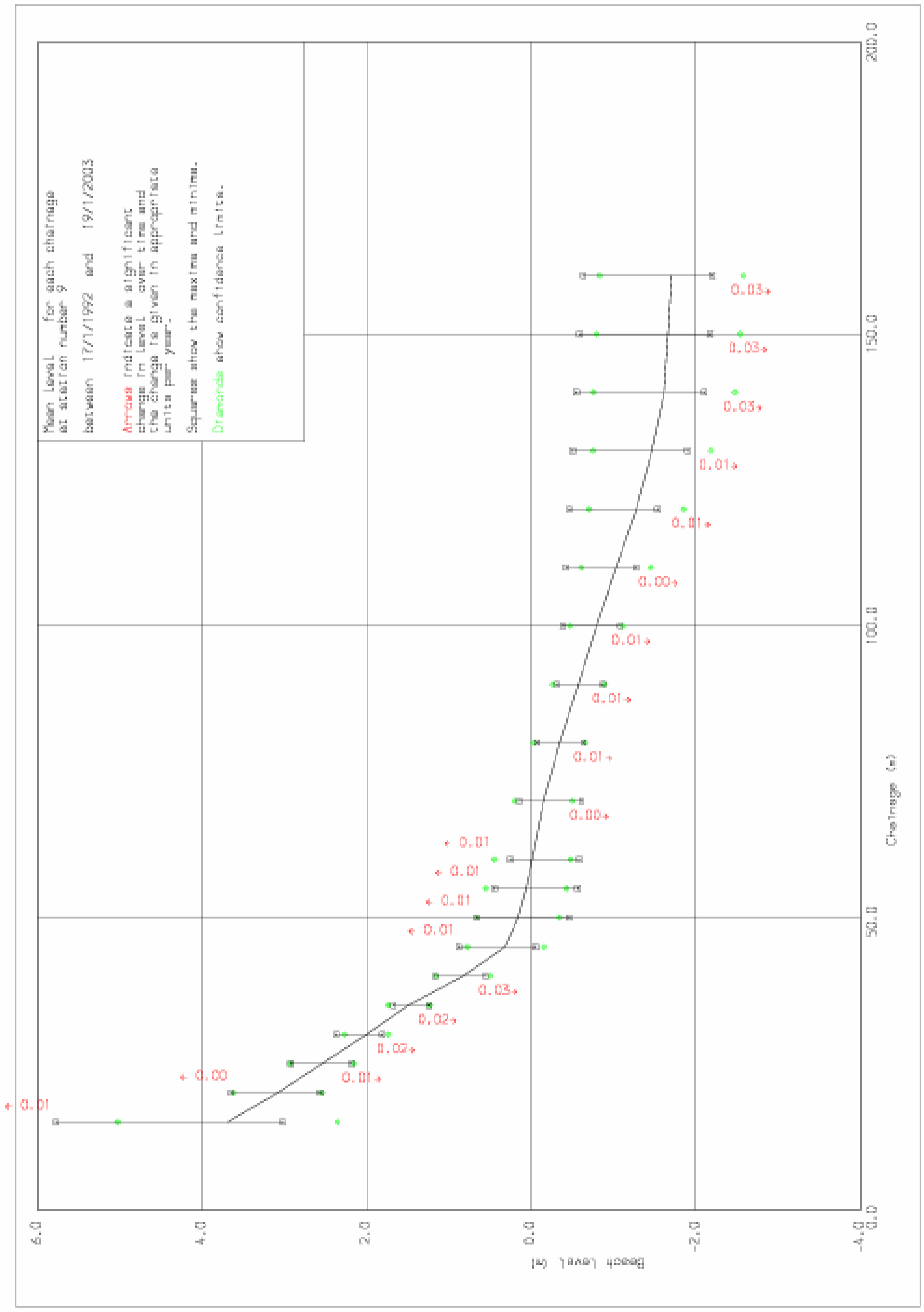

Fig Station 9 mean profile

Figure A12Mean Beach Profile Station 9 (N2A6)

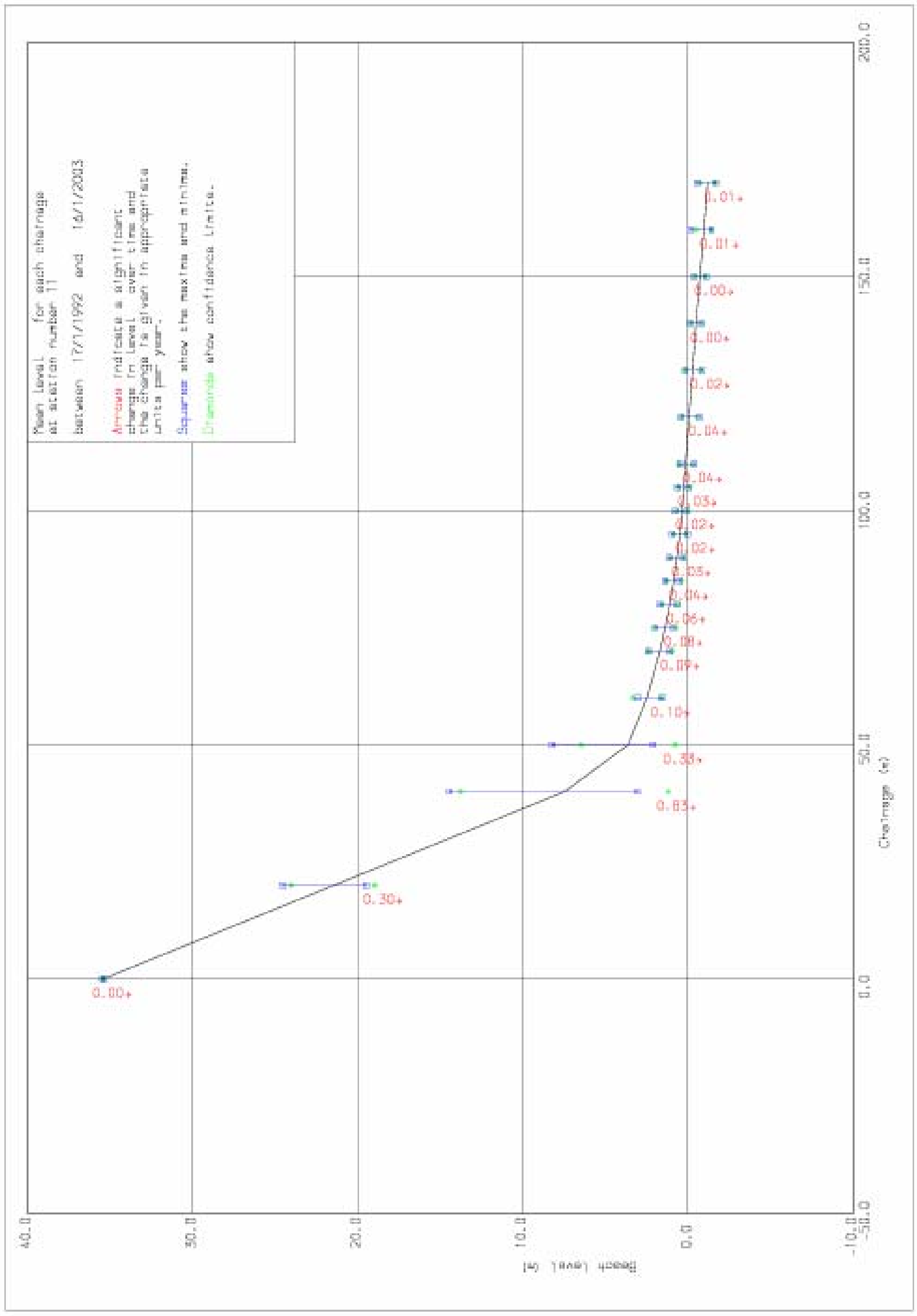

Fig Mean profile

Figure A13 Mean Beach Profile Station 11 (N3E1)

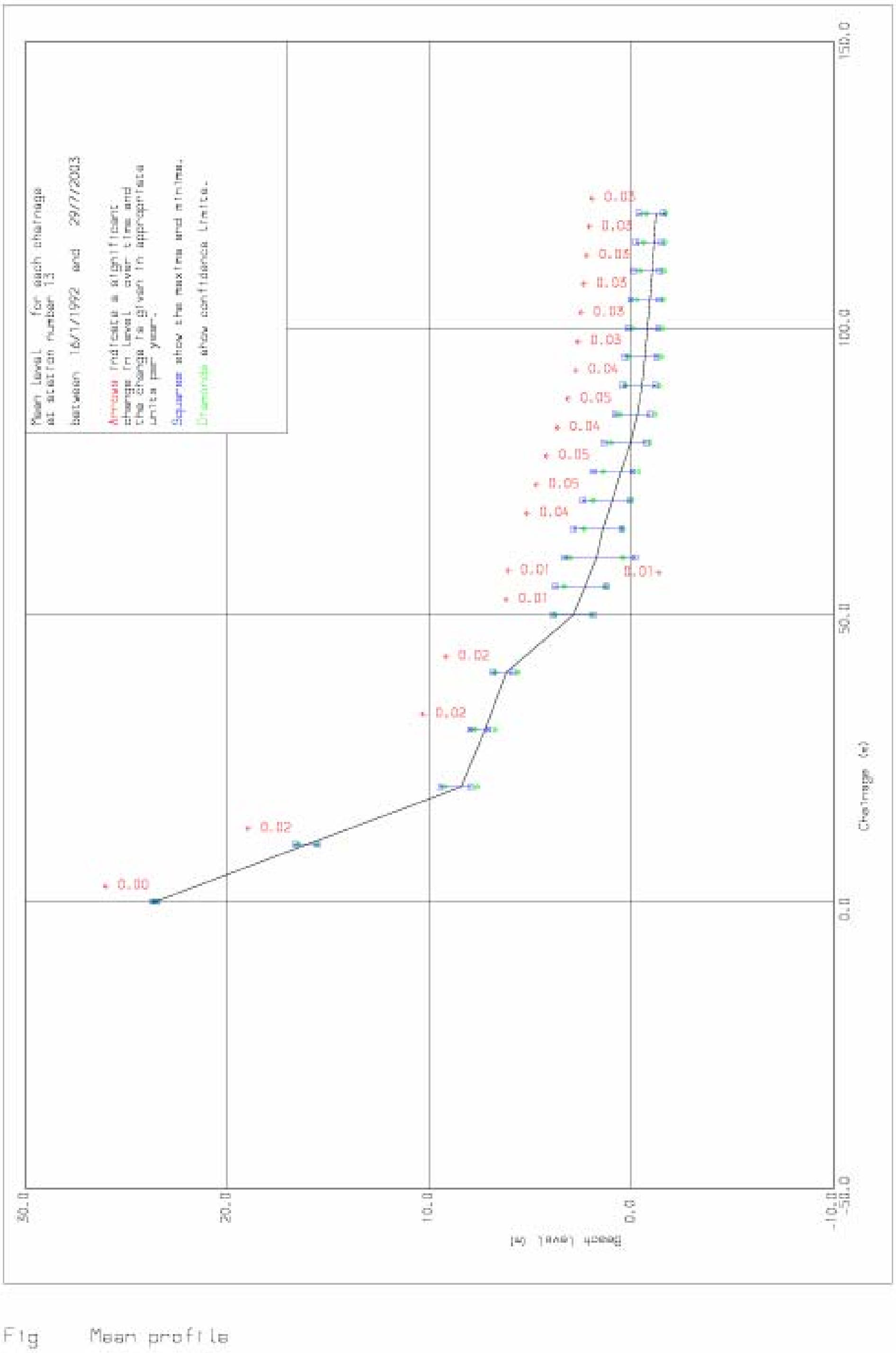

Figure A14 Mean Beach Profile Station 13 (N3E3)

Appendix B The Beach Data Analysis System (BDAS)

Surveying a beach along a fixed cross-section is a standard monitoring method that provides a quick check on its "health". Experience has shown, however, that unusual weather conditions can produce substantial, if temporary, changes in level which make it difficult to identify long-term trends. To separate gradual changes from these short-term fluctuations, it is necessary to repeat surveys, ideally several times a year, for some years, but this soon produces a large volume of information to be stored and analysed.

The Beach Data Analysis System (BDAS) has been developed at HR Wallingford to store, recall, present and analyse large volumes of cross-section beach survey data. The main functions of the system are as follows:

- To store beach profile data, from different sites and dates, in a standard format, in a computer database.
- To add extra profile information to the database as it becomes available, with in-built data quality checking procedures.
- To recall profile data and present it "on-screen" or graphically.
- To carry out statistical analyses of beach levels, gradients, cross-sectional areas and other parameters usually as a function of time.

Cross-sections are normally repeated at different dates along the same "line"; to avoid confusion with nomenclature, we define each "line" as a "station", and generally give it a number and name (e.g. Station 7, Town Beach - west). Surveys at different dates are then stored together for each station, for later analysis. Apart from the surveys, a station number and title, BDAS has the capacity to store further information for each station. This information includes the National Grid co-ordinates of the zero-chainage point, the bearing (Grid North) looking seaward down the profile line, and a "base" profile which can show the promenade, sea wall and, if known, the level of the solid rock stratum below the beach. This supplementary information is useful both to ensure consistency from survey to survey, and to examine beach level changes in the context of the solid defences and the underlying rock stratum.

Provided the surveys have been carried out consistently, however, this extra information is optional, and analysis of the profile data can proceed without it. For each profile, data is stored as a set of chainage-level pairs together with the survey date. Beach levels are normally reduced to Ordnance Datum, and chainages measured to a fixed point near the beach crest, often at the face of a seawall.

Data quality checking
Before any calculations are started, quality control checks on the cross-sectional profiles have to be carried out. For each of the stations, BDAS itself is used to produce plots of all the surveyed profiles. Apparent errors, such as the occasional "rogue" beach level, consistent shifts in chainage values, or simple data input errors, are then identified visually, and necessary corrections made, within the computer database, i.e. without having to re-enter the data. Further checks are carried out as the analysis proceeds, and the same approach to amending the data is adopted. If further information is available to correct, or

confirm the data questioned in this part of the process, the database can be altered, and any analysis can be repeated, at a future time.

Presentation of results
The primary use of BDAS is to gather together profiles from the same station, surveyed on different dates, and then carry out comparisons and statistical analyses of them. Changes over time can be separated into long-term trends, seasonal changes and short-term fluctuations. This type of analysis provides predictions of future beach changes, and a more detailed understanding of past events.

The most straightforward way to present such a statistical analysis of the beach data is by a "mean profile plot" for each station. In this type of plot, information is given on maximum, minimum and mean beach levels, and on the long-term rate of change in beach level, during the period considered. The long-term trend is calculated using a least-squares analysis method, and shown in metres/year upward (accretion) or downward (erosion). The graphs also show the statistical "confidence limits", within which 95% of the survey values can be expected to fall.

However, many other forms of presentation are available, for example graphs showing the changes in beach cross-sectional area over time. The BDAS software has the capacity to calculate a "trend' line which both identifies an underlying linear long-term (secular) trend and/ or any seasonal variations (using a sinusoidal function with a period of one year). Both of these components are calculated using multi-linear regression methods.

BDAS can produce time-series plots for a number of other parameters, for example:

- beach levels at specific locations (i.e. chainage values)
- beach slopes at specific locations (i.e. chainage values)
- the distance (i.e. chainage) to a particular beach contour level
- the distance to the crest of the first beach "bar" or the first "trough"

Further analysis techniques
Following on from the analyses described above, a number of further types of calculation are possible. The most obvious is the calculation of beach volumes, produced by combining information from various stations. We have not tried to generalise this type of analysis, because each beach is likely to be different, i.e. the distance and orientation changes between adjacent profiles, the discontinuities in beach levels caused by groynes, breakwaters etc. However, such calculations can usually be carried out readily using a spread-sheet, and BDAS has been organised in a way that results can be output in a format compatible with such subsequent analysis methods.

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Kelling to Cromer Strategy Study

Cliff processes

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Summary

Kelling to Cromer Strategy Study

Cliff Processes

Report EX 4985
November 2006

This Report describes cliff assessment and recession modelling work on the North Norfolk coast, undertaken as part of the Kelling to Cromer Strategy Study. The objective of the work has been to develop a cliff recession prediction model, which draws on historical records and an understanding of the geomorphology of the site (i.e. the Weybourne to Cromer cliffs) and its surrounding area (i.e. the North Norfolk cliffs, from Weybourne to Ostend).

The output of the model is a series of probability distributions of the predicted recession rates for each of the cliff units.

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1. Introduction

This Report describes cliff assessment and recession modelling work on the North Norfolk coast, undertaken as part of the Kelling to Cromer Strategy Study. The objective of the work has been to develop a cliff recession prediction model, which draws on historical records and an understanding of the geomorphology of the site (i.e. the Weybourne to Cromer cliffs) and its surrounding area (i.e. the North Norfolk cliffs, from Weybourne to Ostend).

The work has involved:

- *identification of cliff units* based on an assessment of surface form, geology, and the known or inferred landslide processes determined during the course of a site visit (July 2004; see Appendix B for a list of photographs – supplied in digital form).
- *determination of historical cliff top recession rates*, from published sources and analysis of the Environment Agency Sea Defence Management Study (SDMS) beach profiles.
- *use of a simple probabilistic cliff recession model* developed by Lee (2003, in press). This has required the derivation of appropriate adjustment factors to represent the impact of changing environmental controls in the future (sea-level, winter rainfall, beach levels and shoreline exposure/protection). Probabilities were assigned to each of these changes (*scenarios*), reflecting the consensus views of the project team.

The output of the model is a series of probability distributions of the predicted recession rates for each of the cliff units.

This report was prepared in 2004 and the information contained is correct to that time. For the current issue, minor revisions have been undertaken but there are no significant changes.

2. The Cliffs

2.1 MATERIALS

The north Norfolk cliffs are developed in a highly variable sequence of Anglian-age deposits (including a complex suite of interbedded tills - the North Sea Drift Formation - and associated meltwater deposits), earlier Pleistocene deposits (the Cromer Forest Bed Formation and Weybourne Crag), overlying an eroded Chalk platform. The main features of these deposits are:

1. *The North Sea Drift Formation*; these materials were deposited by an ice sheet that covered the region during the Anglian glaciation, around 400,000 years ago. It is believed that there was 3 ice advances into the North Norfolk basin, each depositing a distinct subglacial till unit. During each period of ice retreat, sands and laminated clays were laid down in shallow water, pro-glacial lakes.

   The detailed stratigraphy has been the focus of much research over the last 125 years, concentrating on the classic exposures at Trimmingham and West-East Runton; two of the more widely known nomenclatures are presented below.

   The three tills are laterally uniform, well-sorted sandy deposits and are separated by layers of meltwater sands and gravels and lacustrine clays and silts.

Banham (1968)	Reid (1882)
Brick Kiln Dale Gravels Gimingham Sands Third Till Mundesley Sands	Contorted Drift
Second Till Intermediate Beds First Till	Cromer Till

Recent interpretations by Lunkka (1994) and the British Geological Survey (Bowen 1999) have led to further reappraisals of the till sequence:

Banham (1968)	Lunkka (1994)	BGS Proposed Classification (Moorlock et al 2000)
Third Cromer Till	Cromer Diamicton	Overstrand Formation/Briton's Lane Member
Second Cromer Till	Walcott Diamicton	Lowestoft Formation/Walcott Member
First Cromer Till	Happisburgh Diamicton	Corton Formation/Happisburgh Diamicton Member

The diamicton (i.e. till) is highly deformed (i.e. contorted) comprising laminations and deformed blocks of clay, sand and gravel, and large rafts (*schollen*) of Beeston chalk (Figure 1). The deformations are believed to be the result of shearing, extension and flow of the highly saturated materials beneath the ice sheet. Overburden loading (*secondary gravity loading*) by the Gimingham Sands and Briton's Lane Gravels caused diapirism of the underlying water-saturated tills, leading to compensatory sinking of the sand units between the diapirs. An alternative view is that the contorted structures are the result of subaqueous deposition and slumping of the tills (e.g. Zalaziewicz and Gibbard 1988).

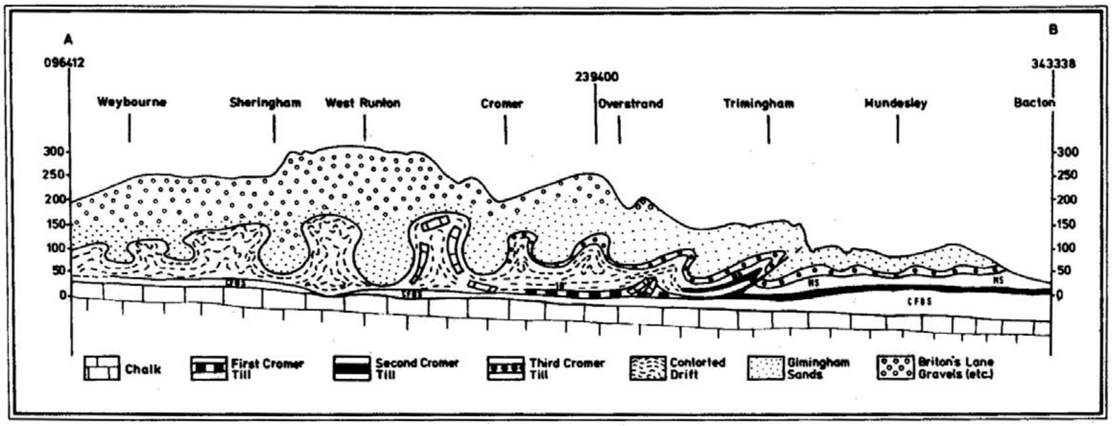

Figure 1 Cliff section along the north Norfolk coast (from Banham 1975)

Perched water tables occur within the glacigenic sediments.

1. *The Pre-Glacial Deposits*; these deposits are the product of a succession of pre-Anglian glaciation, climatic events and often appear at the base of the cliffs, although they may be obscured by landslide debris. The Cromer Forest-bed Formation and associated Freshwater Bed comprises grey shelly sands and shallow-water muddy deposits. The underlying Weybourne Crag is a shallow marine shelly sand deposit.

2. *The Chalk platform*; this declines in elevation from around +5m at Weybourne to +2.7m at Sheringham, –1.5m at West Runton and -2.1m at Cromer Pier. A piezometric surface probably occurs within the Chalk/Cromer Forest Beds that rises from around sea-level to an elevation of +5m OD behind the cliffline. This surface probably fluctuates slightly with the tides.

The cliffline is noted for the rapid changes within the glacial materials (Roberts and Hart 2000 describe it as a "*glacigenic melange*"). It is difficult to be precise about what materials can be expected at a particular section *and* what materials are likely to be encountered behind the cliffline. However, at a practical level the entire North Norfolk cliffline can be regarded as a single broad-scale system i.e. there are no significant changes in competence of the materials or resistance to marine erosion along the frontage.

2.2 CLIFF UNITS: WEYBOURNE TO CROMER

Five separate cliff units have been defined, on the basis of the geology (i.e. the presence of *in situ* Chalk at the cliff foot, beneath the glacial till), degree of protection (i.e. unprotected, palisades or seawalls etc.), beach type and activity state. Key features of these units are described in Table 1.

Table 1 Cliff Units

Cliff unit	Location	Coastal defences	Beach conditions	Activity State	SDMS profiles
1	Weybourne to Dead Mans Hill (E)	None	Fringing shingle beach with storm ridges. Chalk shore platform exposure on upper beach.	Actively retreating	N2B5, N2B6, N2B7, N2A1
2	Robin Friend	None	Fringing shingle beach with storm ridges. Chalk shore platform exposure on upper beach.	Actively retreating	N2A2, N2A3
3	Beeston to West Runton Cliffs	Timber palisades - open for most of the section.	Partitioned sand and shingle beach.	Actively retreating	N2A4, N2A5, N2A6
4	West Runton to East Runton Cliffs	None	Partitioned sand and shingle beach. Chalk shore platform exposed at LW.	Actively retreating	N2A7, N3E1
5	East Runton to Cromer Cliffs	None	Partitioned sand and shingle beach. Chalk shore platform exposed at LW.	Actively retreating	N3E2

Protected cliff sections occur at Sheringham, West Runton and East Runton.

2.3 HISTORICAL RECESSION RATES

Table 2 presents historical cliff recession data for each cliff unit, derived from the following sources:

- 1880-1905, 1905-1946 and 1946-1967, from the recession information presented in Cambers (1976);
- 1966-1985, from recession information presented in Clayton and Coventry (1986);
- 1992-2003, from the analysis of changes in cliff top position on SDMS profiles (sites N2B5-N3E2).

Figure 2 presents this information as a series of recession profiles along the cliffline. It is clear that there is considerable variability between sites along the same cliffline and between measurement periods. A *medium-term* historical recession rate was established by combining the cumulative recession over the periods 1966-1985 and 1992-2003 and dividing by the number of years in the combined periods. This recession rate takes account of both the recent high recession rates and the longer term trends. It also provides a recession rate that is applicable over the period of recorded sea-level change (1956-1995; Woodworth et al., 1999). These rates are presented in Table 3.

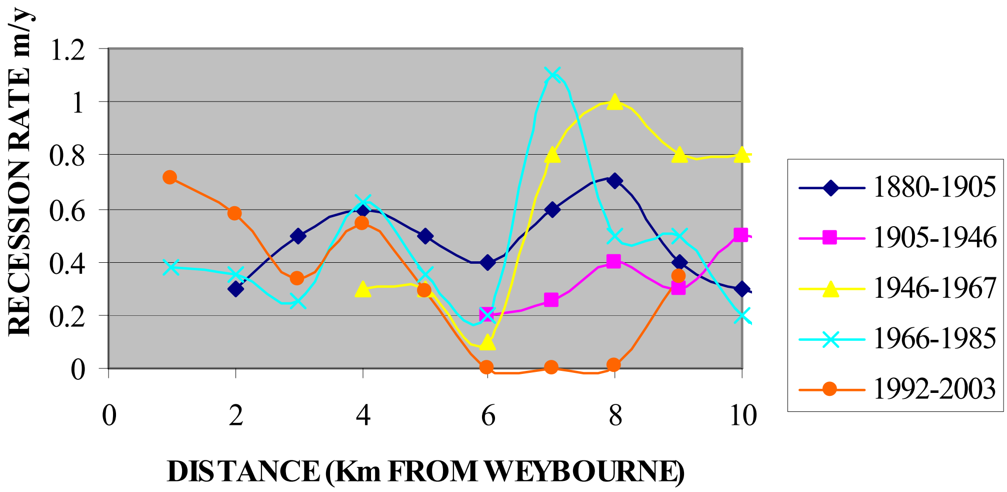

Figure 2 Historical cliff recession trends (various sources, see text)

Table 2 Historical cliff recession rates

Cliff Unit	SDMS Profiles	Recession Rate (m/year) 1880-1905	1905-1946	1946-1967	1966-1985	1992-2003
1 Weybourne to	N2B5				0.375	0.71
Dead Mans Hill	N2B6	0.3			0.35	0.58
	N2B7	0.5			0.25	0.33
	N2A1	0.6		0.3	0.625	0.54
2 Robin Friend	N2A2	0.5		0.3	0.35	0.29
	N2A3	0.4	0.2	0.1	0.2	0
3 Beeston to West	N2A4	0.6	0.25	0.8	1.1	0
Runton	N2A5	0.7	0.4	1	0.5	0.005
	N2A6	0.4	0.3	0.8	0.5	0.34
4 West Runton	N2A7	0.3	0.4	0.8	0.1	0.59
to East Runton	N3E1	0.75	0.5	0.8	0.25	0.09
5 East Runton to Cromer	N3E2	0.5	0.3	0.4	0	0.12

Table 3 Medium-term recession rates (1966-2003)

Cliff Unit	SDMS Profiles	Combined Recession Rate (1966-2003) m/year
1 Weybourne to Dead Mans Hill	N2B5	0.498
	N2B6	0.434
	N2B7	0.279
	N2A1	0.594
2 Robin Friend	N2A2	0.328
	N2A3	Protected Cliff
3 Beeston to West Runton	N2A4	Protected Cliff
	N2A5	0.005*
	N2A6	0.441
4 West Runton to East Runton	N2A7	0.280
	N3E1	0.191
5 East Runton to Cromer	N3E2	0.12

Note: * the 1992-2003 recession rate is considered to be a better reflection of the current state of this protected cliff, which had been unprotected during the period 1966-1985.

3. The Prediction Model

3.1 INTRODUCTION

There is uncertainty about the future conditions that might influence cliff recession, such as sea-level, rainfall patterns, beach conditions and cliff toe exposure. Probabilistic methods aim to acknowledge and take account of these sources of uncertainty and, hence, offer an improvement on conventional deterministic predictions. Such methods are essentially sophisticated sensitivity tests in which single data values (i.e. recession rates) are replaced by probability distributions that cover all possible values or outcomes.

A simple probabilistic model has been used to develop a probability distribution, rather than a single recession rate, for each cliff section (Lee 2003, Lee, in press). The framework for this model is presented as Figure 3 and involves a series of separate stages at which judgements, based on the available knowledge of the site conditions, are made about the need to adjust the historical recession rate because of changing future conditions, especially future sea-level rise. The effects of future conditions are represented by factors that can be used to adjust the historical recession rate e.g.

Future Recession Rate = (Historical Recession Rate + Sea-level Rise Factor) *x*
Winter Rainfall Factor *x*
Beach Erosion/Accretion Factor *x*
Cliff Toe Exposure Factor

Choice of values for these factors is largely subjective, but judgements can be based on understanding of local conditions and cliff behaviour.

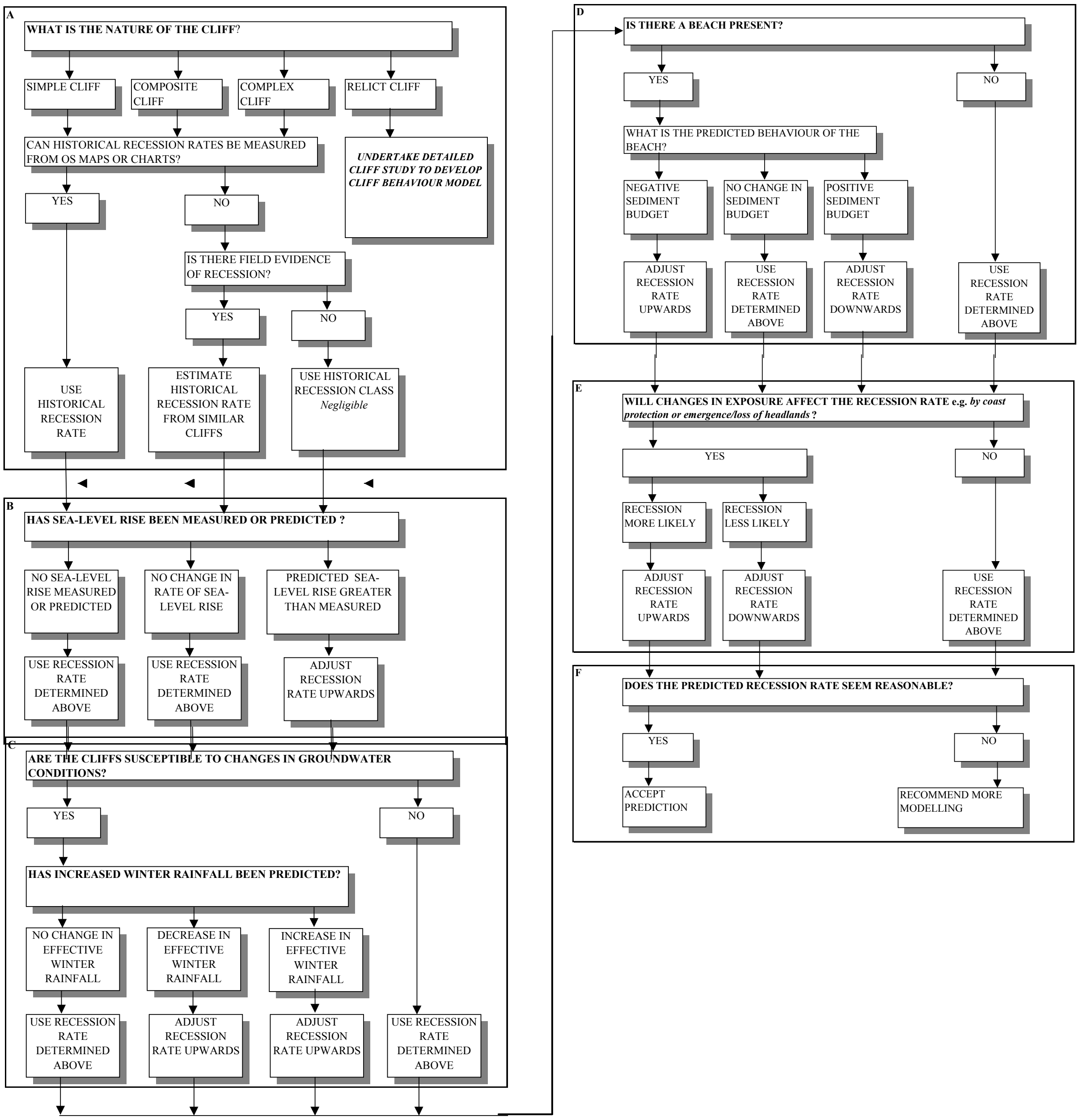

Figure 3 Framework for the simple prediction model (from Lee, in press)

It is possible to develop *numerous* possible cases, each with different combinations of future condition changes. For example:

- Case 1, rate of sea-level rise greater than the historical rate, an increase in the effective winter rainfall, a decline in beach levels and an increase in cliff toe exposure;
- Case 2, rate of sea-level rise the same as the historical rate, no change in the effective winter rainfall, a decline in beach levels and an increase in cliff toe exposure;
- Case 3, rate of sea-level rise greater than the historical rate, no change in the effective winter rainfall, no change in beach levels, and no change in cliff toe exposure.

Each of these cases and the other possible cases will result in a different average annual recession rate and can be assigned a conditional probability:

Prob. (Case *n*) = Prob. (Sea Level Rise) x Prob. (Winter Rainfall) x Prob. (Beach Levels) x Prob. (Cliff Toe Exposure)

The probabilistic model is essentially an event tree that represents all the possible outcomes represented in Figure 3. Event trees are a specific form of branching logic diagram which allow all likely sequences of events, or combinations of scenarios to be mapped as a branching network, with estimated probabilities at each branch (e.g. Cox and Tait, 1991). Once the structure of the tree has been developed by establishing all the likely sequences of events and resultant outcomes then probability values can be assigned to each of the branches (Figure 4).

The individual probability of achieving a certain outcome is the product of the likelihood of the initial condition (i.e. historical recession rate) and the conditional probabilities of all intervening conditions along a pathway leading to that specific outcome (i.e. an individual recession scenario). For example, suppose an initial condition i.e. historical recession rate (R) has a probability P(R). Given that this condition occurs, the sea-level rise factor, S, has the probability P(S|R). Likewise, the winter rainfall factor (W) has a conditional probability P(W|S), and so on. The probability of a particular scenario occurring is:

Scenario Probability = P(R) x P(S|R) x P(W|S) x P(B|W) x P(E|B)

The sum of the conditional probabilities for *all possible cases* adds up to 1.0 and can be presented as a simple plot of average annual recession rate against its probability.

3.2 PROBABILISTIC MODEL: DATA INPUTS

In this study, the model takes account of the following sources of uncertainty:

- *historical recession rate*; rather than establishing an average value for each cliff unit, it has been assumed that the recession value at each SDMS site within a particular cliff unit is equally likely. For example, on the Weybourne-Dead Man's Hill section there are 4 SDMS profiles, each with a different historical rate. Each separate rate has been used in a series of different cases for the site (Probability = 0.25).
- *sea-level rise;* although sea-level is expected to rise over the next 50 years, there is uncertainty over the actual rate of rise. It is suggested that a range of rates will be possible, although the likelihood of some rates (e.g. the DEFRA recommended rate of 6mm/year) will be higher than other, more extreme values.

The local change in sea-level is expected to be between 0.22m (low emissions scenario) and 0.82m (high emission scenario) by 2080, yielding average annual rates of between 2.7mm/year and 10mm/year (Hulme et al 2002).

A probability distribution has been established for the rate of sea-level rise, based on the consensus views of the project team (Table 4).

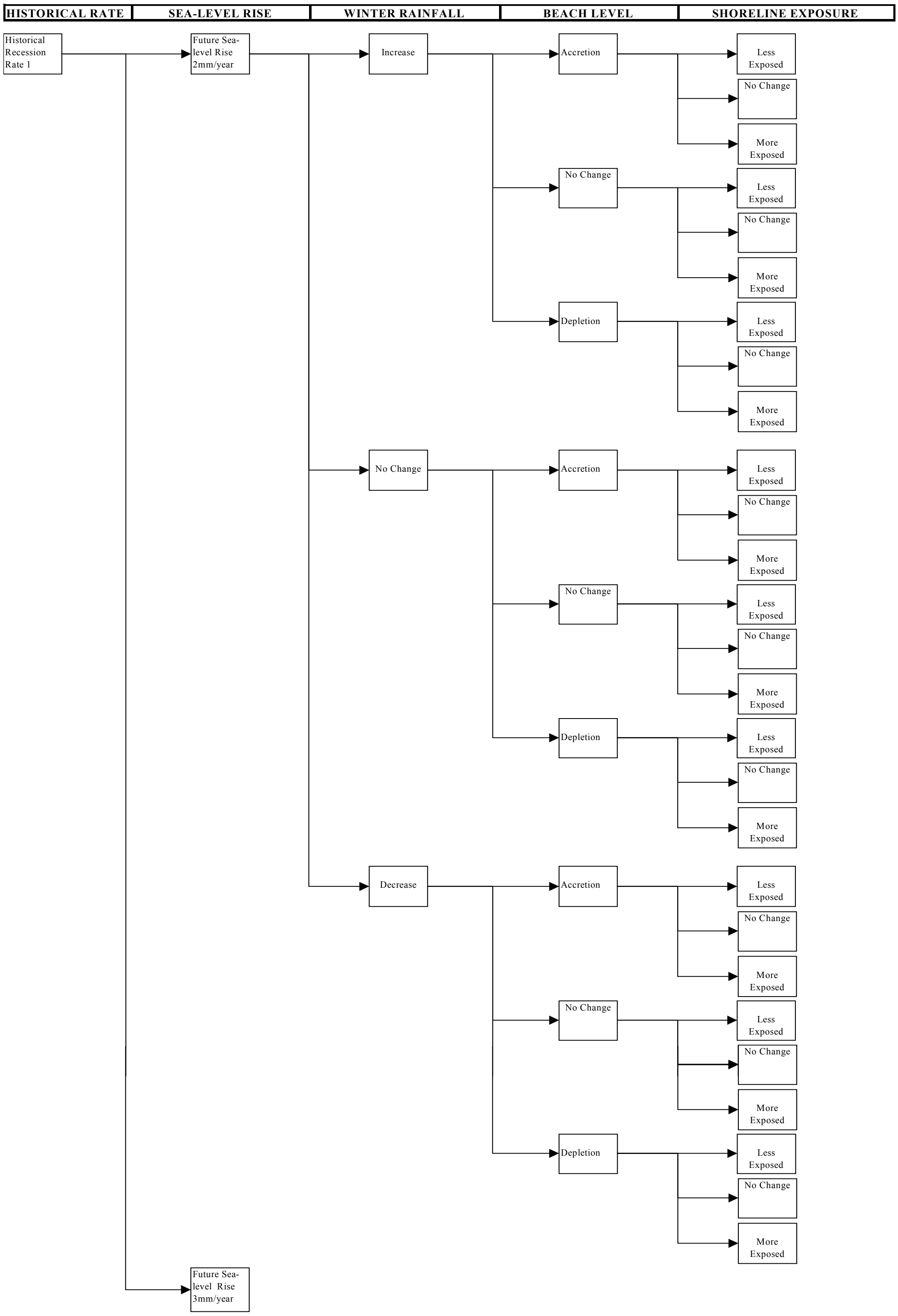

Figure 4 Event tree representing part of the outcomes associated with the prediction model (from Lee, in press)

Table 4 Sea-level rise: Probability distribution

Sea-level Rise (m/year)	Estimated Probability	Adjustment Factor*
0.002	0	0.009
0.003	0.025	0.055
0.004	0.05	0.102
0.005	0.2	0.148
0.006	0.4	0.195
0.007	0.2	0.242
0.008	0.05	0.288
0.009	0.05	0.335
0.010	0.025	0.381

Note: * The adjustment factor is an additional increment to the historical rate, not a multiplication factor. The factor varies with cliff height and sediment yield. The figures above are for SDMS profile N2B6; slightly different figures apply to the other sites.

Adjustment factors for each of these sea-level rise cases have been generated through the modified Bruun Rule (see Appendix A). Although the Bruun Rule is not without its critics for predicting beach behaviour (e.g. Komar et al 1991), the overall validity of this approach appears to have been confirmed for the eroding cliff shores of Chesapeake Bay and the Great Lakes (Rosen 1978; Hands, 1983; Dubois 1992; Zurek et al 2003).

- *winter rainfall*; this factor represents the change in average annual cliff recession rate related to change in effective winter rainfall (i.e. changes in pore water pressure and lower factor of safety of the slopes). Recent climatic modelling by the Hadley Centre (Hulme et al 1998) has predicted an increase in the average winter rainfall (December, January, February) equivalent to around 0.75mm/day by the year 2100 i.e. an increase of around 25-30% from the current winter daily average of around 2mm/day. The impacts of these changes on the recession rate are uncertain, although it is widely recognised that coastal landslide activity is related to wet-year sequences (e.g. Brunsden and Lee 2004; see Appendix A). The adjustment factors and their estimated probabilities are shown in Table 5.

Table 5 Winter rainfall: Probability of Future Scenarios and Adjustment Factors

Winter Rainfall	Estimated Probability	Adjustment Factor
Increase	0.6	1.1
No Change	0.3	1
Decrease	0.1	0.95

- *beach erosion/accretion factor*; this factor represents the change in average annual cliff recession rate related to changes in the degree of cliff protection provided by the beach. This in turn is related to changing sediment inputs (e.g. different geology exposed), changes in the regional sediment budget or simply the continuation of existing trends. The relationship between the average beach volume (measured as the beach profile area above High Water Mark – the "beach wedge") and annual cliff recession rate for unprotected sections of the Suffolk and Norfolk clifflines has been defined by Lee (in prep.) and is shown in Figures 5 and 6 (see Appendix A). This indicates that average annual recession rates increase exponentially as beach volumes above HWM fall (i.e. "wedge area").

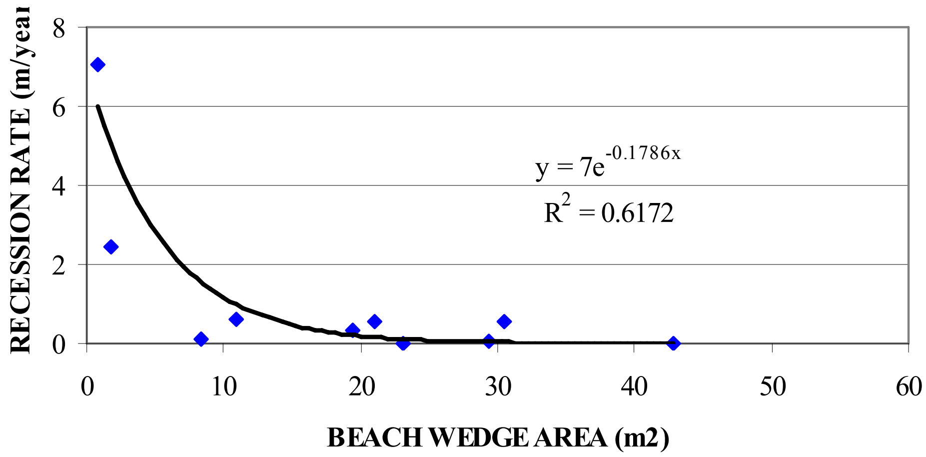

Figure 5 **Norfolk Cliffs: Recession Rate and Beach Volume (Unprotected) (from Lee, in Prep)**

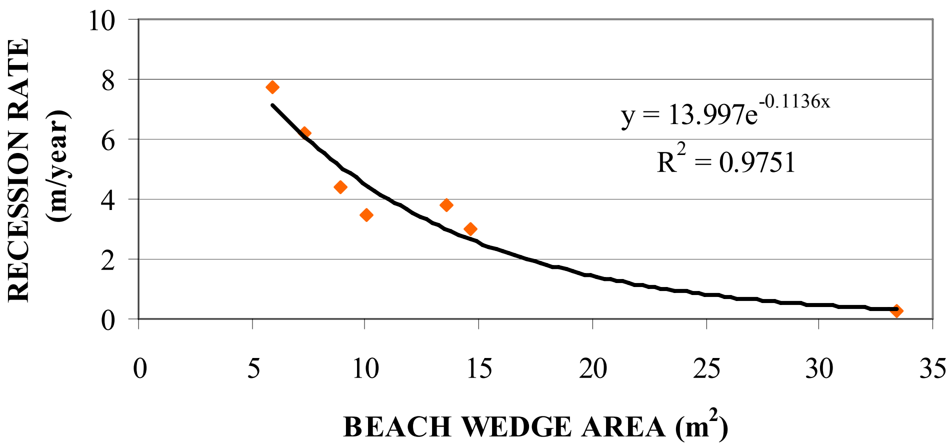

Figure 6 **Suffolk Cliffs: Recession Rate and Beach Volume (Unprotected) (from Lee, in prep)**

Using the relationship between beach volume (i.e. the wedge area) and recession rate, it has been possible to estimate the potential impact of future beach depletion or accretion at different SDMS sites along the coastline, relative to the 1992-2003 average beach conditions (Table 6; see Appendix A).

For the Norfolk coast, it was estimated that beach changes would be relatively minor, around ±10%. The estimated probability of different beach erosion/accretion scenarios (i.e. 10% accretion, 10% depletion, no change) varies between cliff units, reflecting the relative position of the unit within a sediment transport cell (e.g. a tendency for accretion on the updrift side of defences and erosion on the downdrift side). Note that the judgement for each site takes account of the relationship between accelerated recession at one location and increased sediment supply to adjacent beaches (i.e. longshore sediment exchanges). Table 7 presents the estimated likelihoods for each cliff unit; these are based on the consensus views of the project team.

Table 6 Sediment Budget Factors

SDMS profile	1992-2003 Average Beach wedge area (m^2)	Adjustment factor: depletion 10%	Adjustment factor: depletion 25%	Adjustment factor: accretion 10%	Adjustment factor: accretion 25%
B6	30.47	1.71	3.82	0.59	0.26
B7	29.29	1.56	3.05	0.64	0.33
A1	20.94	1.43	2.44	0.70	0.41
A2	23.04	1.43	2.44	0.70	0.41
A5	9.18	1.09	1.25	0.91	0.80
A6	8.16	1.09	1.25	0.91	0.80
A7	10.93	1.20	1.56	0.84	0.64
E1	7.9	1.09	1.25	0.91	0.80
E2	42.8	1.71	3.82	0.59	0.26

Table 7 Estimated Probabilities of Different Beach Erosion/Accretion Scenarios

Cliff unit	Location	Beach Levels Accretion	No Change	Depletion
1	Weybourne to Dead Mans Hill (E)	0.01	0.39	0.6
2a	Robin Friend	0.01	0.39	0.6
2b	Robin Friend - Sheringham	0.1	0.6	0.3
3a	Beeston Cliffs	0.05	0.9	0.05
3b	Beeston to West Runton Cliffs	0.1	0.3	0.6
4	West Runton to East Runton Cliffs	0.01	0.39	0.6
5a	East Runton to Cromer Cliffs	0.01	0.39	0.6
5b	Cromer (W)	0.39	0.6	0.01

- *cliff toe exposure factor*; this factor represents the change in average annual cliff recession rate related to change in cliff toe protection at the site. The effectiveness of different types of coast protection measures on the Norfolk cliffline has been defined by Lee (in prep.) in terms of the reduction in recession rate between protected and unprotected cliffs with comparable beach wedge areas (see Appendix A).

Table 8 Comparison of the relative effectiveness of different coast protection measures relative to unprotected cliff sections

Beach Wedge Area (m^2)	Unprotected Cliffs	Timber Palisades	Seawalls
<15	1.0	0.02	0.0
15-25	1.0	0.25 – 0.4	0.0
>25	1.0	1.0	0.0

Note: For a beach wedge area of <15m2 with a timber palisade defence, the average annual recession rate would be 2% of that for an equivalent unprotected site.

Analysis of SDMS beach and cliff profiles has revealed that timber palisades have been effective in reducing cliff recession over the monitoring period (1992-2000). The palisades appear to be particularly effective in preventing rapid recession under low beach conditions (i.e. low beach wedge areas; see Table 8).

An indication of their effectiveness is provided by comparing the actual measured recession (1992-2002/2003) for a particular site, with the predicted rate without the palisades in place, *given* the average beach levels. For example:

- Profile A5 (Beeston); the recorded recession rate was 0.005m/year with average beach wedge area of 9m^2. An unprotected cliff with a beach wedge area of 9m^2 is predicted to have had a recession rate of 1.3m/year.

- Profile D6 (Marl Point); the recorded recession rate was 0.11m/year with average beach wedge area of 2.9m^2. A comparable unprotected cliff is predicted to have had a recession rate of 4.2m/year.

The ratio between the actual measured recession rate (1992-2000/2003) and the predicted rates indicate that at very low beach levels (beach wedge area <15m^2) the palisades have reduced recession rates by over 97%; between 15-25m^2 the reduction is around 60-75%. For higher beach levels (beach wedge area >25m^2) the palisades do not appear to reduce the recession rate, presumably because the high beach provides sufficient protection already.

An increase in cliff toe exposure (e.g. failure of the palisades) is expected to have the reverse effect i.e. a currently protected site would experience an increase in recession rate. The increase in rate would be related to the beach levels at that particular site. For example, failure of the palisades at Profile A5 (Beeston) could result in a change in average recession rate from 0.005m/year to 1.3m/year.

Three different cliff toe exposure scenarios have been developed, each with an associated adjustment factor (Table 9). The decreased protection scenario is assumed to involve the removal or deterioration of timber palisade sections. Table 10 presents the estimated likelihoods for each cliff unit; once again, these are the consensus views of the project team.

Table 9 Cliff Toe Exposure Factors

Cliff Toe Exposure	Adjustment Factor
Increased protection/less exposed	0 - 0.1
No Change	1
Decreased protection/more exposed	10 (Low beach levels < 15m^2)
	4 (Moderate beach levels 15-25m^2)
	1 (High beach levels >25m^2)

Table 10 Estimated Probabilities of Different Cliff Toe Exposure Scenarios

Cliff unit	Location	Cliff Toe Exposure Scenario		
		Increased	No Change	Decreased
1	Weybourne to Dead Mans Hill (E)	0.05	0.95	0
2a	Robin Friend	0.05	0.95	0
2b	Robin Friend - Sheringham	0.05	0.85	0.1
3a	Beeston Cliffs	0.75	0.25	0
3b	Beeston to West Runton Cliffs	0.95	0.05	0
4	West Runton to East Runton Cliffs	0.05	0.95	0
5a	East Runton to Cromer Cliffs	0.05	0.95	0
5b	Cromer (W)	0.05	0.95	0

3.3 PREDICTION MODELS

A series of event tree models have been developed to provide predictions of cliff recession in each cliff unit. Figure 7 relates the model numbers to the cliff units and SDMS profile sites, and provides a summary of the conditions and expected future controls in each cliff unit. Models 4, 5 and 9 were developed to represent local conditions at the updrift and downdrift margins of the defence lines at Sheringham and Cromer.

Tables 11 and 12 provide a summary of the adjustment factors and scenario probabilities used for each model.

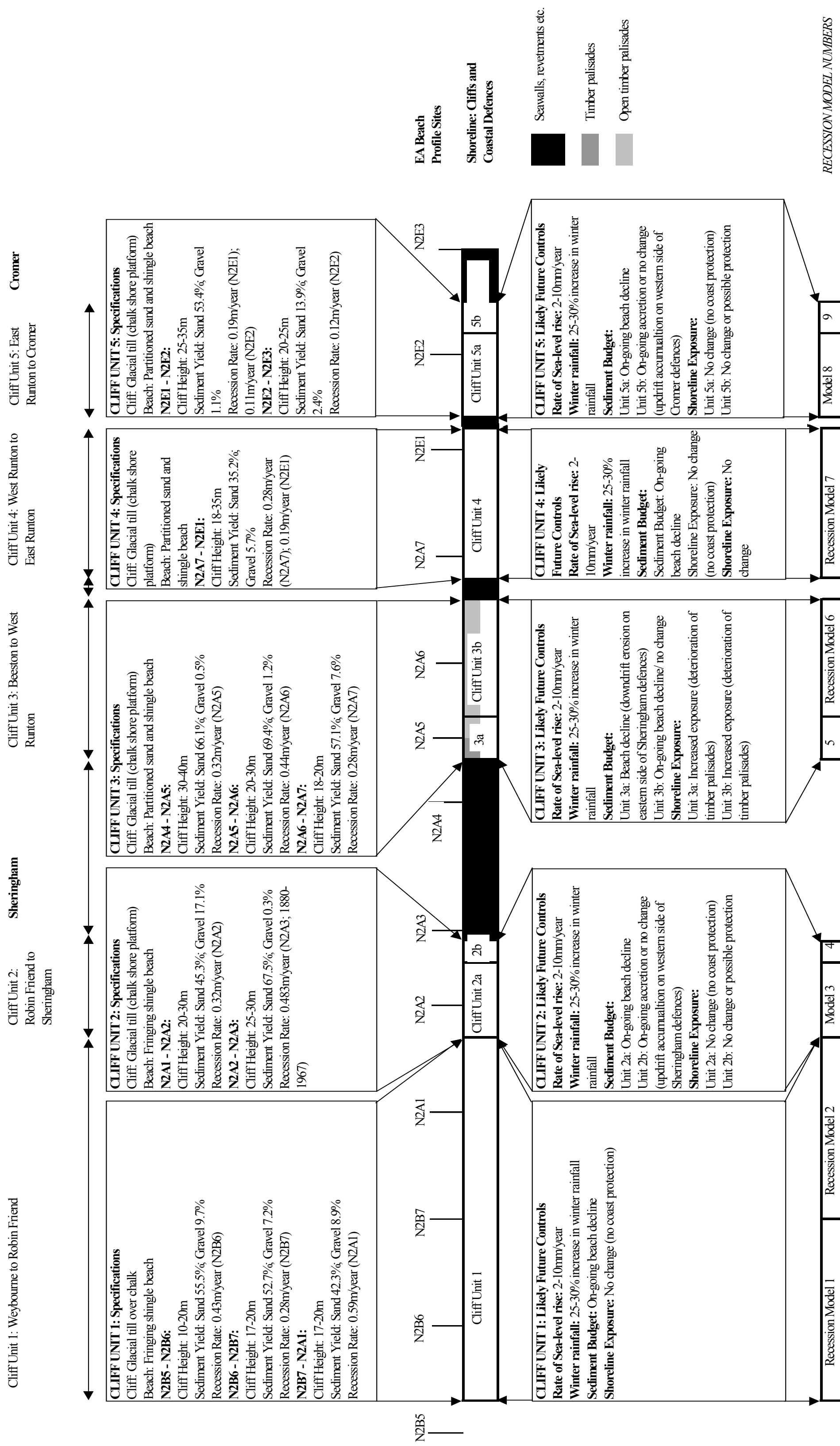

Figure 7 A schematic summary of he cliff units and recession models

Table 11 Prediction models: adjustment factors

RECESSION MODEL	Rate of Sea-level Rise mm/year (Addition)									Winter Rainfall			Beach Levels			Exposure		
	2	3	4	5	6	7	8	9	10	Increase	No Change	Decrease	Accretion	No Change	Depletion	Increased	No Change	Reduced
1	0.009	0.055	0.102	0.148	0.195	0.242	0.288	0.335	0.381	1.1	1	0.95	0.59	1	1.71	1	1	0
2	0.01	0.065	0.12	0.175	0.23	0.285	0.339	0.394	0.449	1.1	1	0.95	0.64	1	1.56	1	1	0
3	0.007	0.042	0.077	0.112	0.147	0.182	0.217	0.252	0.288	1.1	1	0.95	0.7	1	1.43	4	1	0
4	0.006	0.04	0.074	0.108	0.141	0.175	0.209	0.242	0.276	1.1	1	0.95	0.7	1	1.43	4	1	0
5	0.007	0.042	0.077	0.113	0.148	0.183	0.219	0.254	0.289	1.1	1	0.95	0.91	1	1.71	10	1	0
6	0.007	0.047	0.086	0.126	0.165	0.205	0.244	0.284	0.323	1.1	1	0.95	0.91	1	1.71	10	1	0
7	0.011	0.067	0.122	0.178	0.234	0.29	0.346	0.402	0.458	1.1	1	0.95	0.84	1	1.2	10	1	0
8	0.011	0.067	0.124	0.18	0.237	0.293	0.35	0.406	0.463	1.1	1	0.95	0.59	1	1.71	1	1	0
9	0.011	0.067	0.124	0.18	0.237	0.293	0.35	0.406	0.463	1.1	1	0.95	0.59	1	1.71	1	1	0

Table 12 Prediction models: estimated scenario probabilities

RECESSION MODEL	Rate of Sea-level Rise mm/year									Winter Rainfall			Beach Levels			Cliff Toe Exposure		
	2	3	4	5	6	7	8	9	10	Increase	No Change	Decrease	Accretion	No Change	Depletion	Increased	No Change	Reduced
1 & 2	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.01	0.39	0.6	0.05	0.95	0
3	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.01	0.39	0.6	0.05	0.95	0
4	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.1	0.6	0.3	0.05	0.85	0.1
5	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.05	0.9	0.05	0.75	0.25	0
6	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.1	0.3	0.6	0.95	0.05	0
7	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.01	0.39	0.6	0.05	0.95	0
8	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.01	0.39	0.6	0.05	0.95	0
9	0	0.025	0.05	0.2	0.4	0.2	0.05	0.05	0.025	0.6	0.3	0.1	0.39	0.6	0.01	0.05	0.95	0

3.4 PREDICTION MODELS: RESULTS

The results of the modelling for each site are presented as:

- a probability distribution of the annual recession rate (Figures 8 to 16);
- a cumulative probability distribution of the annual recession rate (Figures 17 to 25);
- a probability distribution of the predicted 50-year recession distance (Figures 26 to 34).

The results are summarised In Table 13 below in terms of the percentage confidence that the 50-year recession would be less than a particular "*upper bound*" value. For example, at Robin Friend cliff, there is a 95% chance that the cumulative recession over the next 50 years would be less than 55m (i.e. a 5% chance it would be greater than this value) and a 75% chance that the cumulative recession would be less than 50m.

Table 13 Summary of cliff modelling results

Cliff unit	Recession Model	Location	*Upper Bound* Recession: 95% Cumulative Probability distance (m)	75% Cumulative Probability distance (m)
1	1 & 2	Weybourne to Dead Mans Hill (E)	<70	<50
2a	3	Robin Friend	<55	<50
2b	4	Robin Friend - Sheringham	<32.5	<25
3a	5	Beeston Cliffs	<137.5	<20
3b	6	Beeston to West Runton Cliffs	<130	<100
4	7	West Runton to East Runton Cliffs	<32.5	<25
5a	8	East Runton to Cromer Cliffs	<40	<25
5b	9	Cromer (W)	<30	<20

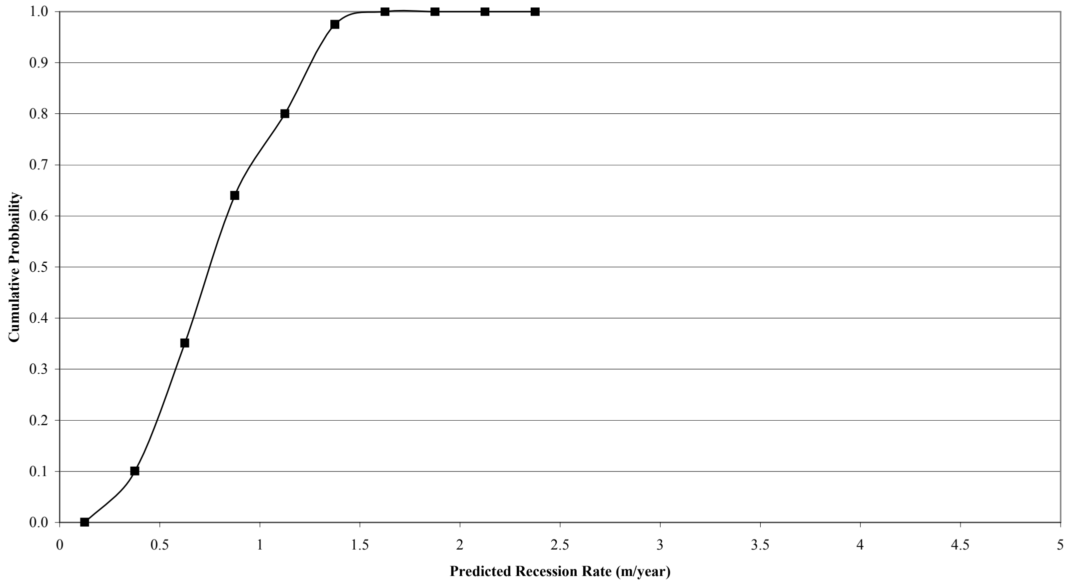

Figure 8 N2B5-N2B7 Cumulative Probability: Annual Recession Rate (m/year)

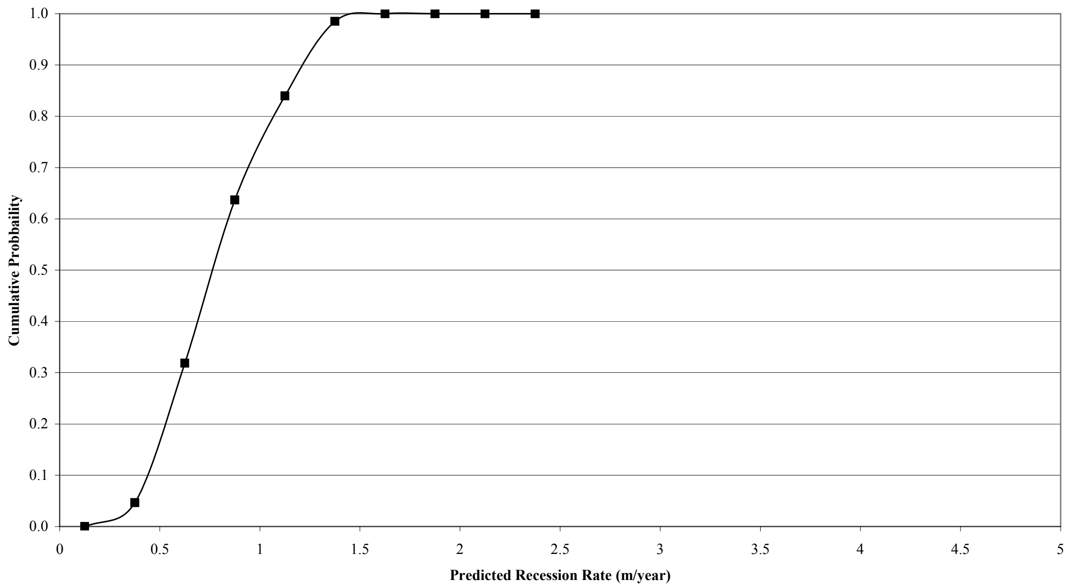

Figure 9 N2B7-N2A1 Cumulative Probability: Annual Recession Rate (m/year)

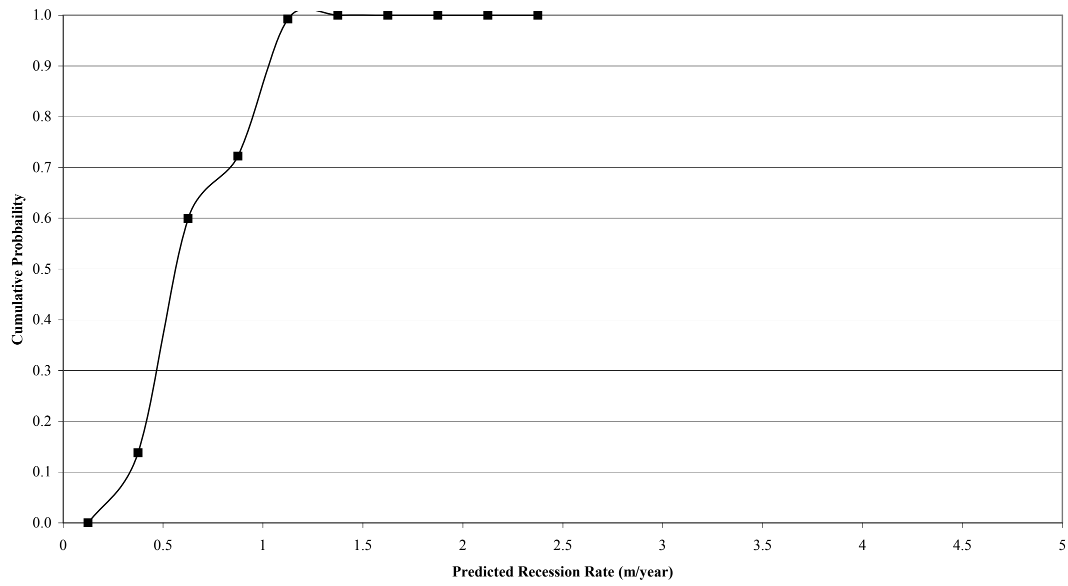

Figure 10 N2A2 Cumulative Probability: Annual Recession Rate (m/year)

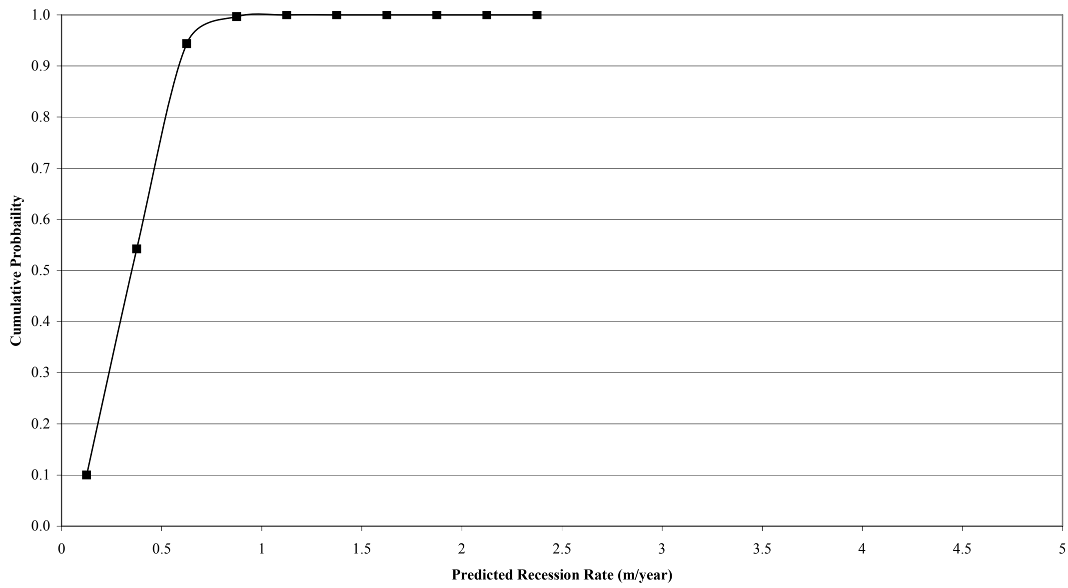

Figure 11 N2A2-3 (Cliff Unit 2b) Cumulative Probability: Annual Recession Rate (m/year)

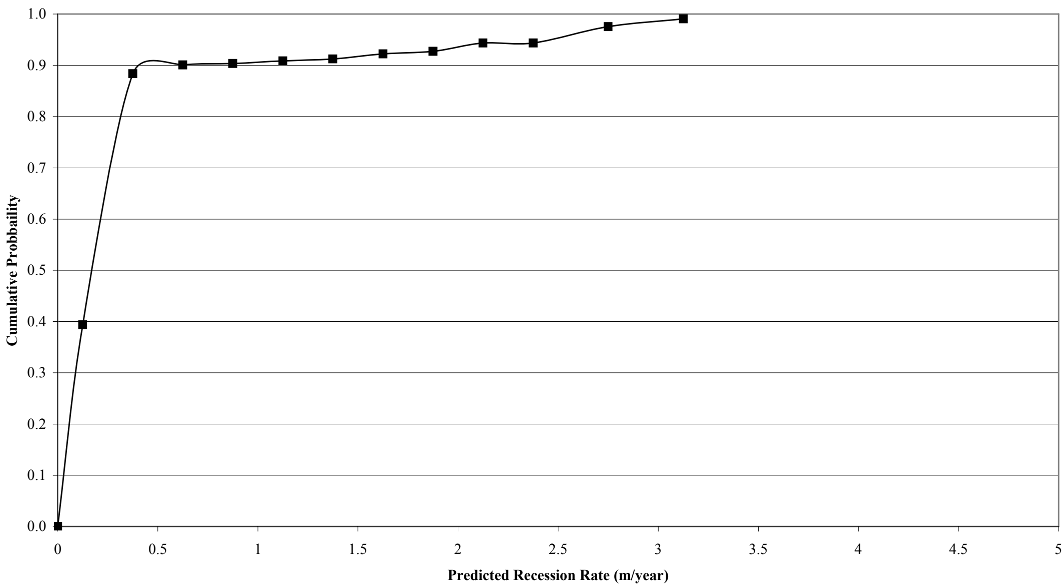

Figure 12 N2A5 Cumulative Probability: Annual Recession Rate (m/year)

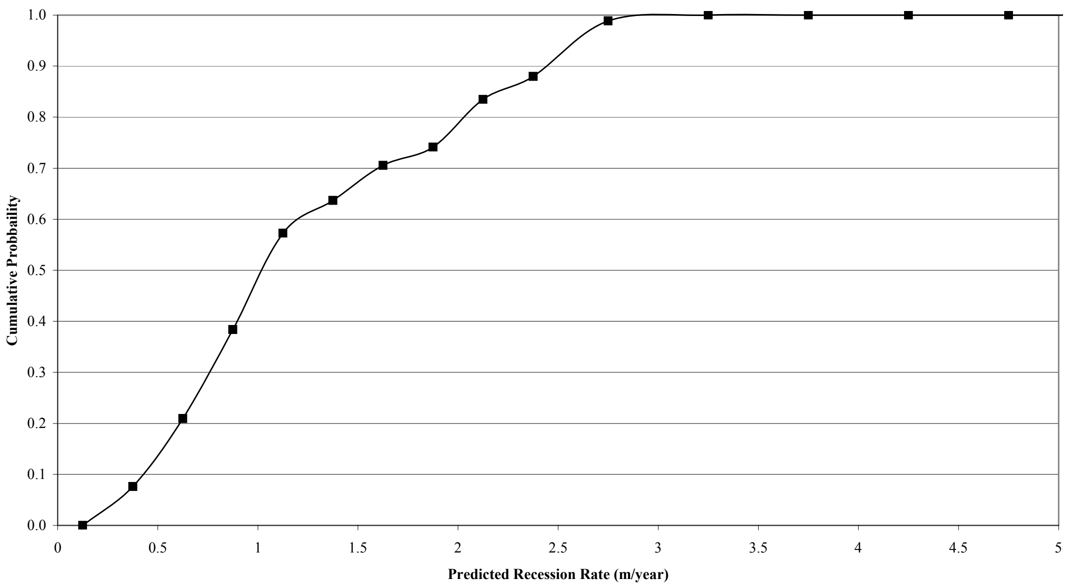

Figure 13 N2A6 Cumulative Probability: Annual Recession Rate (m/year)

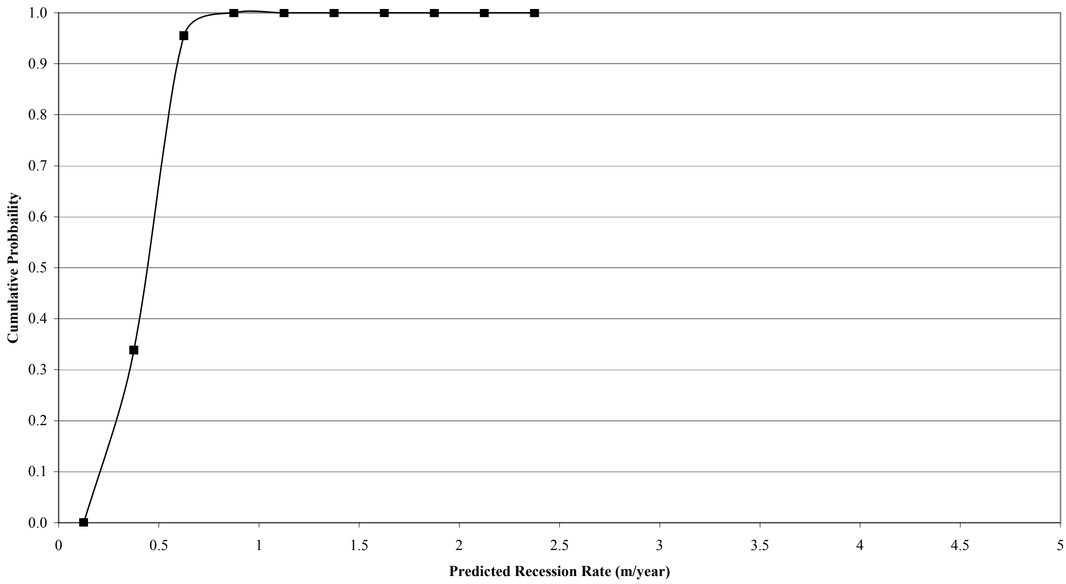

Figure 14 N2A7-N2E1 Cumulative Probability: Annual Recession Rate (m/year)

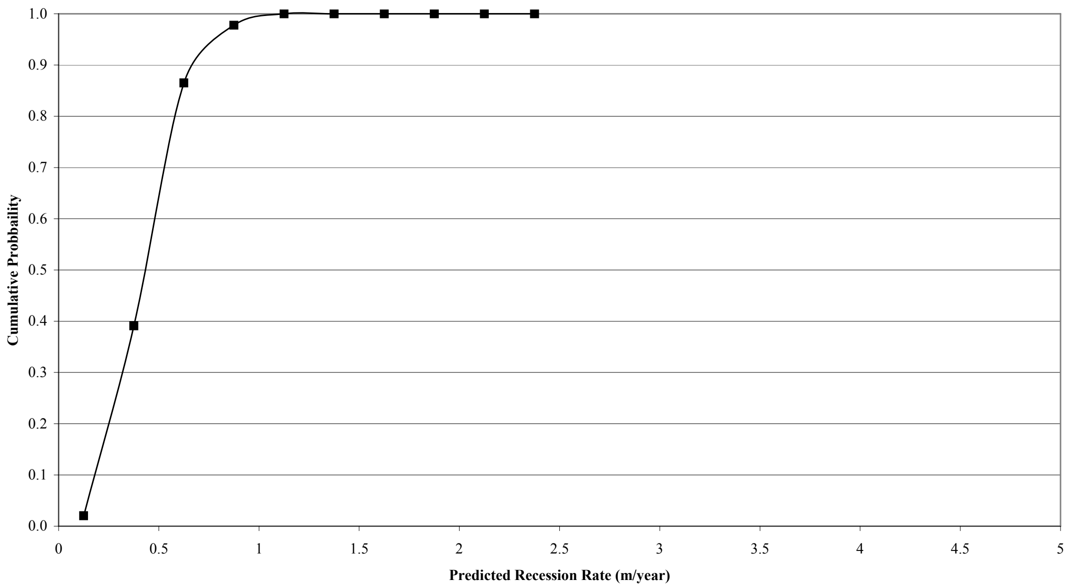

Figure 15 N2E2Cumulative Probability: Annual Recession Rate (m/year)

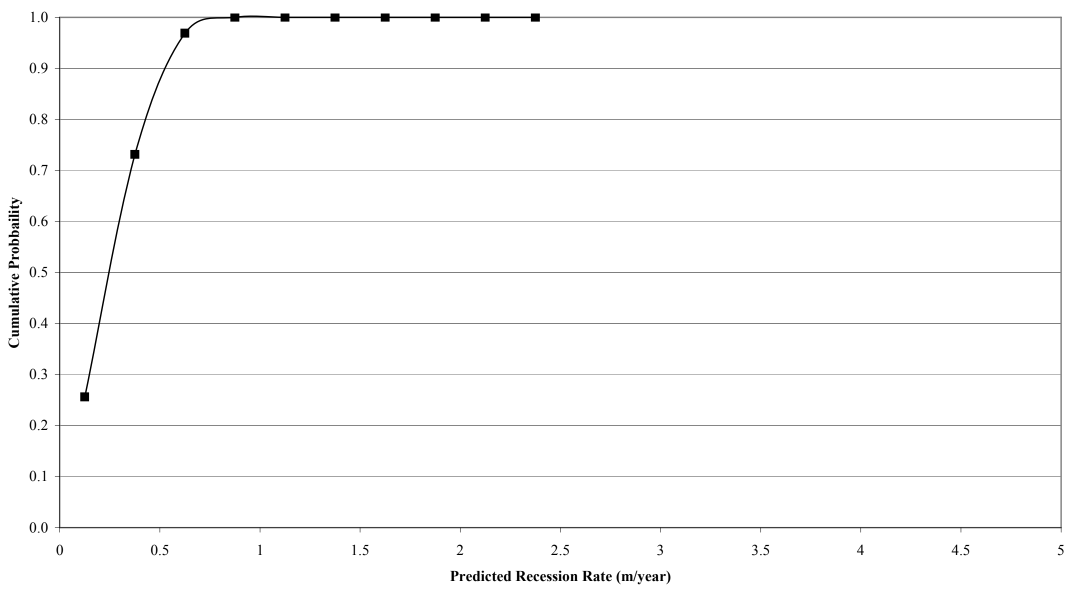

Figure 16 N2E2-N2E3 (Cliff Unit 5b) Cumulative Probability: Annual Recession Rate (m/year)

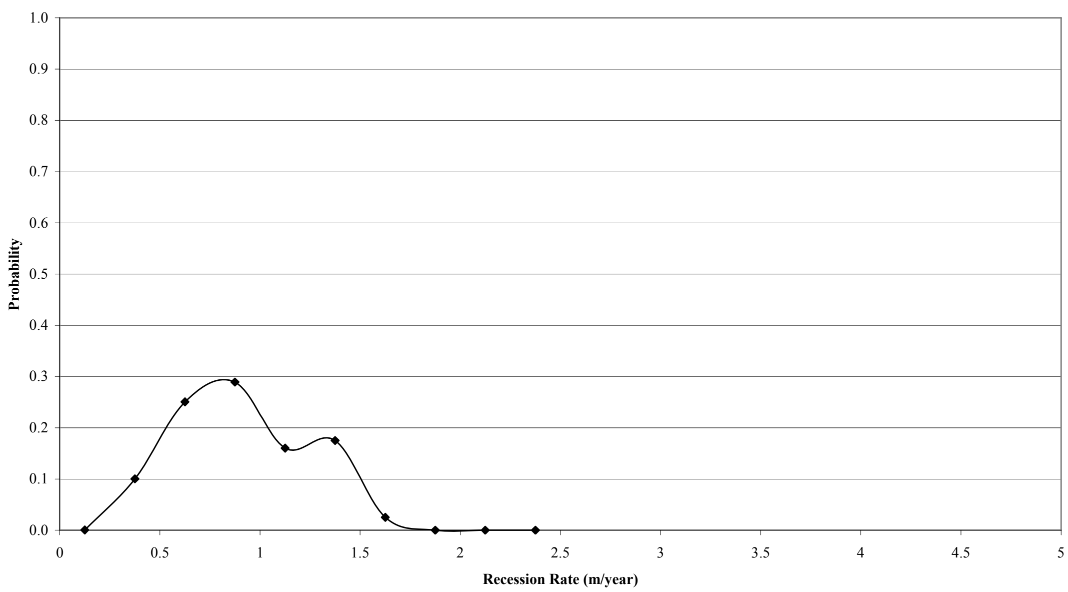

Figure 17 N2B5-N2B7: Recession Rate Probability

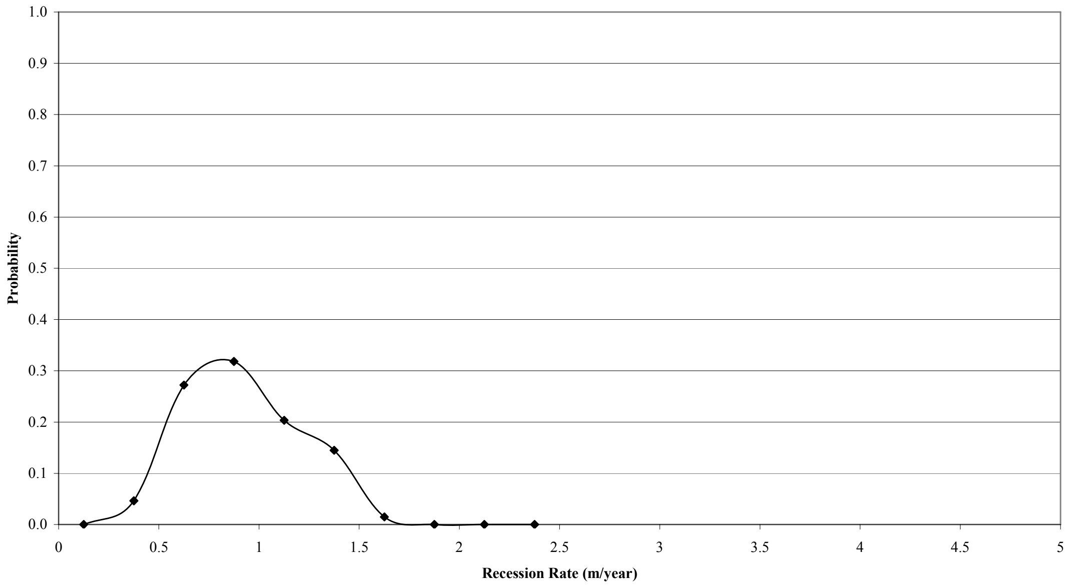

Figure 18 N2B7-N2A1: Recession Rate Probability

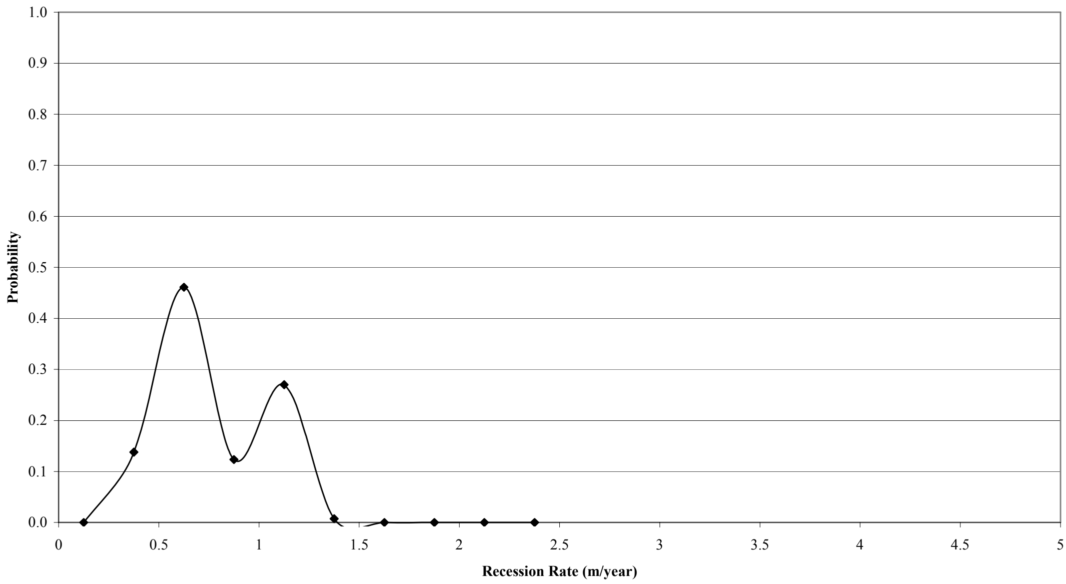

Figure 19 N2A2: Recession Rate Probability

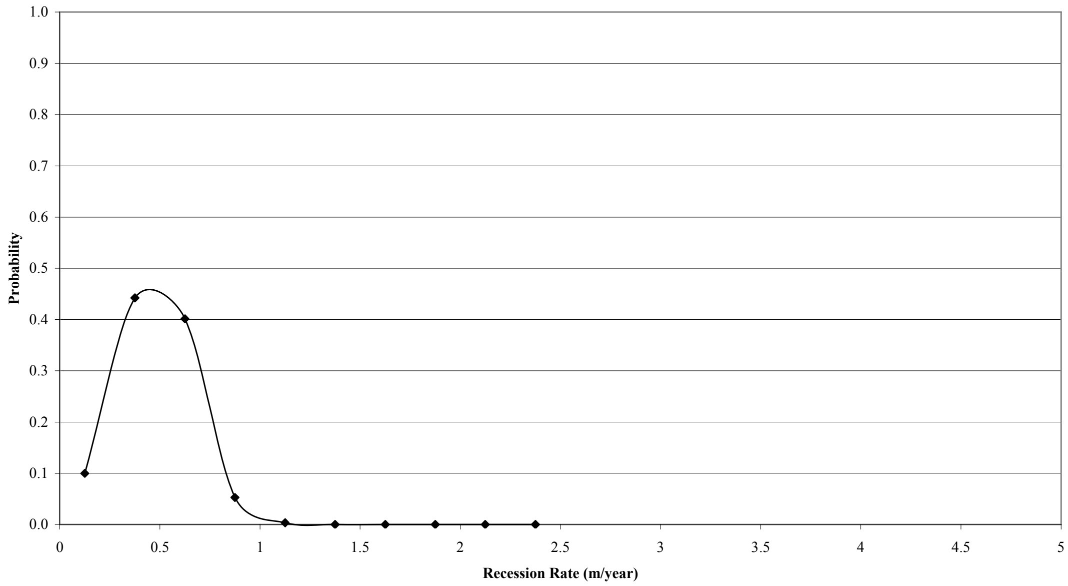

Figure 20 N2A2-3 (Cliff Unit 2b): Recession Rate Probability

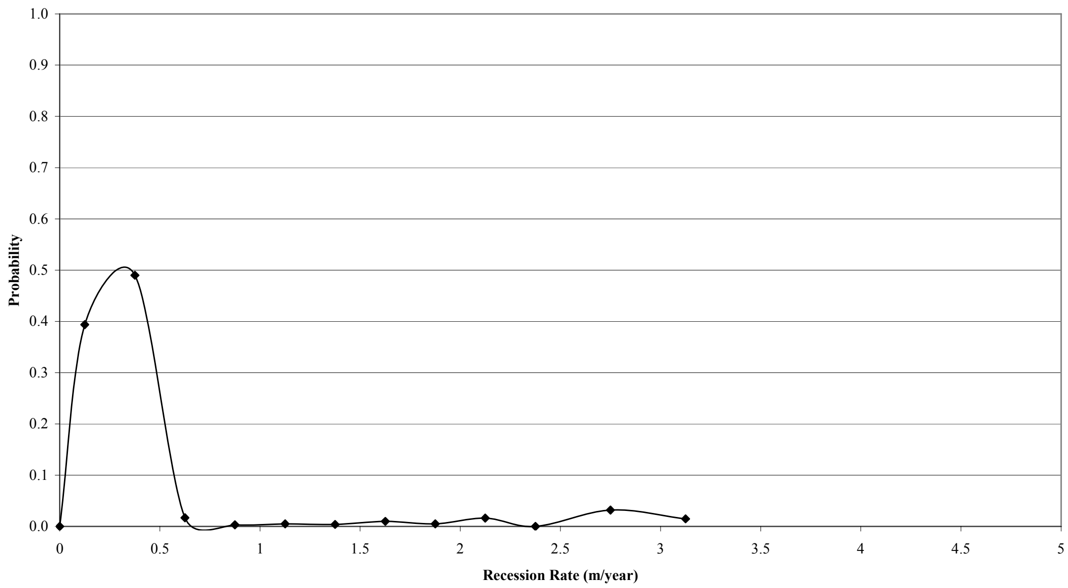

Figure 21 N2A5: Recession Rate Probability

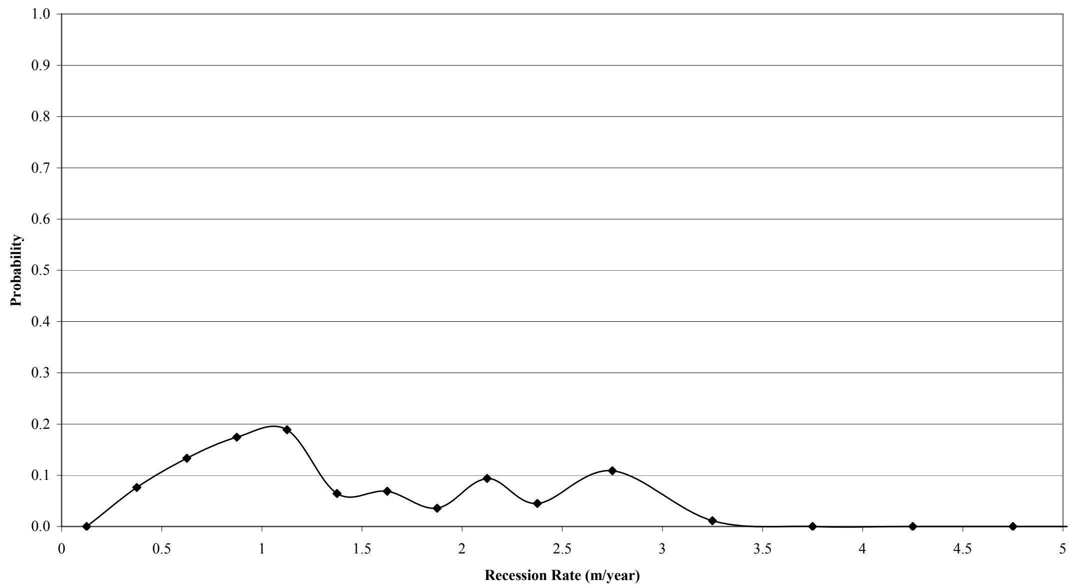

Figure 22 N2A6: Recession Rate Probability

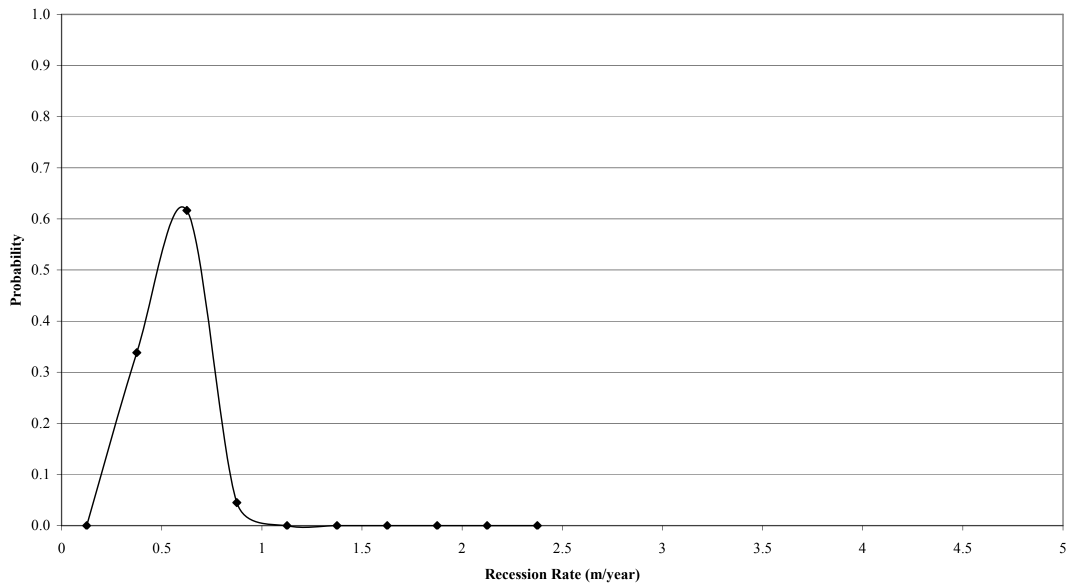

Figure 23 N2A7-N2E1: Recession Rate Probability

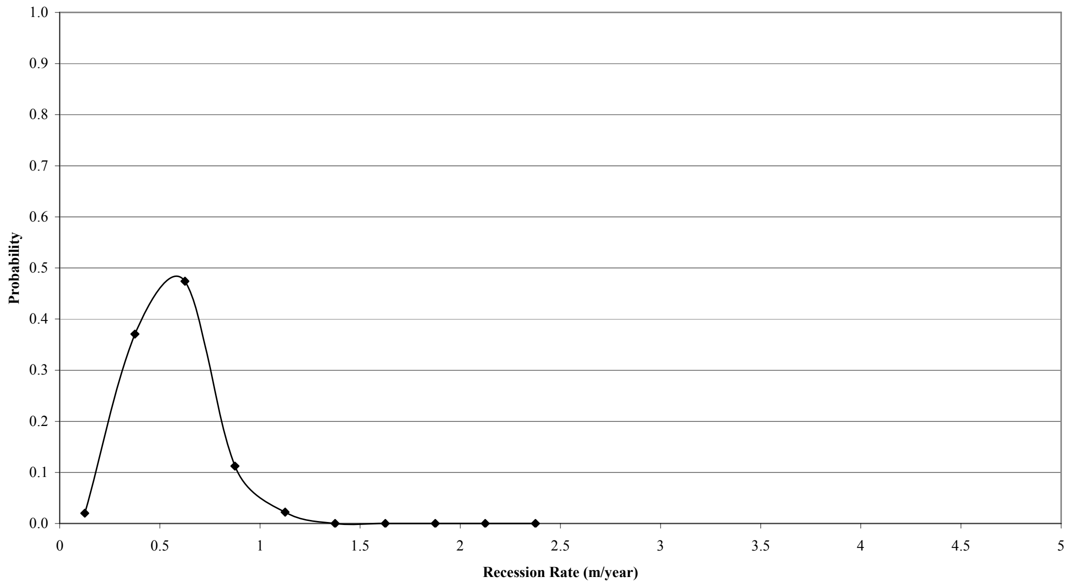

Figure 24 N2E2: Recession Rate Probability

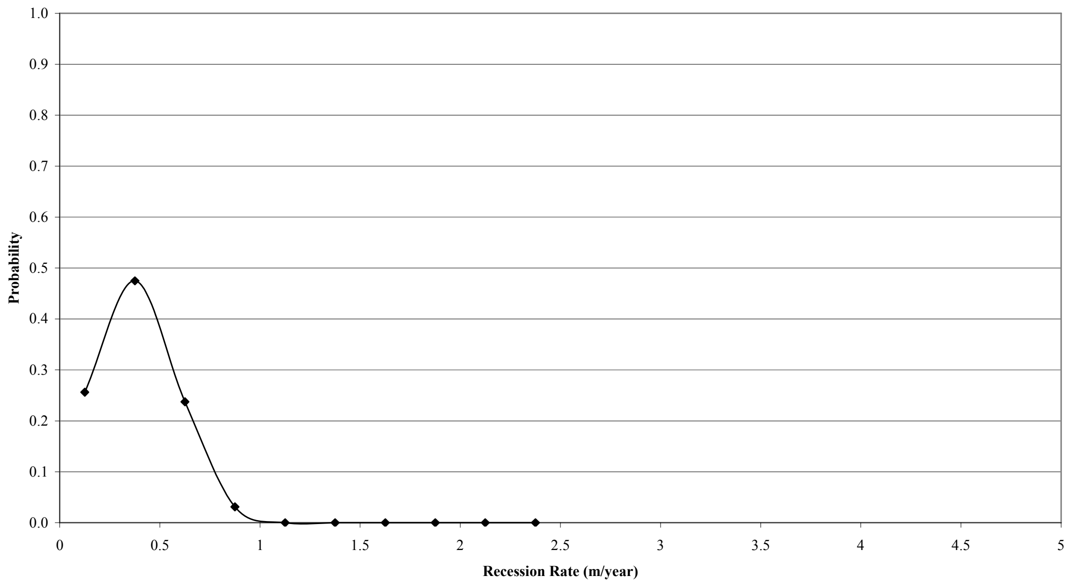

Figure 25 N2E2-N2E3 (Cliff Unit 5b): Recession Rate Probability

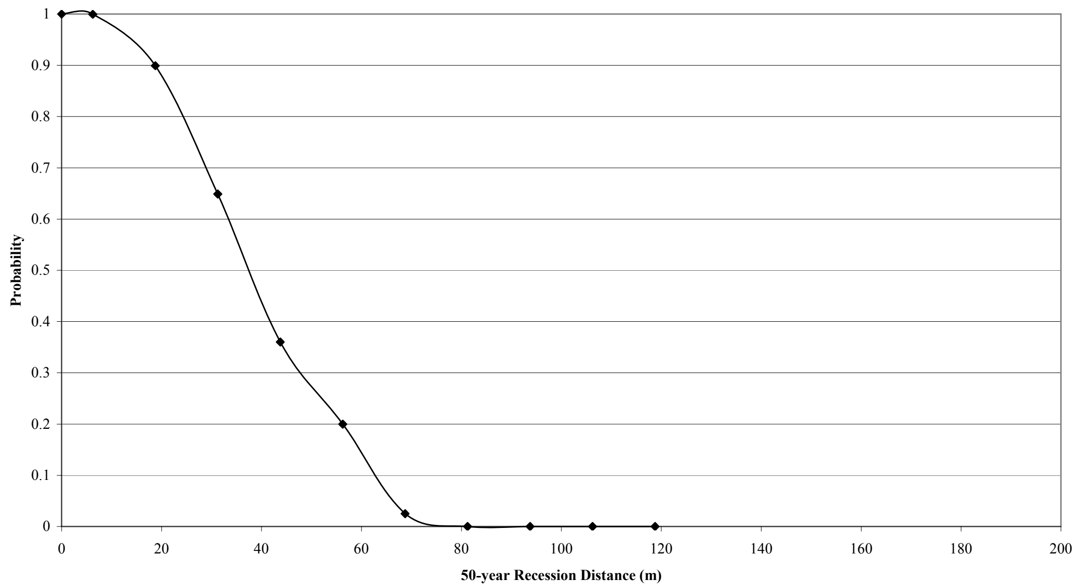

Figure 26 N2B5-N2B7: 50-Year Recession Zoning

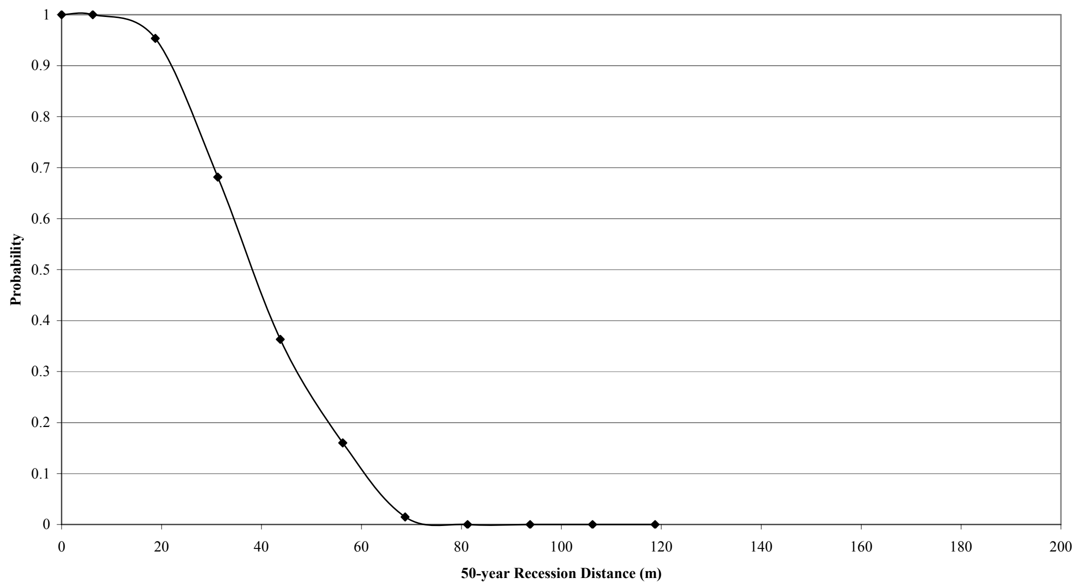

Figure 27 N2B7-N2A1: 50-Year Recession Zoning

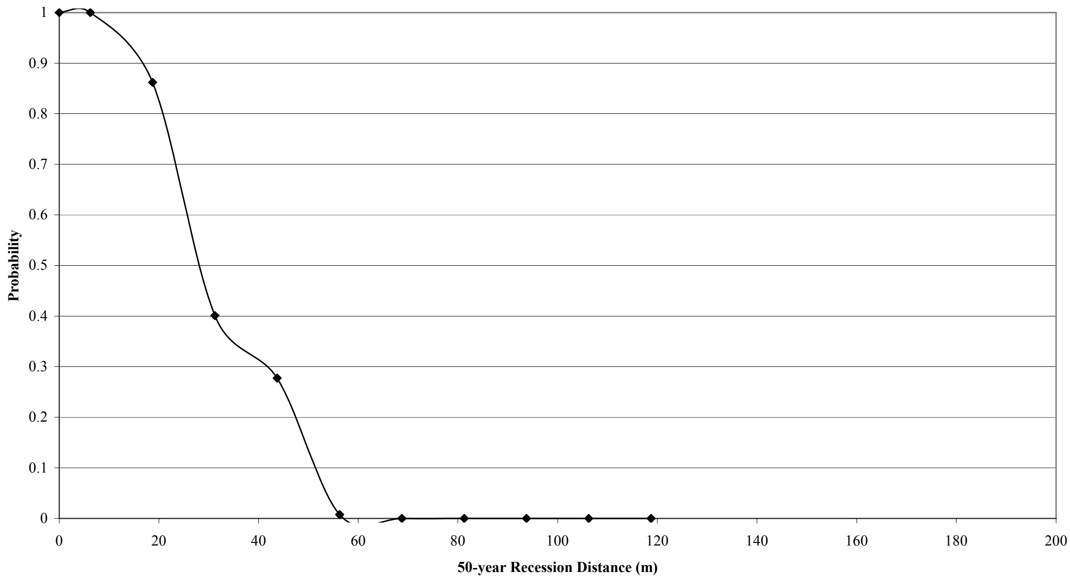

Figure 28 N2A2: 50-Year Recession Zoning

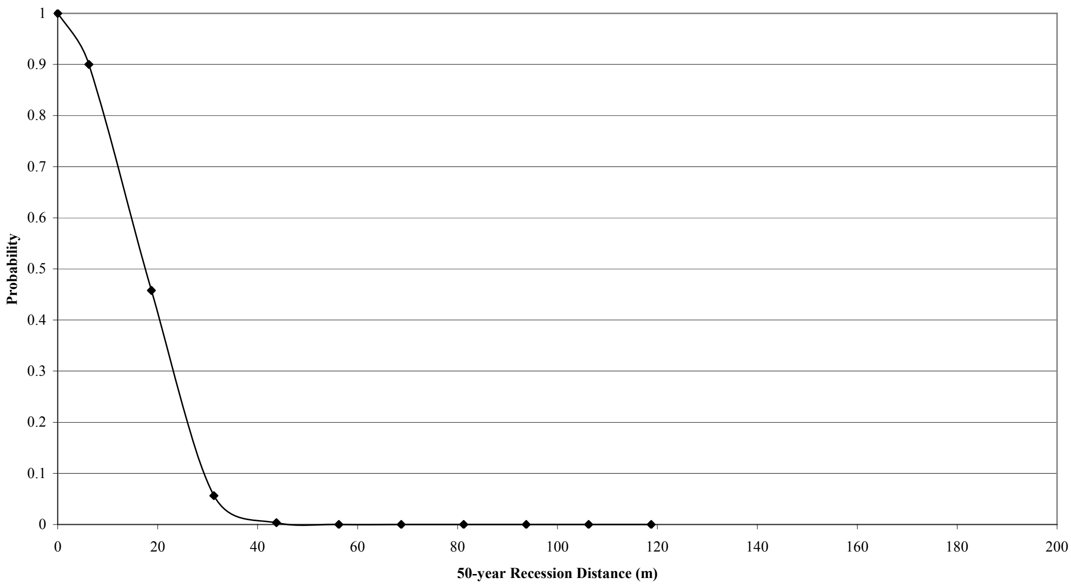

Figure 29 N2A2-3 (Cliff Unit 2b): 50-Year Recession Zoning

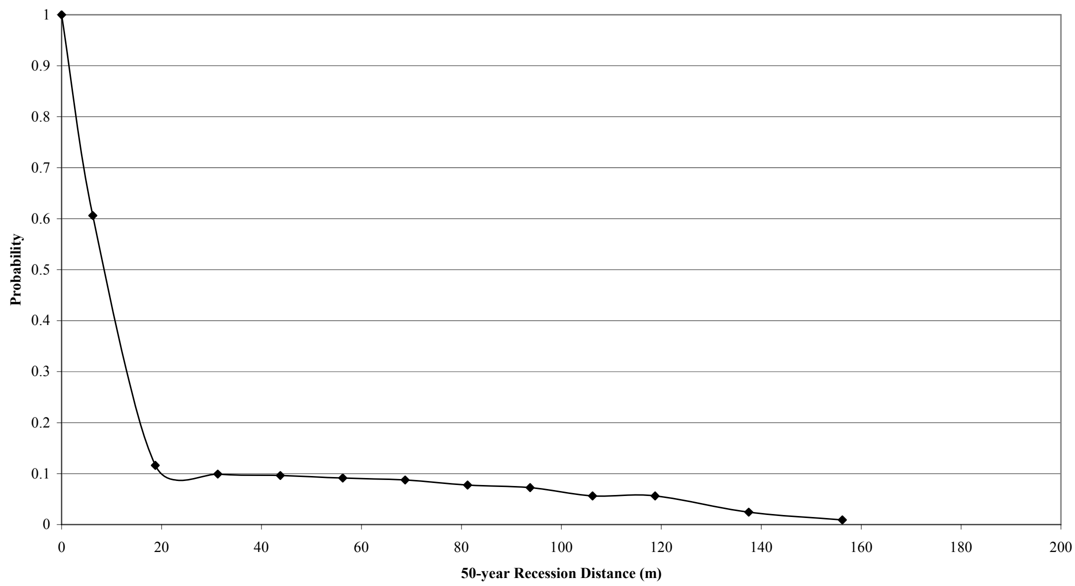

Figure 30 N2A5: 50-Year Recession Zoning

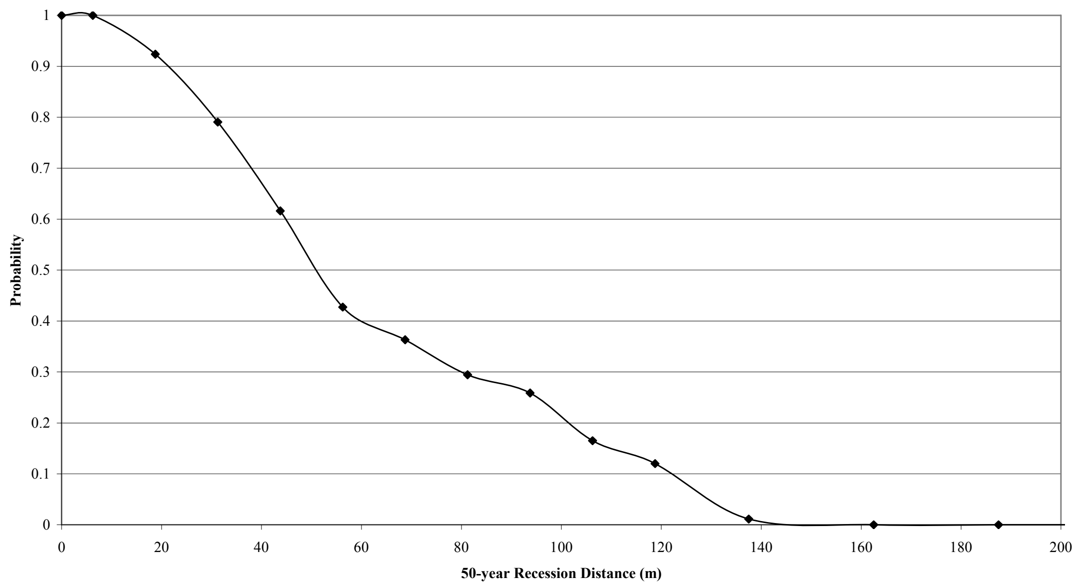

Figure 31 N2A6: 50-Year Recession Zoning

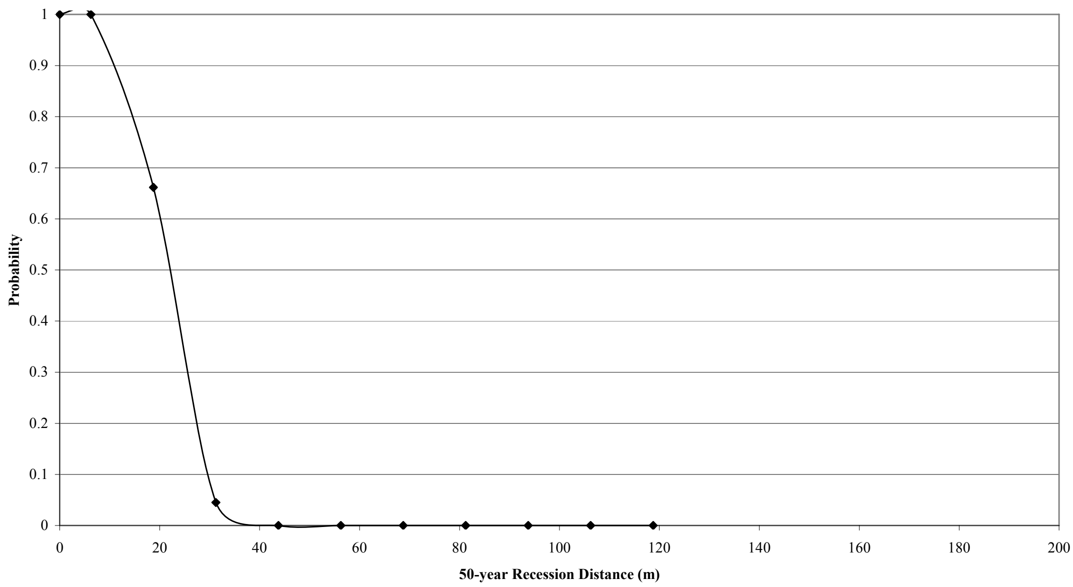

Figure 32 N2A7-N2E1: 50-Year Recession Zoning

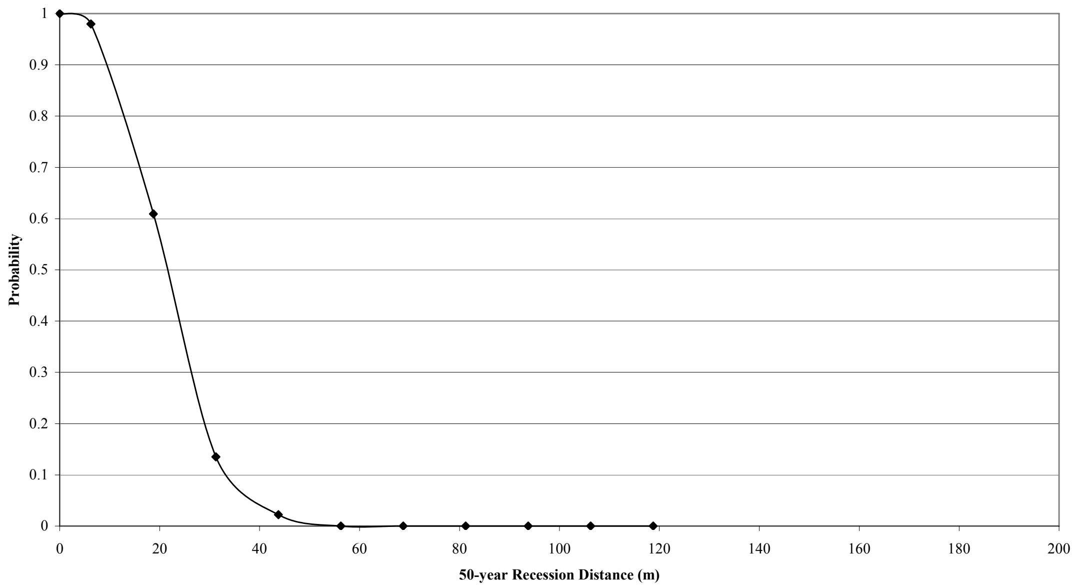

Figure 33 50-Year Recession Zoning

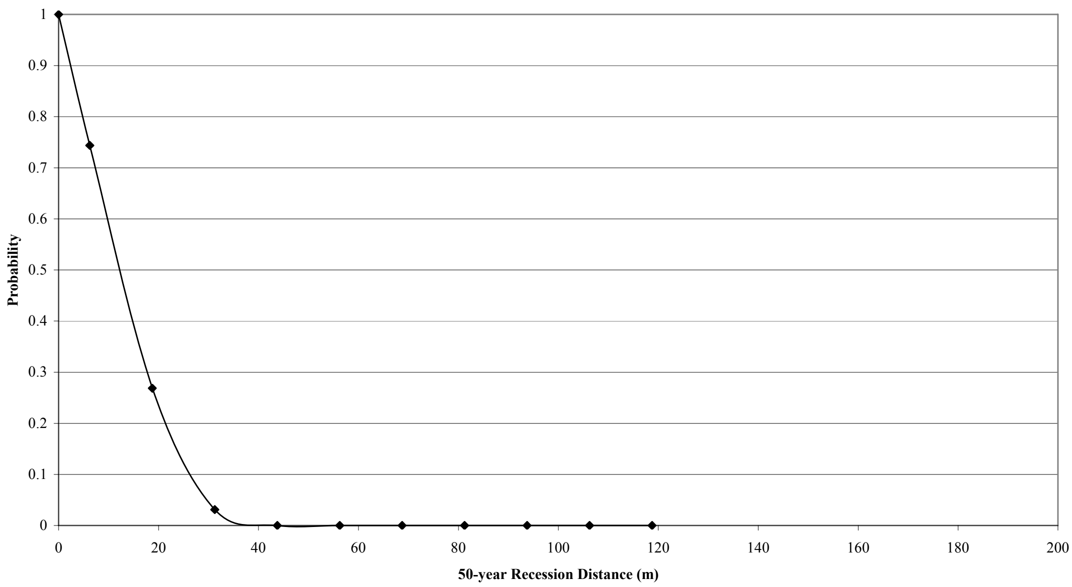

Figure 34 N2E2-N2E3 (Cliff Unit 5b): 50-Year Recession Zoning

4. References

Banham P H 1968 A preliminary note on the Pleistocene stratigraphy of northeast Norfolk. Proc. Geol. Ass. 69, 507-512.

Banham P H 1975 Glacitectonic structures: a general discussion with particular reference to the Contorted Drift of Norfolk. In A E Wright and F Moseley (eds.) Ice Ages: Ancient and Modern. Geol. Journal Special Issue 6, 69-94.

BGS 1996. Sediment input from coastal cliff erosion. Technical Report 577/4/A. Environment Agency.

Bowen D Q 1999. A revised correlation of Quaternary deposits in the British Isles. Geological Society Special Report No 23.

Brunsden D and Lee E M 2004. Understanding the Behaviour of Coastal Landslide Systems: an Inter-disciplinary View. Zeitschrift fur Geomorphologie, Suppl Vol 134.

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.

Dean, R. G., 1991. Equilibrium beach profiles: characteristics and applications. Journal of Coastal Research, 7, 53-84.

Dubois R N 1992. A re-evaluation of Bruun's Rule and supporting evidence. Journal of Coastal Research, 8, 3, 618-628.

Halcrow Group Ltd., 2001. Preparing for the Impacts of Climate Change. Report to SCOPAC.

Hands, E. B., 1983. The Great Lakes as a test model for profile responses to sea-level changes. In P.D. Komar (ed.) Handbook of Coastal Processes and Erosion. Boca Raton, Florida: CRC Press, 176-189.

Hulme, M., Barrow, E. M., Jenkins, G. J., New, M., Osborn, T. J. and Viner, D., 1998. Climate change scenarios for the UK Climate Impacts programme. UKCIP Technical Report. Norwich: Climatic Research Unit.

Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R. and Hill, S. 2002. Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK.

Komar, P. D., et al. (Scientific Committee on Ocean Research (SCOR) Working Group 89.) 1991. The Response of Beaches to Sea-Level Changes: A Review of Predictive Models. Journal of Coastal Research, Vol 7, No. 3, 895-921.

Lee, E.M., 2003. Coastal Change and Cliff Instability: Development of a Framework for Risk Assessment and Management. Unpublished PhD thesis, University of Newcastle upon Tyne.

Lee E. M. in press. Coastal Cliff Recession Risk: A Simple Judgement-based Model. Quarterly Journal of Engineering Geology and Hydrogeology.

Lee E. M. in prep. Cliff recession and beach levels: the Suffolk cliffline, UK.

Lunkka J P 1994. Sedimentation and lithostratigraphy of the North Sea Drift and Lowestoft Till Formations in the coastal cliffs of Eastern Norfolk. Journal of Quaternary Science 9, 209-233.

Moorlock B P S, Booth S, Fish P, Hamblin R J O, Kessler, H, Riding J, Rose J, and Whiteman C A. 2000. The North Sea Drift Formation: a revised glacial stratigraphy. In S G Lewis, C A Whiteman and R C Preece (eds.) The Quaternary of Norfolk and Suffolk, 53-54 QRA Field Guide.

Reid C 1882 The geology of the country around Cromer. Memoir of the Geological Survey of England and Wales.

Roberts D H and Hart J K 2000. The glacial deposits of West Runton. In S G Lewis, C A Whiteman and R C Preece (eds.) The Quaternary of Norfolk and Suffolk, 77-84 QRA Field Guide.

Rosen, P. S., 1978. A regional test of the Bruun Rule on shoreline erosion. Marine Geology 26, M7-M16.

Woodworth P L, Tsimplis M N, Flather R A and Shennan I, 1999. A review of trends observed in British Isles mean sea level data measured by tide gauges. Geophys. J. Int., 136, 651-670.

Zalasiewicz J A and Gibbard P L 1988. The Pliocene to Early Middle Pleistocen of east Anglia: an overview. In P L Gibbard and J A Zalasiewicz (eds.) Ploicene-Middle Pleistocene of East Anglia, 1-32. QRA Field Guide, Cambridge.

Zurek P J, Nairn R B and Theime S J 2003. Spatial and temporal considerations for calculating shoreline change rates in the Great Lakes Basin. Journal of Coastal Research, 38, 125-146.

Appendices

Appendix A Derivation of Adjustment Factors

Sea-level Rise Factor: The Bruun Rule

The *Bruun Rule* assumes that an equilibrium beach profile is maintained as a landform (i.e. cliff) moves inland in response to sea-level rise, by the transfer of eroded material from the upper profile to the lower profile. The Bruun Rule can be used to estimate the rate of profile migration (R):

$R = (LS)/H$

(S is the rate of sea-level rise; L is the profile width i.e. the offshore distance to the depth of closure – see below - and H is the profile depth at the depth of closure)

For example, if sea level rise was 5mm/yr, and the depth of closure of 10m occurs 300m offshore, the annual predicted profile migration rate would be:

$$\begin{aligned} R &= (LS)/H \\ &= (0.005 \times 300)/10 \\ &= 0.15\text{m/yr} \end{aligned}$$

The Bruun Rule is essentially two-dimensional (onshore-offshore) and assumes that longshore sediment inputs and outputs are equal and equivalent, a condition rarely achieved in reality. To model reliably the three-dimensional situation, a full sediment budget needs to be calculated for the shoreline. If it is assumed, however, that the historical recession rate represents the net contribution to the sediment budget, then the Bruun Rule can be modified to provide an adjustment factor that represents the recession increase due to sea level rise (R) as follows (Hands 1983; Dean 1991):

$$R = R_1 + Sc \times \frac{L \times P}{(B+h)}$$

R_1 = Historical recession rate (m/year)
Sc = Change in rate of sea level rise (m)
P = Sediment overfill ratio (the ratio of the total sediment volume eroded to that retained within the equilibrium profile)
B = Cliff height (m)
h = Closure depth (m)
L = Length of cliff profile (to the closure depth, m)

The *change in sea level rise* is the difference between the historical and future sea level rise at the site. The historical rate on this shoreline is 1.81mm per year (1956-1995; standard error of ± 0.48mm; Woodworth et al., 1999). Although there is uncertainty about the future rate of sea-level rise over the next century, the local change in average rate is expected to be between 2mm/year and 10mm/year (Hulme et al 2002).

The *closure depth* is the boundary of the profile beyond which there is little loss of sediment. The closure depth can be estimated as being twice the maximum wave height for a 50 year return period i.e. a closure depth of 10m on this coastline.

The *sediment overfill* function is the proportion of sediment eroded that is sufficiently coarse to remain within the equilibrium profile. This was derived from the study of cliff recession inputs carried out by the BGS (1996) and was calculated as the combined sand and gravel yield (Table A.1).

The *length of active cliff profile* was measured from the hydrographic charts by using the closure depth to indicate the seaward limits, taken here as 800m.

Table A.1 Summary of Cliff Data

	Cliff Unit	SDMS Profiles	Cliff Height	Sediment Yield (BGS 1996)		Historical Recession Rate* (m/year)
				Sand	Gravel	
1	Weybourne to Robin Friend	N2B5 - N2B6	10-20m	55.5%	9.7%	0.43m/year (N2B6)
		N2B6 – N2B7	17-20M	52.7%	7.2%	0.28m/year (N2B7)
		N2B7-N2A1	17-20m	42.3%	8.9%	0.59m/year (N2A1)
2	Robin Friend	N2A1-N2A2	20-30m	45.3%	17.1%	0.32m/year (N2A2)
		N2A2-N2A3	25-30m	67.5%	0.3%	0.48m/year (N2A3 1880-1967)
3	Beeston to West Runton	N2A4-N2A5	30-40m	66.1%	0.5%	0.32m/year (N2A5)
		N2A5-N2A6	20-30m	69.4%	1.2%	0.44m/year (N2A6)
		N2A6-N2A7	18-20m	57.1%	7.6%	0.28m/year (N2A7)
4	West Runton to East Runton	N2A7-N2E1	18-35m	35.2%	5.7%	0.28m/year (N2A7) 0.19m/year (N2E1)
5	East Runton to Cromer	N2E1-N2E2	25-35m	53.4%	1.1%	0.19m/year (N2E1) 0.12m/year (N2E2)

Note: * Combined recession rate for the period 1966-2003

Winter Rainfall Factor: Landslide Activity
The dominant recession mechanism on the Norfolk cliffs is landsliding, as indicated in Table A.2. This highlights the importance of episodic cliff top failure events rather than continuous year-by-year loss in causing cliff retreat.

Table A.2 Recession Mechanisms on the Norfolk cliffline (from Cambers 1976)

Site	Landslides %	Mudflows %	Wind Erosion%	Water Erosion %
Weybourne	100	0	0	0
Sherringham	72	0	28	0
Overstrand	73	7	0	20
Mundesley	86	0	5	9

The link between rainfall, groundwater and landslide activity is well established, and can be explained in terms of the change in pore water pressures associated with fluctuations in groundwater levels (e.g. Brunsden and Lee 2004). The UKCIP98 climate change scenarios give estimates of future potential change to mean precipitation and mean evapo-transpiration for southern Britain. Hacrow (2001) applied the UKCIP98 change scenarios to the Ventnor Undercliff rainfall data; this analysis suggests a 5 to 6% increase in mean monthly effective rainfall under the *Low scenario* and a 12 to 25% increase for the *High scenario* (Table A.2; Halcrow Group 2001). This is expected to result in an increase in the frequency or probability of landslide events.

Figure A.1 presents the mean monthly effective rainfall frequency distribution for the period December to February based on 1839-2000 Ventnor data. The UKCIP98 change scenarios have been applied to this distribution to derive 2080 *Low* and *High* change scenarios. The distributions indicate the current probability of mean monthly effective rainfall of 100 mm is 0.1 (or 1:10 years). Under the UKCIP98 *Low scenario* the probability will remain largely unchanged but under the *High scenario* the probability is increased to 0.2 (1:5 years). The potential change for more extreme conditions is greater with, for example, the probability of mean monthly effective rainfall of 150 mm increasing from the current 0.005 (1:200 years) to 0.02 (1:50years) for the UKCIP98 *High scenario*.

However, the link between changing rainfall patterns, landslide activity and recession rates on the North Norfolk cliffline has yet to be established. The adjustment factors presented in Table A.4 are, therefore, judgements.

Table A.3 Predicted changes in effective rainfall, Ventnor, UK (from Halcrow 2001)

	September - November		December - February	
	mm	% Change	mm	% Change
Mean Effective Rainfall (2000)	76.4	0	67.4	0
Mean Effective Rainfall: Low	80.2	5	71.7	6
Mean Effective Rainfall: Medium-Low	84.4	11	74.6	11
Mean Effective Rainfall: Medium-High	82.7	8	81.8	21
Mean Effective Rainfall: High	85.2	12	84.0	25

Note: Low, Med-Low, Med-High and High estimates based on UKCIP98 climate change scenarios

Table A.4 Winter rainfall: Probability of Future Scenarios and Adjustment Factors

Winter Rainfall	Adjustment Factor
Increase (25%)	1.1
No Change	1
Decrease (10%)	0.95

Beach Erosion/Accretion Factor: Beach Levels

The relationship between the average beach volume (measured as the beach profile area above High Water Mark – the "beach wedge") and annual cliff recession rate for *unprotected* sections of the North Norfolk cliffline has been defined by Lee (in prep.). This is based on the analysis of SDMS profile site surveys between 1992 and 2003 (for sites east of Cromer the monitoring period is 1992-2000; see Table A.5). Each survey profile was analysed to determine:

Table A.5 SDMS Profile Sites between Weybourne and Mundesley

SDMS Profile Site	Cliff unit	Defences	Recession Rate (1992-2003)
N2B6	1 Weybourne	**None**	0.58
N2B7	1 Weybourne	**None**	0.33
N2A1	1 Weybourne	**None**	0.54
N2A2	2a Robin Friend	**None**	0.29
N2A3	Sheringham	Seawalls	
N2A4	Sheringham	Seawalls	
N2A5	3a Beeston	***Timber palisades***	0.01
N2A6	3b West Runton	***Timber palisades***	0.34
N2A7	4 East Runton	**None**	0.59
N2E1	4 East Runton	**None**	0.09
N2E2	5a East Runton (E)	**None**	0.12
N2E3	3 Cromer	Seawalls	
N3E4	3 Cromer	Seawalls	
N3E5	23 Lighthouse Hill	**None**	0.33
N3E6	2B Overstrand Slipway	Seawalls	
N3D1	4 Overstrand	Seawalls	
N3D2	6A Sidestrand (W)	**None**	7.04
N3D3	8 Trimingham (W)	**None**	2.47
N3D4	10 Trimingham (E)	Seawalls	
N3D5	11 Beacon Hill	***Timber palisades***	0.02
N3D6	12 Marl Point	***Timber palisades***	0.11
N3C1	13 Cliftonville	***Timber palisades***	0.10
N3C2	14 Mundesley (W)	Concrete blocks	
N3C3	16 Mundesley (E)	***Timber palisades***	0.05
N3C4	16 Mundesley (E)	***Timber palisades***	0.05

- *annual cliff recession*; calculated as the change in position of the cliff top between survey dates;
- *average annual recession rate*; the cumulative cliff top recession (1992-2003) divided by the number of years in the record;
- *beach wedge area*; calculated for each SDMS profile as a triangle defined by the width and maximum height of the beach above MHWS (2.55m at Kelling; 2.5m at Sheringham; 2.45m at Cromer; 2.36m at Overstrand; Trimingham 2.27m; 2.14m at Mundesley; 1.99m at Bacton);
- *average beach wedge area*; the sum of the beach wedge area for each winter profile (1992-2003), divided by the number of years in the record.

  The average beach wedge area and recession rate for each of the unprotected SDMS profile sites is plotted on Figure 5. The results suggest an exponential relationship similar in form to that previously defined for the Suffolk cliffs (Figure 6):

  Recession rate = $7e^{-0.1786x}$ where x is the beach wedge area.

  This relationship provides the basis for predicting the effects of changing beach conditions on recession rates. Tables A.6 and A.7 provide an indication of the reduction in recession rate that could be expected with particular beach level changes.

Table A.6 Predicted Effect of Beach Accretion on Recession Rate

Initial Beach wedge area	Accretion	Predicted recession rate (m/year)	Recession reduction factor
5	0	2.866	
	10%	2.621	0.91
	25%	2.293	0.80
10	0	1.173	
	10%	0.981	0.84
	25%	0.751	0.64
15	0	0.480	
	10%	0.368	0.76
	25%	0.246	0.51
20	0	0.197	
	10%	0.138	0.70
	25%	0.081	0.41
25	0	0.081	
	10%	0.052	0.64
	25%	0.026	0.33
30	0	0.033	
	10%	0.019	0.59
	25%	0.009	0.26

Table A.7 Predicted Effect of Beach Depletion on Recession Rate

Initial Beach wedge area	Depletion	Predicted recession rate (m/year)	Recession increase factor
5	0	2.866	
	10%	3.134	1.09
	25%	3.583	1.25
10	0	1.173	
	10%	1.403	1.20
	25%	1.834	1.56
15	0	0.480	
	10%	0.628	1.31
	25%	0.939	1.95
20	0	0.197	
	10%	0.281	1.43
	25%	0.480	2.44
25	0	0.081	
	10%	0.126	1.56
	25%	0.246	3.05
30	0	0.033	
	10%	0.056	1.71
	25%	0.126	3.82

Cliff Toe Factor

The relationship between the average annual recession rate (1992-2000/2003) and the average beach wedge area (1992-2000/2003) was established by Lee (in prep.) for the 6 SDMS profile sites where timber palisades have been constructed at the cliff foot

(N2A5, N3D5, N3D6, N3C1, N3C3, N3C4; Table A.2). The results are shown in Figure A.2; each data point represents an individual SDMS profile site. Comparison of these results with those for the unprotected cliff sections (Figure 5) reveals that the timber palisades have been effective in reducing cliff recession over the monitoring period (1992-2000). The palisades appear to be particularly effective in preventing rapid recession under low beach conditions (i.e. low beach wedge areas).

Table A.8 provides some confirmation of this pattern. For each of the 6 sites, the exponential relationship between beach wedge area and recession rate described above was used to predict an average annual recession rate that could be expected if the profile sites were unprotected. The ratio between the actual measured recession rate (1992-2000/2003) and the predicted rates indicate that at very low beach levels (beach wedge area <15m^2) the palisades have reduced recession rates by 97% of the predicted; between 15-25m^2 the reduction is around 60-75%. For higher beach levels (beach wedge area >25m^2) the palisades do not appear to reduce the recession rate, presumably because the high beach provides sufficient protection already.

Table A.8 Palisade Efficiency (1992-2000)

SDMS Profile	Beach Wedge Area (m^2)	Predicted recession rate (m/year)	Actual recession rate (m/year)	Palisade Efficiency Ratio (Actual to Predicted Recession)
D6	2.85	4.209	0.11	0.03
A5	9.16	1.364	0.005	0.004
D5	12.92	0.697	0.02	0.03
C1	15.61	0.431	0.099	0.23
C4	22.43	0.128	0.05	0.41
C3	39.83	0.006	0.05	9.44

Note: Predicted recession = $7e^{-0.1786x}$ where x is the beach wedge area.

Appendix B List of Photographs

LOCATION	PHOTO NUMBER	GRID REFERENCE	COMMENT
Weybourne to Dead Mans Hill (E)	1.2	TG 14231 43527	Cliff profile
	1.3	TG 13591 43546	Cliff profile
	1.4	TG 12972 43611	Cliff profile
	1.5	TG 12245 43622	Beach shingle
	1.6	TG 12245 43622	Cliff profile
	1.7	TG 11236 43692	Eroded chalk remnants
	1.8	TG 11651 43664	Recent rockfall
	1.9	TG 11651 43664	Cliff profile
	1.10	TG 12134 43638	Cliff profile
	1.11	TG 12600 43612	Eroded chalk remnants
	1.12	TG 12905 43600	Cliff profile
	1.13	TG 13156 43589	Remnant shore platform
	1.14	TG 13665 43530	Cliff profile
	1.15	TG 13665 43530	Cliff profile
	1.16	TG 13665 43530	Recent rockfall
	1.17	TG 14005 43505	Cliff profile
	1.18	TG 14005 43505	Former defences
	1.19	TG 14005 43505	Defences around stream mouth
Robin Friend	1.1	TG 15224 43541	Cliff profile
Sheringham	2.28-2.32		Shallow failures on coastal slopes
Beeston to West Runton Cliffs	1.25	TG 16585 43423	Cliff profile
	1.26	TG 16585 43423	Cliff profile
	1.27	TG 16585 43423	Seawall and rubble revetment
	1.28	TG 16890 43378	Timber palisades (closed)
	1.29	TG 16890 43378	Timber palisades (closed)
	1.30	TG 17118 43332	Timber palisades (open)
	1.31	TG 17118 43332	Cliff profile
	1.32	TG 17362 43308	Recent rockfall
	1.33	TG 17675 43280	Cliff profile
	1.34	TG 17675 43280	Cliff profile
	1.35	TG 17675 43280	Isolated stack
	1.36	TG 18196 43232	Cliff profile
	2.1	TG 18196 43232	Cliff profile
	2.2	TG 18196 43232	Cliff profile
West Runton Gap	2.3	TG 18536 43195	West Runton defences
	2.4	TG 18536 43195	West Runton defences
	2.5	TG 18536 43195	West Runton defences
East Runton Cliffs	2.6	TG 18662 43134	West Runton defences
	2.7	TG 18883 43103	Cliff profile
	2.8	TG 18883 43103	Cliff profile
	2.9	TG 19219 43048	Large non-circular failure with pinnacles
	2.10	TG 19336 43018	Cliff profile
	2.11	TG 19690 42949	Cliff profile
	2.12	TG 19690 42949	Raft of chalk at cliff foot

LOCATION	PHOTO NUMBER	GRID REFERENCE	COMMENT
	2.13	TG 19690 42949	Cliff profile
	2.14	TG 19690 42949	Cliff profile
	2.15	TG 19936 42873	Cliff profile
	2.16	TG 19936 42873	Cliff profile
East Runton Gap			
East Runton to Cromer Cliffs	2.17	TG 20378 42725	Cliff profile
	2.18	TG 20378 42725	Cliff profile
	2.19	TG 20640 42660	Relict landslide system
	2.20	TG 20640 42660	Relict landslide system
	2.21	TG 20825 42615	Large non-circular failure
	2.22	TG 20825 42615	Large non-circular failure
	2.23	TG 20976 42588	Large non-circular failure
	2.24	TG 20976 42588	Large non-circular failure
	2.25	TG 21162 42547	Cliff profile
Cromer (West) Cliffs	2.26	TG 21220 42503	Sheet pile wall
	2.27	TG 21232 42508	Seawall

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EX 4985

Kelling to Cromer Strategy Study
Defence condition survey

Report EX 4985
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November 2006

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Summary

Kelling to Cromer

Part II – Technical support information
Defence Condition Survey

Report EX 4985
November 2006

This report describes surveys of coastal defences protecting the town of Sheringham, communities and land between Kelling Quag and the outskirts of Cromer. Visual inspections of the defences in the study area have led to an initial assessment of the condition of the defences, expressed as a defence condition rating. These assessments were then reviewed, where appropriate, to take account of the serviceability limit state of the structures. The defence lengths in the study area are summarised below, starting at the western end of the study area.

Kelling Quag to Sheringham
This is now a completely undefended stretch of coast. There was a defence at Weybourne protecting the very small area of low-lying land adjacent to the village. That defence was taken out recently and the shingle beach allowed to naturalize. It is understood that the beach performs well without the defence providing a high degree of protection. Cliff failure is often regarded as an issue by the public but this has to be set in the context that the Weybourne cliffs are a geological Site of Special Scientific Interest. (SSSI).

Sheringham
The majority of Sheringham's defences were refurbished in the period 1995 to 1997. The refurbishment included encasing seawalls, reconfiguring and reconstructing the groyne field and the placing of a rock armour revetment. Along the west beach, only the groynes were reconstructed whilst the original 1895 seawall was left untouched. No work was done to the wall as it was still serviceable, despite its poor condition, and there was a consistently high beach in front of it. That particular wall is heavily cracked, damaged and is beyond repair. This wall also relies on the presence of a good beach in front of it to ensure stability. Hence, it has a defence condition rating of very poor.

The western flank of Sheringham was again left when the defences were refurbished. Here there is a mixture of wall types in poor condition with access for people, plant and equipment being very poor and occasionally hazardous.

The promenades throughout the system are in good to very good condition but the back walls behind the promenades on both the east and west beaches are poor reflecting their age. The cliff behind the wall on the east beach shows a tendency to surface instability, typical of North Norfolk's cliffs and requires surface drainage works at least to assist their stability.

West Runton
The length between West Runton Gap and Sheringham was once defended by a timber revetment. This is now derelict and unsightly. Its remains however continue to provide a defence principally acting as a sill retaining a slightly higher beach behind the line of the steel sheet pile toe.

Summary continued

West Runton Gap
This important access point for fishermen and amenity use is protected by concrete walls on both flanks. These walls are in good condition. Outflanking of these walls continues to be an issue as evidenced by the recent works done by the Council on the east flank. Here, a wall and ramp was constructed to do the duty once performed by the derelict West Runton revetment.

East Runton Gap
Another important access point and again defended by concrete walls on both flanks. However, the walls are in very poor condition reflecting their age. Both of the flanking walls are slender concrete walls with no toe protection and have both partially failed. Both walls rely on the presence of a high beach to ensure stability. The eastern end of the East wall has been outflanked and has failed, whereas the centre of the West wall overturned during a storm in early 2005 due to the gradual lowering of the beach level a the toe of the wall. Without remedial works, there will slowly be progressive failure of the wall and it may only be several years until the ramp itself is directly threatened. The East wall is in private ownership and is not maintained by NNDC.

East Runton to Cromer
This is a length of coast that has never been defended and, as such, ensures that the geological interest of the East Runton Cliffs SSSI is preserved.

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Appendix

Appendix List of photos of defence lengths

1. Introduction

All of the defences in the study area have been visually inspected, enabling an initial defence condition rating to be assessed. These assessments were then reviewed where appropriate to take account of ultimate and serviceability limit state calculations of the stability of the walls.

In general terms, the integrity of a defence length depends on the condition of the weakest component in that length. Hence, for each section a combined defence condition rating has been determined as well as ratings for the individual components.

This report was drafted in 2004 and updated for the current issue in respect of the new ramp in Run 2.02 and the reconstruction of the beach defences in Run 2.04.

1.1 METHODOLOGY

The condition of coastal defences (i.e. both sea defences and coast protection works) in the study area was assessed visually using the criteria shown in Table 1.1. This table is an adaptation of the condition descriptions that the Environment Agency developed for their Condition Assessment manual.

A number of trial holes were excavated adjacent to the defences to determine local ground conditions, to identify the geological platform for the beach and to allow an assessment of the condition of the defences below beach level. The information obtained from those trial holes was used in serviceability limit state calculations based on the criteria and mobilisation factors stated in BS 8002:1994 Code of practice for Earth Retaining Structures. Where appropriate, the defence condition rating derived from the visual survey has been reviewed to take account of the results of the stability calculations.

It should be noted that no original drawings for the walls that were not refurbished in Sheringham or those for East and West Runton were found. Also that because of severe access constraints, it was not possible to do trial holes on the walls on the east flank of Sheringham.

The groynes within the study area were also the subject of a detailed inspection again using the criteria shown in Table 1.1.

1.2 RESIDUAL LIFE

For the purposes of the residual life assessment no attempt has been made to prescribe the minimum acceptable performance criteria, instead, the assessment is based purely on engineering judgement. This is mainly because the actual performance of any defence is strongly influenced by the effects of the individual deterioration mechanisms; a complex process that depends on many physical influences including coastal geology, construction materials, structural geometry and wave climate.

Table 1.1 Definitions of defence conditions

Grade	Defence Condition Rating	General	Concrete	Timber	Steel	Promenades	Slopes
1	Very Good	No significant defects. No maintenance required	No significant visible defects. Some hairline cracking permitted	No significant defects. No maintenance required	No visible defects	No significant defects. No maintenance required	Stable with no slumps, cracking makes or water and good vegetative cover
2	Good	Minor defects only. Minor maintenance required to no more than 5% of the structure	Cracks <0.5mm. Some honeycombing, flaking or loss of joint sealant	Slight loss of section. No movement of joints.	Localised surface erosion with loss of section. No physical deformation	Minor defects that can be solved by localised patching. Generally waterproof and safe for vehicle or pedestrians.	Minor departures from Grade 1
3	Fair	Significant defects. Major maintenance required to no more than 20% of the structure	Some rust staining or localised spalling, some loss of steel cover, cracking or movement or extensive honeycombing.	More significant loss of section. Some movement of joints. Occasional plank missing.	More significant loss of section. Impact damage or minor movement.	Significant defects that can only be solved by non-structural overlay. Loss of water proofing and a potential hazard for vehicle or pedestrians.	Minor slumps, cracks or makes of water
4	Poor	Structurally unsound. Major remedial works need within 5 years. Up to 50% affected	Extensive spalling exposed steel or extensive movement. Loss of joint sealant of other defect likely to affect structural integrity.	Severe loss of section. Movement of most joints. Several elements missing with structure severely weakened.	Severe loss of section affecting structural integrity. Severe impact damage or extensive movement	Major defects that can only be solved with a structural overlay / redecking. Dangerous to vehicles or pedestrians. Temporary closure necessary.	Larger slumps with cracking and significant flows of water
5	Very Poor	Totally failed or derelict. Require complete reconstruction	Derelict or complete failure. Beyond repair.	Totally failed. Requires reconstruction.	Derelict or beyond repair	Totally failed and requires reconstruction.	Total collapse

2. Overview of Study Area

2.1 DESCRIPTION OF AREA

The study area consists of soft cliffs, primarily composed of sand and gravel. Land use is predominately recreational and agricultural in nature, but includes the town of Sheringham and the villages of Weybourne, West Runton and East Runton. In Sheringham, coastal defence is provided by seawalls and groynes most of which were renewed in 1995. For the Management Units along this frontage, coastal erosion is an issue of primary importance, and the erosion rate is highly dependent upon management options adopted for adjacent Units. In the remainder of the study area the frontage is mainly unprotected, although to the east of Sheringham there are a couple short lengths of concrete walls protecting concrete ramps onto the beach in both West Runton and East Runton.

The location of the SMP management units and the defence lengths they are composed of, are shown in Figure 2.1.

2.2 SUMMARY OF DEFENCE CONDITIONS

A summary of the defence type and their conditions for each of the defence lengths in the study area is shown below in Table 2.1.

Table 2.1 Summary of defence conditions

SMP Management Unit	Defence Length	Location	Defence Type	Condition Rating
MU1/CU1	1	Muckleburgh	Undefended	-
	2	Weybourne	Undefended	-
RUN1	1	Sheringham	Reinforced concrete seawall	Fair
	2	Sheringham	Concrete seawall	Very poor
	3	Sheringham	Concrete seawall	Very poor
	4	Sheringham	Concrete seawall with rock toe	Very good
	5	Sheringham	Concrete seawall with rock revetment armour	Good
	6	Sheringham	Concrete seawall with rock revetment armour	Good
	7	Sheringham	Concrete seawall with apron	Fair
	8	Sheringham	Timber revetment	Very poor
RUN2	1	West Runton	Timber revetment	Very poor
	2	Old Woman Hithe (West Runton Gap)	Concrete ramp and walls	Good
	3	Runtons	Undefended	-
	4	East Runton Gap	Concrete walls	Very poor
	5	East Runton / Cromer	Undefended	-

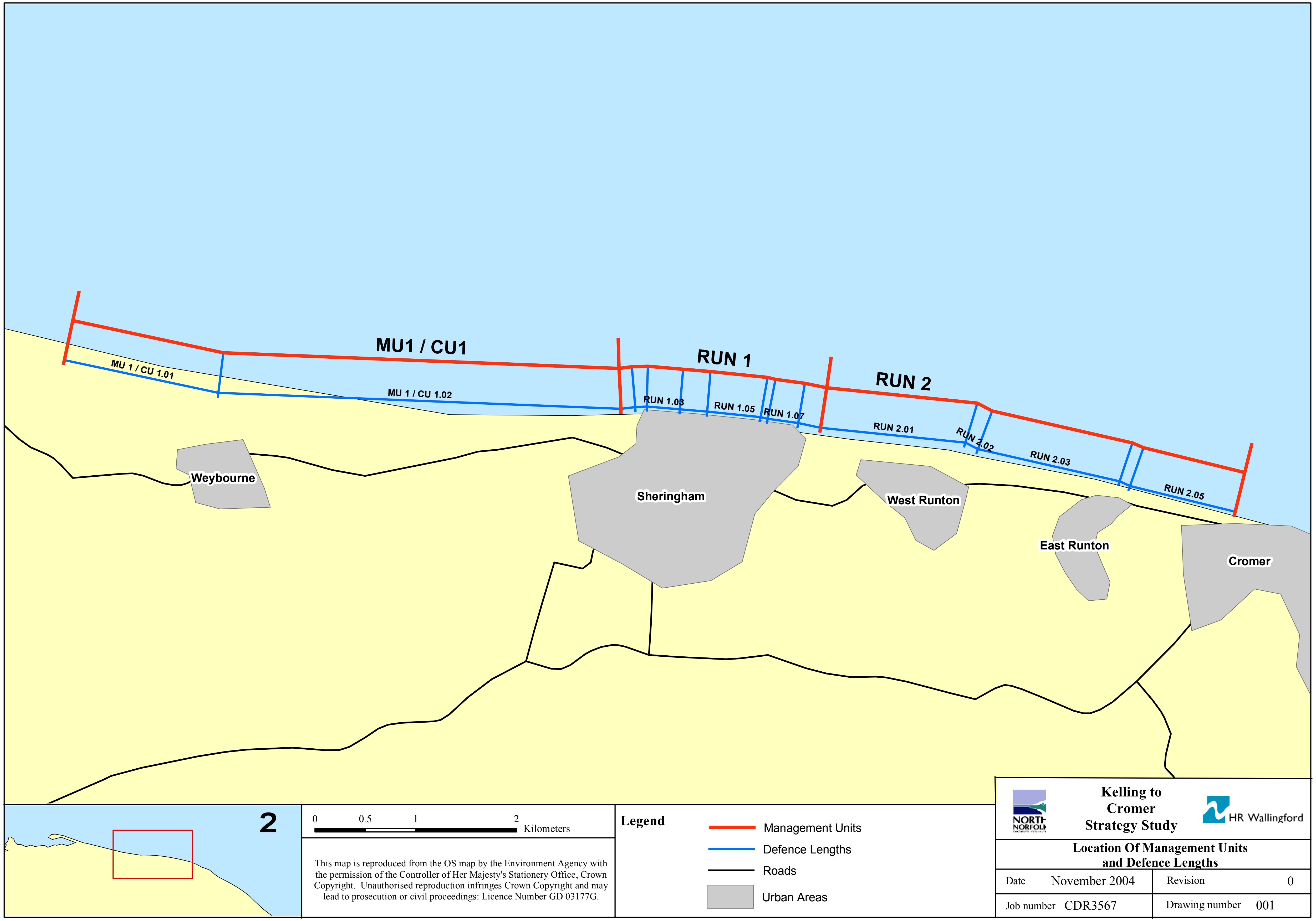

Figure 2.1 Locations of SMP Management Units and Defence Lengths

3. MU1/CU1 – Muckleburgh and Weybourne

3.1 HISTORY

The management unit at the western end of the study area (MU1/CU1) runs from Kelling Hard up to the western edge of Sheringham. The shoreline along this length is composed of a shingle beach 5.5 Km long that is in very good condition and has a wide crest. Weybourne Cliffs SSSI is located to the west of the village of Weybourne and they afford the best Pleistocene sections, showing the pre-Cromerian deposits of the Cromer Forest bed. The Pastonian 'Weybourne Crag', here at its type locality, with its marine molluscs has been known since the early days of geology. A short length of beach was once defended near Kelling hard and this now fronts a small low lying area used for public car parking, otherwise there is no history of any defences in this management unit. There is a potential risk of flooding of several isolated properties to the landward of the car park, from breaching of the shingle bank. The last known breach occurred in 1996 although know flood damage was recorded at these properties.

NNDC has developed a scheme to implement a drainage channel land-ward of the shingle bank, to assist in the draining of floodwaters. This scheme is not considered a current priority.

Within this management unit is the village of Weybourne. The hinterland is mainly occupied by a redundant military camp, now used by the Muckleburgh Military Collection and agricultural land, which is owned by the National Trust. Sheringham Golf Club is located at the eastern end of the management unit on top of the Weybourne Cliffs SSSI.

3.2 CONDITION SUMMARY

The beaches in both defence lengths are in very good condition and have a wide crest width.

3.3 DEFENCE SUMMARY TABLES

Since there are only natural defences in front of Muckleburgh and Weybourne, there is no predicted lifespan. The natural defences will adapt over time as the coastal processes shape the shoreline. The defence lengths in MU1/CU1, and their positions, are shown in Figure 3.1

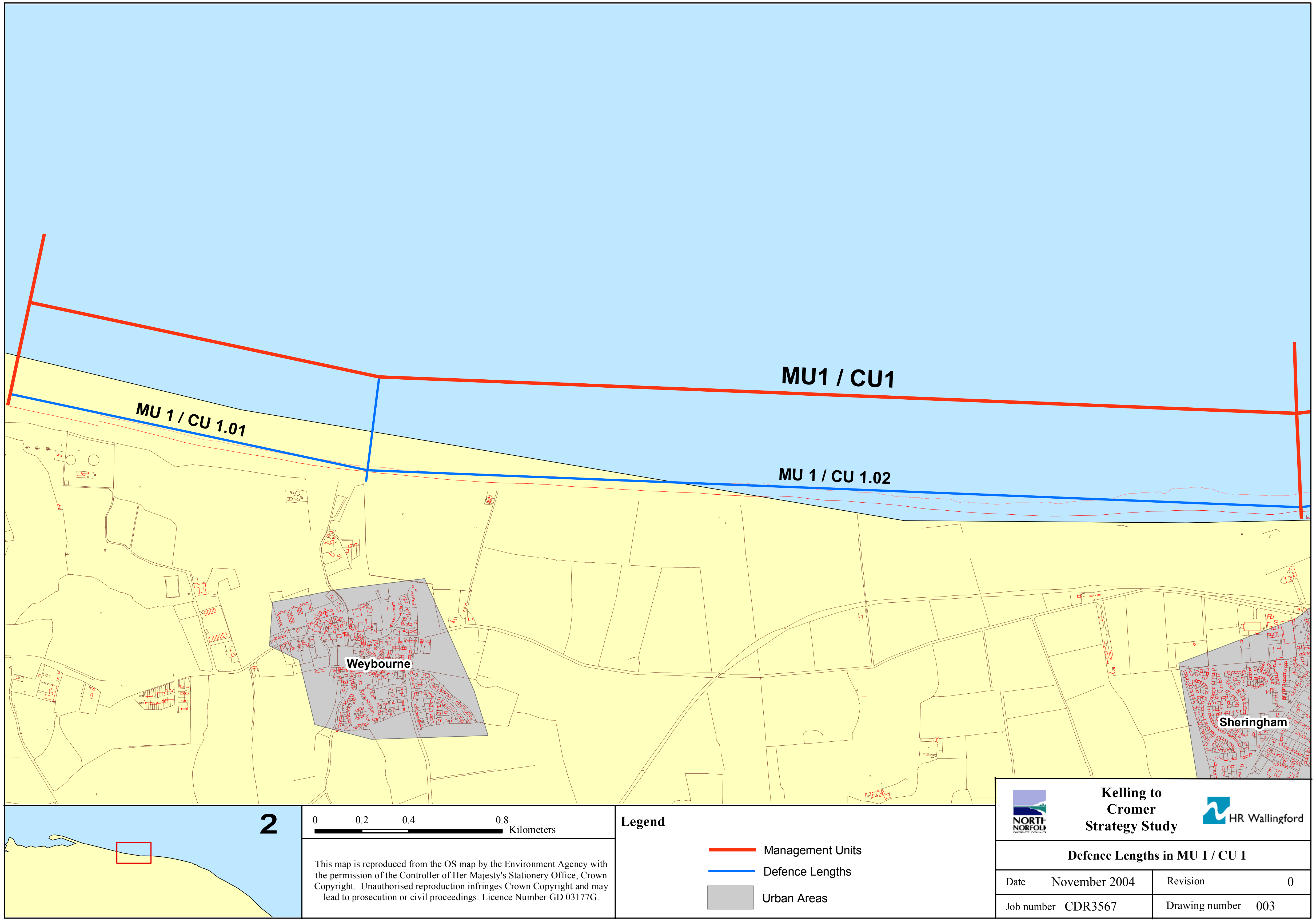

Figure 3.1 Locations of Defence Lengths in MU 1 / CU 1

3.3.1 Defence Length MU1/CU1.01 Muckleburgh

Location: **Muckleburgh**

Start / Finish NG Co-ordinates			**Survey Date:**
	Start	**Finish**	
Easting:	609605	611138	
Northing:	344000	343674	
Length:	1588m		

Management Unit: MU1/CU1 — **Defence Length Reference:** 01

Description of Defences and Beach

Undefended.

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Natural shingle beach in very good condition. Steep upper beach topped with slowly eroding soft clay cliffs approximately 10 metres high. Hinterland behind the cliffs gradually lowers.

Control Structures

None

Conditions and Performance of Backshore Defences

Type: **Built:** **Refurbished:**

Description:

Defence Condition Rating:

Updates to CPSE (1997):

Description of Hinterland and Development

The hinterland is almost wholly occupied by a redundant military camp. Now used by the Muckleburgh Military Collection, a museum which is a locally important tourism facility. Also the site of a military communications/radar facility. A short length of beach was once defended by a wooded breastwork and fronts a small low lying area uses for public car parking. The crest of the shingle beach has retreated and now the breastwork is almost completely buried with small volumes of shingle overtopping into the car park. Several isolated properties are located several hundred metres landward of the car park.

Photograph Log

Ref. No.	**Description of View**
E05	View along beach to west

Cause and Consequence of Failure	
Likely Failure Mechanism:	Undermining and slip of cliff face
Consequence of Failure:	Landward retreat of cliffs

Plate 3.1 View along beach to west

3.3.2 Defence Length MU1/CU1.02 Weybourne

Location: **Weybourne**

Start / Finish NG Co-ordinates

	Start	Finish
Easting:	611138	615143
Northing:	343674	343515
Length:	4008m	

Survey Date:

Management Unit: MU1/CU1

Defence Length Reference: 02

Description of Defences and Beach

Undefended

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Shingle beach with step lower beach and wide crest. Very good condition. Beach is topped by soft clay cliffs 12 to 15 metres high.

Control Structures

None

Conditions and Performance of Backshore Defences

Type: **Built:** **Refurbished:**

Description:

Defence Condition Rating:

Updates to CPSE (1997):

Description of Hinterland and Development

Weybourne Cliffs SSSI. Approximately half of the land is agricultural, owned by the national Trust, with the balance used by Sheringham Golf Club.

Photograph Log

Ref. No.	Description of View
E12	View to east

Cause and Consequence of Failure	
Likely Failure Mechanism:	Undermining and slip of cliff face
Consequence of Failure:	Landward retreat of cliffs

Plate 3.2 View to east

4. RUN1 – Sheringham

4.1 HISTORY

In 1883, it was recorded that "Lower Sheringham is a considerable fishing station, having a road and rivulet winding down to the beach through a ravine in the lofty sea-cliffs. It has three curing-houses, and 23 large and about 150 small fishing boats. Cod, skate, whiting, crabs, and lobsters are taken in abundance, especially the two latter, of which great quantities are sent to London. As at Cromer, the sea is here continually encroaching on the cliffs, of which about a yard disappears every year. In 1800, a large inn was tumbled in a heap of ruins upon the beach; and on St. Thomas' Day, 1862, a large portion of the cliff was washed away."

Lower Sheringham has existed for about 700 years. In the 1300s the village was a mile to the west and there were a few merchants dealing in fish landed at Blakeney; later some owned ships that sailed as far as Iceland. By 1600, that village had been swallowed by the sea and a village was developing on the present site. The crab and lobster fishing began in the 1700s when local fishermen became major suppliers to the London markets.

The mid 1800s was a boom time for the fishing industry with over 100 inshore boats catching crabs and many luggers crewed by local men working out of Great Yarmouth and Grimsby. During that time the population of Lower Sheringham swelled from a few hundreds to one thousand. In the 1870s, the crab industry collapsed due to over-fishing and never regained its supremacy. The opening of the railway line in 1887 revived the fortunes of Lower Sheringham and it quickly became a thriving holiday resort, popular with the middle class Londoners, only a four-hour train trip away. There was a major recession in farming and all of the land in the lower village was sold for development. In 1889, Sheringham Hotel opened and in the 1890s, The Grand and The Burlington were accommodating the society visitors. Many large houses were built to be let as apartments and all types of shops opened to cater for the holidaymakers. In 1901, the village became a town when it was granted status as a self-governing urban district. The town lost its identity as a primitive fishing community and became today's modern resort thriving on tourism.

By 1886, the town had seawalls protecting its centre together with a launch ramp serving the Coastguard Station at the end of Driftway and its first groyne close to the site of the modern groyne, A10. As more land was released for development, there was a corresponding extension to the defences. The most significant of these was the construction of the seawall to the west of Driftway by the Upcher Estate in 1895 and the related groyne field. Those defences form the basis of today's system with the Upcher wall still in use. The seawalls and groynes continued to be developed in the early 20th century with the very first walls being replaced in 1910.

In the period 1994 to 1997, the system was almost completely overhauled with the construction of new groynes and the refurbishment of the central seawalls. An important aspect of that project was the proposal to recharge the beaches with dredged sand. Despite the building of groynes to cater for it, the recharge scheme was not implemented due to funding constraints.

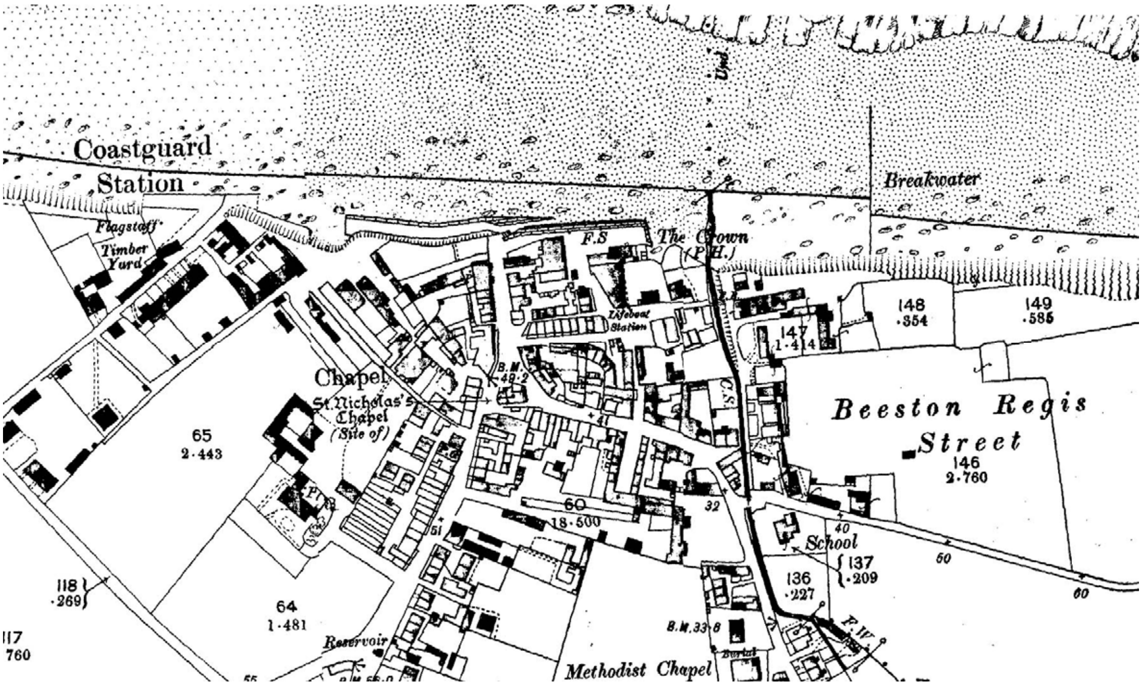

Figure 4.1 Sheringham c1886

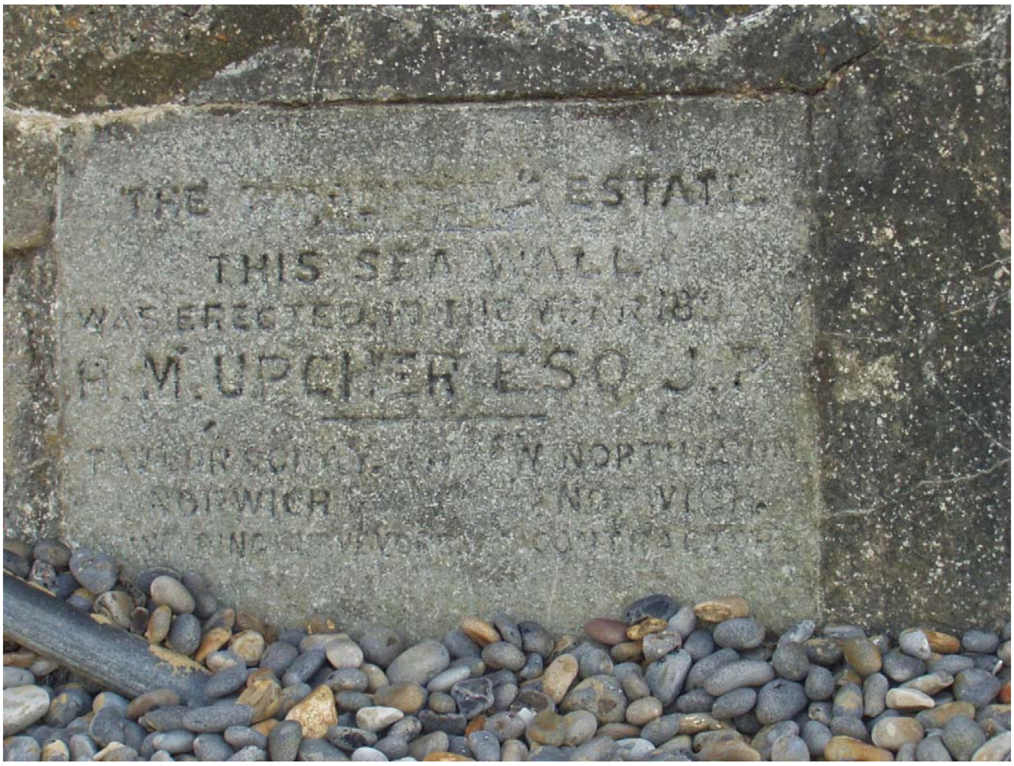

Plate 4.1 Plaque commemorating the building of the seawall in 1895

4.2 CONDITION SUMMARY

The eight defence lengths defined for Sheringham reflects the way the system has evolved over time. The core of the system was refurbished in 1995 to 1997. All of the refurbished or new groynes and walls are in very good condition. Whilst the groynes at the western end of Sheringham were reconstructed, the 1895 seawall (defence length 3) was left in its original state. This wall is badly abraded with extensive spalling and extensive large scale cracking. The extent of the defects are such that the wall has been assessed as beyond repair and therefore has a defence condition rating of very poor, although it still provides a level of residual defence. This conclusion is supported by an analysis of the serviceability of the wall as a retaining structure. This shows that the wall relies entirely on the presence of a good beach in front of it for stability. Serviceability limit state calculations of the wall's stability show that for stability, a beach level 1.03 metre below the promenade is needed (5.44m AOD). When the trial holes were done, the beach was 1.20 metres below the promenade.

Beyond the promenade at the east end of Sheringham, there are three different types of seawall described as defence lengths 6 to 8 respectively. The wall in defence length 6 is in good condition and protected by a rock revetment. The curved profile wall with a steel pile toe in defence length 7 has been badly abraded revealing reinforcing steel. The defence condition rating here is fair. The wall in section 8 is of composite construction with a timber revetment on a concrete base wall and steel pile toe. The revetment is contiguous with that in management unit RUN2. The concrete is so badly damaged that it is beyond repair and the steel piles are very badly corroded. The timber revetment is again beyond repair. As a defence it has failed but still acts as a sill retaining a high level of beach between it and the base of the cliff. The defence condition rating is very poor.

Throughout the entire system, the promenades are in good to very good condition giving little cause for concern although the joints along the western promenade may need attention. The only exception to this is the facility for pedestrians in defence lengths 6 to 8 inclusive. Once pedestrians leave the promenade, access along the back of the walls is difficult and sometimes hazardous. More pertinent is the lack of safe access points for people to and from the beach along this section. With low beach levels, it is difficult and hazardous to climb over the defences, be they groynes or walls, in order to traverse or escape the beach.

The retaining walls to the back of the promenade in the central sections are in very good condition. The wall behind the 1895 seawall along the western section is badly cracked and spalling. This wall attracts a defence condition rating of poor. The retaining walls in the central section and adjacent to the RNLI boatshed are in very good condition. The crib wall that protects the turning bay on the west promenade is serviceable and in good condition. The walls behind the eastern promenade are extensively cracked and are spalling. These have a condition rating of poor. Towards the end of the promenade NNDC were, at the time of preparing this report, reconstructing a relatively short length of wall.

Again, along the eastern promenade, the cliffs are steep and show signs of surface instability. Elsewhere, the cliffs are tending to be stable.

Overall, system is in very good condition but attention is needed to the 1895 walls and the walls on the eastern flank.

All of the system is owned by NNDC except for the extreme western end (Defence length RUN1.01), which is owned and maintained by the RNLI.

4.3 DEFENCE SUMMARY TABLES

The table below shows the minimum, most likely and maximum assessments of the residual life of Sheringham's sea walls. The condition of the defences is summarised in more detail in the following tables. The defence lengths in RUN1, and their positions, are shown in Figure 4.2

Defence Length	Minimum (years)	Likely (years)	Maximum (years)
RUN1.01	15	16	20
RUN1.02	2	5	6
RUN1.03	2	3	3.5
RUN1.04	19	25	30
RUN1.05	19	22	30
RUN1.06	16	20	22.5
RUN1.07	4	6	10
RUN1.08	0	0	0

The following table shows the assessment of minimum, likely and maximum residual lives of the groynes in RUN1.

Groyne Numbers	Minimum (years)	Likely (years)	Maximum (years)
A1, A2	16	20	22.5
A3 to A8	19	22.5	30
A9 to A12	20	40	50
A13	4	7	8
A14 to A15	16	20	22.5
B1	16	20	22.5

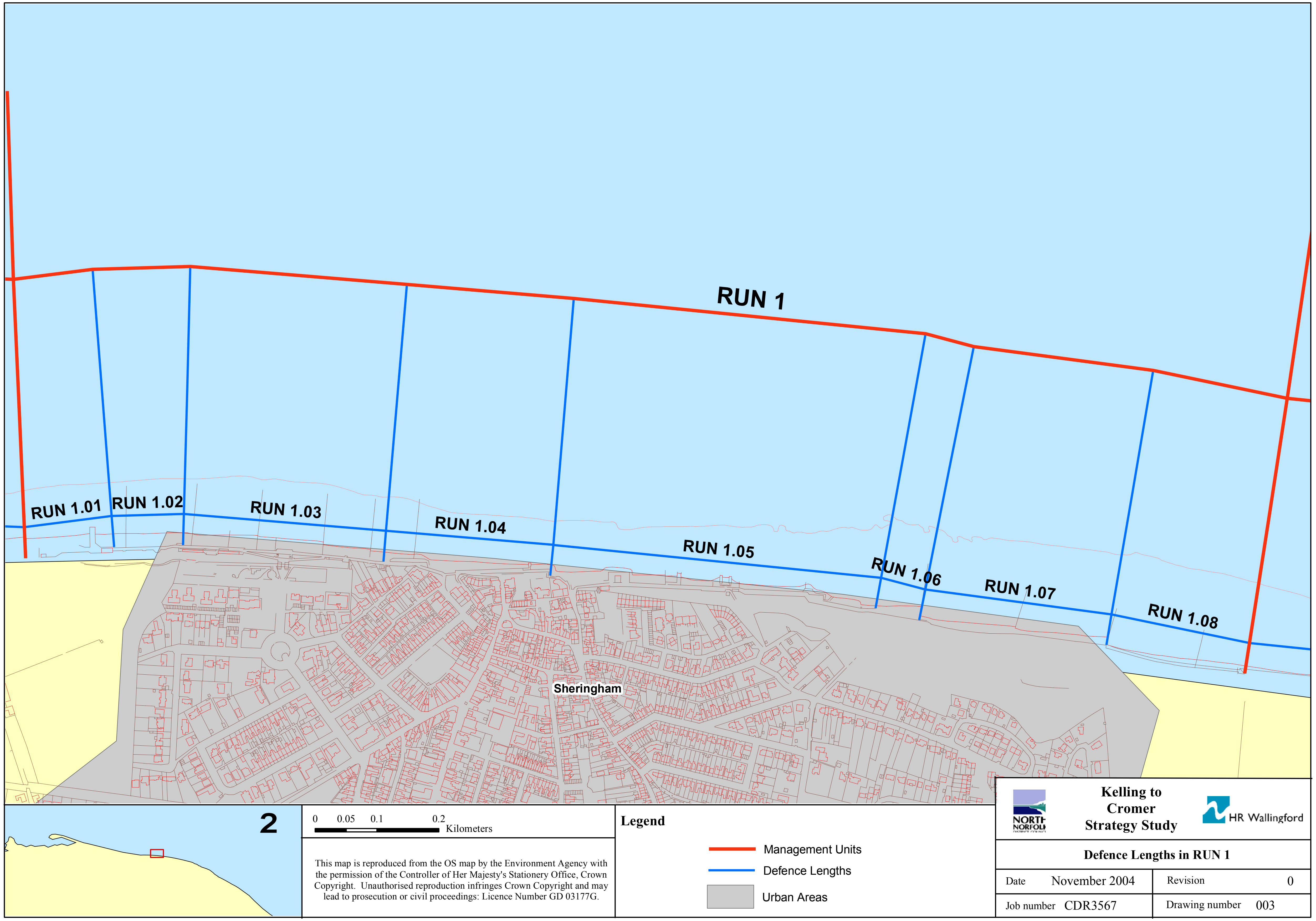

Figure 4.2 Locations of Defence Lengths in RUN 1

4.3.1 Defence Length RUN1.01

Location: **Sheringham**	
Start / Finish NG Co-ordinates **Start** **Finish** **Easting:** 615143 615285 **Northing:** 343515 343533 **Length:** 143m	**Survey Date:** April 2004
Management Unit: RUN1	**Defence Length Reference:** 01

Description of Defences and Beach

Reinforced concrete seawall at the toe of the cliff. Upper shore – stone, lower shore – sand on chalk platform

Defences maintained by: RNLI & North Norfolk District Council

Condition and Performance of Beach

Steeply sloping high stone upper shore with a shallow lower shore. Height known to be volatile. Good condition

Control Structures

Groynes A1, A2

Conditions and Performance of Backshore Defences

Type: **Built:** 1960 **Refurbished:**

Description: Vertical buttressed sea wall to the west of the lifeboat station.

Defence Condition Rating: Fair

Updates to CPSE (1997):

Description of Hinterland and Development

Semi urban. Bed and Breakfast, Golf Course and residential development.

Photograph Log

Ref. No.	Description of View
B02	Groyne A1
B06	Seawall

Cause and Consequence of Failure **Likely Failure Mechanism:** Cliff failure and/or sustained loss of beach causing structural instability **Consequence of Failure:** Loss of RNLI facilities. Cliff failure damage to golf course.

Groyne A1

Location **Sheringham** **Groyne No.** **A1**	
Start / Finish NG Co-ordinates **Root** **Easting:** 615143 615141 **Northing:** 343515 343560 **Length:** 45m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 01
Conditions and Performance of Groyne **Type:** Timber/steel sheet piles **Built:** 1968 **Refurbished:** **Defence Condition Rating:** Fair **Updates to CPSE (1997):** **Comment:** No beacon. Built by RNLI	

Groyne A2

Location **Sheringham** **Groyne No.** **A2**	
Start / Finish NG Co-ordinates **Root** **Easting:** 615164 615164 **Northing:** 343516 343531 **Length:**	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 01
Conditions and Performance of Groyne **Type:** Timber **Built:** 1968 **Refurbished:** **Defence Condition Rating:** Good **Updates to CPSE (1997):** **Comment:**	

Plate 4.2 Groyne A1

Plate 4.3 Sea wall

4.3.2 Defence Length RUN1.02

Location: **Sheringham**	
Start / Finish NG Co-ordinates **Start** **Finish** **Easting:** 615285 615396 **Northing:** 343533 343536 **Length:** 112m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 02
<u>Description of Defences and Beach</u> Concrete seawall, promenade and retaining wall. Stone upper beach with sand on chalk platform on lower beach. **Defences maintained by:** North Norfolk District Council	
<u>Condition and Performance of Beach</u> Good. Both sand and stone levels are volatile **Control Structures** Groyne A3	
<u>Conditions and Performance of Backshore Defences</u> **Type:** **Built:** 1895 **Refurbished:** 1972 **Description:** Very old concrete sea wall. Relies on a good high beach for continuing stability. **Defence Condition Rating:** Very poor. **Updates to CPSE (1997):**	
<u>Description of Hinterland and Development</u> Semi urban area with a number of residential properties and Bed and Breakfasts. The remainder of the area is taken up by a Golf course on the western edge of Sheringham.	

<u>Photograph Log</u>

Ref. No.	Description of View
B09	Groyne A3
D05	Seawall and steps

Cause and Consequence of Failure

Likely Failure Mechanism: Overturning following a large loss of stone off the beach

Consequence of Failure: Loss of access to RNLI. Damage to golf course and threat to dwellings. Loss of promenade amenity.

Groyne A3

Location **Sheringham**

Groyne No. **A3**

Start / Finish NG Co-ordinates			**Survey Date:**
	Root		April/May 2004
Easting:	615305	615306	
Northing:	343533	343632	
Length:	100m		

Management Unit: RUN1

Defence Length Reference: 02

Conditions and Performance of Groyne

Type: Timber **Built:** 1974 **Refurbished:** 1997

Defence Condition Rating: Very good

Updates to CPSE (1997):

Comment: Rock scour protection at seaward end

Plate 4.4 Groyne A3

Plate 4.5 Sea wall and steps

4.3.3 Defence Length RUN1.03

Location: **Sheringham**	
Start / Finish NG Co-ordinates **Start** **Finish** **Easting:** 615396 615721 **Northing:** 343536 343510 **Length:** 326m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 03
<u>Description of Defences and Beach</u> Concrete seawall, promenade and retaining wall. Stone upper beach with sand on chalk platform on lower beach. **Defences maintained by:** North Norfolk District Council	
<u>Condition and Performance of Beach</u> Fair. Both sand and stone levels are volatile **Control Structures** Groynes A4, A5, A6, A7	
<u>Conditions and Performance of Backshore Defences</u> **Type:** **Built:** 1895 **Refurbished:** **Description:** Very old concrete sea wall built by Upcher estate. Relies on a good high beach for continuing stability **Defence Condition Rating:** Very poor **Updates to CPSE (1997):**	
<u>Description of Hinterland and Development</u> Urban area, predominately residential housing but with a number of Bed and Breakfasts. Amenity beach with related services.	
<u>Photograph Log</u>	

Ref. No.	**Description of View**
B15	Groyne A4 inshore end note shingle gates
D08	Seawall

Cause and Consequence of Failure
Likely Failure Mechanism: Instability following beach drawdown
Consequence of Failure: Loss of amenity space and dwellings

Groyne A4

Location Sheringham **Groyne No.** A4	
Start / Finish NG Co-ordinates **Root** **Easting:** 615410 615420 **Northing:** 343536 343636 **Length:**	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 03
Conditions and Performance of Groyne **Type:** Timber **Built:** 1974 **Refurbished:** 1997 **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:** Rock scour protection at seaward end	

Groyne A5

Location Sheringham **Groyne No.** A5	
Start / Finish NG Co-ordinates **Root** **Easting:** 615516 615526 **Northing:** 343529 343626 **Length:**	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 03
Conditions and Performance of Groyne **Type:** Timber **Built:** 1974 **Refurbished:** 1997 **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:** Rock scour protection at seaward end	

Groyne A6

Location **Sheringham** **Groyne No.** **A6**	
Start / Finish NG Co-ordinates **Root** **Easting:** 615622 615631 **Northing:** 343522 343619 **Length:** 98m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 03
<u>Conditions and Performance of Groyne</u> **Type:** Timber **Built:** 1974 **Refurbished:** 1997 **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:** Rock scour protection at seaward end	

Groyne A7

Location **Sheringham** **Groyne No.** **A7**	
Start / Finish NG Co-ordinates **Root** **Easting:** 615699 615708 **Northing:** 343512 343612 **Length:** 100m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 03
<u>Conditions and Performance of Groyne</u> **Type:** Timber **Built:** 1948 **Refurbished:** 1997 **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:** Rock scour protection at seaward end	

Plate 4.6 Groyne A4 inshore end note shingle gates

Plate 4.7 Sea wall

4.3.4 Defence Length RUN1.04

Location: **Sheringham**

Start / Finish NG Co-ordinates

	Start	Finish
Easting:	615721	615991
Northing:	343510	343487
Length:	271m	

Survey Date: April/May 2004

Management Unit: RUN1

Defence Length Reference: 04

Description of Defences and Beach

Concrete seawalls with rock revetment at toe. Stone upper beach with sand on chalk platform on lower beach.

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Good. Both sand and stone levels are volatile

Control Structures

Groynes A8, A9

Conditions and Performance of Backshore Defences

Type: **Built:** 1910 **Refurbished:** 1997

Description: Reinforced concrete facing to original seawalls. New steel pile toe. Rock protection at the base of the wall. Fishermen's ramp and bridge over ramp

Defence Condition Rating: Very good

Updates to CPSE (1997):

Description of Hinterland and Development

Sheringham town centre (urban area), mixture of both residential and commercial properties with a number of Bed and Breakfasts. Amenity beach with related services.

Photograph Log

Ref. No.	Description of View
B28	Groyne A8 inshore end
D31	Rock revetment adjacent to groyne A9

Cause and Consequence of Failure **Likely Failure Mechanism:** Very severe and sustained loss of beach leading to toe failure. **Consequence of Failure:** Substantial loss of residential and commercial property. Loss of the sewerage storm tank and pumping station serving the town and environs. Consequent gross pollution of blue flag beach.

Groyne A8

Location **Sheringham** **Groyne No.** **A8**	
Start / Finish NG Co-ordinates **Root** **Easting:** 615770 615780 **Northing:** 343515 343611 **Length:** 97m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 04
Conditions and Performance of Groyne **Type:** Timber **Built:** 1997 **Refurbished:** **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:** Rock scour protection at seaward end	

Groyne A9

Location **Sheringham** **Groyne No.** **A9**	
Start / Finish NG Co-ordinates **Root** **Easting:** 615940 615947 **Northing:** 343499 343607 **Length:** 108m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 04
Conditions and Performance of Groyne **Type:** Rock **Built:** 1997 **Refurbished:** **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:**	

Plate 4.8 Groyne A8 inshore end

Plate 4.9 Rock revetment adjacent to groyne A9

4.3.5 Defence Length RUN1.05

Location: **Sheringham**

Start / Finish NG Co-ordinates

	Start	Finish
Easting:	615991	616517
Northing:	343487	343434
Length:	529m	

Survey Date: April/May 2004

Management Unit: RUN1

Defence Length Reference: 05

Description of Defences and Beach

Concrete seawall, promenade and retaining wall. Stone upper beach with sand on chalk platform on lower beach.

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Fair. Thin veneer of sand on chalk platform with low volumes of stone on the upper shore.

Control Structures

Groynes A10, A11, A12

Conditions and Performance of Backshore Defences

Type: **Built:** 1910 -1930 **Refurbished:** 1994, 1994

Description: Original concrete seawalls protected by rock revetment.

Defence Condition Rating: In isolation, poor but in combination with the rock revetment, good.

Updates to CPSE (1997):

Description of Hinterland and Development

Urban area, predominantly residential with a number of Bed and Breakfasts. Amenity beach with related services.

Photograph Log

Ref. No.	Description of View
D51	General view – rock revetment
D52	Cliff damage and repair

Cause and Consequence of Failure **Likely Failure Mechanism:** Cliff failure leading to surcharge or overturning. **Consequence of Failure:** Loss of the sewerage storm tank and pumping station serving the town and environs. Consequent gross pollution of blue flag beach. Substantial property loss and damage to amenity.

Groyne A10

Location Sheringham **Groyne No.** A10	
Start / Finish NG Co-ordinates **Root** **Easting:** 616102 616103 **Northing:** 343493 343598 **Length:** 105m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 05
Conditions and Performance of Groyne **Type:** rock **Built:** 1997 **Refurbished:** **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:**	

Groyne A11

Location Sheringham **Groyne No.** A11	
Start / Finish NG Co-ordinates **Root** **Easting:** 616275 616278 **Northing:** 343473 343578 **Length:** 105m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 05
Conditions and Performance of Groyne **Type:** Rock **Built:** 1997 **Refurbished:** **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:**	

Groyne A12

Location **Sheringham** **Groyne No.** **A12**			
Start / Finish NG Co-ordinates **Root** **Easting:** 616414 616422 **Northing:** 343465 343568 **Length:** 103m		**Survey Date:** April/May 2004	
Management Unit:	RUN1	**Defence Length Reference:**	05
Conditions and Performance of Groyne **Type:** Rock **Built:** 1997 **Refurbished:** **Defence Condition Rating:** Very good **Updates to CPSE (1997):** **Comment:**			

Plate 4.10 General view – rock revetment

Plate 4.11 Cliff damage and repair

4.3.6 Defence Length RUN1.06

Location: **Sheringham**

Start / Finish NG Co-ordinates

	Start	Finish
Easting:	616517	616588
Northing:	343434	343415
Length:	72m	

Survey Date: April/May 2004

Management Unit: RUN1

Defence Length Reference: 06

Description of Defences and Beach

Concrete wall set in front of cliff with rock armour revetment. Sand and shingle beach

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Quite shallow with a small amount of shingle against the rock revetment. Fair condition

Control Structures

Groynes A13

Conditions and Performance of Backshore Defences

Type: **Built:** 1930 **Refurbished:**

Description: Reinforced concrete wall of simple profile. Protected by a rock revetment placed in 1995.

Defence Condition Rating: Good

Updates to CPSE (1997):

Description of Hinterland and Development

Urban area, predominantly residential with a number of Bed and Breakfasts. Amenity beach with related services. Beeston Cliffs SSSI

Photograph Log

Ref. No.	Description of View
A90	Looking east along line of seawall
A91	Base of seawall

Cause and Consequence of Failure	
Likely Failure Mechanism:	Cliff failure causing overturning or surcharging causing sliding
Consequence of Failure:	Damage to SSSI, loss of local landmark, damage to housing.

Groyne A13

Location Sheringham **Groyne No.** A13	
Start / Finish NG Co-ordinates **Root** **Easting:** 616588 616602 **Northing:** 343414 343507 **Length:** 93m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 06
Conditions and Performance of Groyne **Type:** Timber and steel pile **Built:** **Refurbished:** **Defence Condition Rating:** poor **Updates to CPSE (1997):** **Comment:**	

Plate 4.12 Looking east along line of seawall

Plate 4.13 Base of groyne A13

4.3.7 Defence Length RUN1.07

Location: **Sheringham**

Start / Finish NG Co-ordinates **Start** **Finish** **Easting:** 616588 616891 **Northing:** 343415 343375 **Length:** 306m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 07

Description of Defences and Beach

Concrete wall with slightly concave face set forward of the cliff. Sandy beach

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Shallow beach allowing wave attack of the wall at most high tides.

Control Structures

Groynes A14, A15

Conditions and Performance of Backshore Defences

Type: **Built:** 1959 **Refurbished:**

Description: Concrete wall with apron and steel pile toe. High degree of abrasion, exposed aggregate, rust stains from reinforcement.

Defence Condition Rating: Fair

Updates to CPSE (1997):

Description of Hinterland and Development

Urban area, predominantly residential with a number of Bed and Breakfasts. Amenity beach with related services. Beeston Cliffs SSSI

Photograph Log

Ref. No.	Description of View
A72	Base of seawall
A80	Seaward end groyne A14

Cause and Consequence of Failure

Likely Failure Mechanism: Cliff failure causing overturning or surcharging causing sliding

Consequence of Failure: Damage to SSSI, loss of local landmark, damage to housing.

Groyne A14

Location **Sheringham**

Groyne No. **A14**

Start / Finish NG Co-ordinates			**Survey Date:**
	Root		April/May 2004
Easting:	616744	616764	
Northing:	343405	343468	
Length:	67m		
Management Unit:	RUN1		**Defence Length Reference:** 06

Conditions and Performance of Groyne

Type: Timber and steel sheet pile **Built:** 1950 **Refurbished:**

Defence Condition Rating: Fair

Updates to CPSE (1997):

Comment: No beacon

Groyne A15

Location **Sheringham**

Groyne No. **A15**

Start / Finish NG Co-ordinates			**Survey Date:**
	Root		April/May 2004
Easting:	616891	616908	
Northing:	343376	343434	
Length:	63m		
Management Unit:	RUN1		**Defence Length Reference:** 06

Conditions and Performance of Groyne

Type: Timber and steel sheet pile **Built:** 1950/1978 **Refurbished:**

Defence Condition Rating: Fair

Updates to CPSE (1997):

Comment:

Plate 4.14 Base of sea wall

Plate 4.15 Seaward end of groyne A14

4.3.8 Defence Length RUN1.08

Location: **Sheringham**

Start / Finish NG Co-ordinates			**Survey Date:** April/May 2004
	Start	**Finish**	
Easting:	616891	617114	
Northing:	343375	343328	
Length:	228m		
Management Unit: RUN1			**Defence Length Reference:** 08

Description of Defences and Beach

Timber revetment on concrete base wall with steel pile toe. Sandy beach.

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Very shallow allowing wave attack of the wall at most high tides.

Control Structures

B1

Conditions and Performance of Backshore Defences

Type: **Built:** 1969/1981 **Refurbished:**

Description: Derelict timber revetment on badly abraded concrete base. Steel pile toe very badly abraded with major loss of section. Health and safety hazard in respect of dereliction and the safe movement of people along the foreshore.

Defence Condition Rating: Very poor

Updates to CPSE (1997):

Description of Hinterland and Development

Urban area, predominantly residential with a number of Bed and Breakfasts. Amenity beach with related services. Beeston Cliffs SSSI

Photograph Log

Ref. No.	Description of View
A51	Derelict revetment at transition
A56	Root of groyne B1

Cause and Consequence of Failure	
Likely Failure Mechanism:	Cliff failure causing overturning or surcharging causing sliding
Consequence of Failure:	Damage to SSSI, loss of local landmark, damage to housing.

Groyne B1

Location **Sheringham** **Groyne No.** **B1**	
Start / Finish NG Co-ordinates **Root** **Easting:** 617035 617049 **Northing:** 343343 343400 **Length:** 58m	**Survey Date:** April/May 2004
Management Unit: RUN1	**Defence Length Reference:** 06
Conditions and Performance of Groyne **Type:** Timber **Built:** 1976 **Refurbished:** **Defence Condition Rating:** Fair **Updates to CPSE (1997):** **Comment:** No beacon	

Plate 4.16 Derelict revetment at transition

Plate 4.17 Root of groyne B1

5. RUN2 – West Runton to Cromer

5.1 HISTORY

The management unit RUN2 at the eastern end of the study area runs from the eastern edge of Sheringham to the western edge of Cromer. The villages of West Runton and East Runton are both within this management unit. The shoreline is defended in a number of defence lengths, the earliest historical recording of sea defences in this management unit is from 1930 in defence length 4 (East Runton Gap) where there is a concrete ramp that provides access onto the beach and provides access to the sea for boats. The concrete ramp was first defended in plain concrete sea walls on each flank, in 1930. However, the Ordnance Survey's 1938 – 1940 map does not show any defences at that time.

More recently, in 1976, defences have been constructed in defence lengths 1 (West Runton) and 2 (Old Woman Hithe / West Runton Gap). As a reaction to increased rates of erosion and loss of cliff top land in defence length 1, a timber revetment with a steel pile toe together with timber groynes was erected. At the same time the concrete road and ramp in defence length 2, which has been an important access point for fishermen and lately visitors for over 150 years, was first protected by flanking sea walls in 1976. Outflanking is an issue here with there being a slowly spiralling increase in works necessary to protect the flanks of the sea walls. There is no history of any other defences prior to these.

There is no history of any hard defences in either defence length 3 (Runtons) or 5 (East Runton / Cromer) and they are still undefended

5.2 CONDITION SUMMARY

The timber revetment in defence length 1 (West Runton) is in an advanced state of dereliction along the entire frontage. Therefore, its corresponding defence condition rating is very poor. It does however, continue to function as a sill retaining a higher beach between it and the base of the cliff. The associated timber groynes are in fair to good condition.

In defence length 2 (Old Woman Hithe / West Runton Gap) the flanks of the concrete ramp are protected by concrete revetments with steel pile toes, which is itself becoming outflanked. The easterly concrete revetment also has a concrete apron. At the end of this revetment in particular the joints are open but there is no indication of movement. The smaller west flank concrete revetment is relatively new and was built to provide the protection once offered by the now derelict timber revetment referred to above. Both concrete revetments have steel pile toes that are driven into the very high chalk platform and which is often exposed. The steel piles have a remaining design life of approximately 50 years and are secondary to the outflanking issue in the assessment of the residual life of the defences. The defence condition rating for both concrete revetments is good.

Both the flanking walls in defence length 4 (East Runton Gap) are in very poor condition as there are failures in both walls and elsewhere they are heavily cracked and there is significant spalling. The west wall failed through overturning, due to low beach levels at toe level, during a storm early in 2005. The east wall, which is privately owned, shows significant signs of having moved in the past and at the eastern end of the wall it has collapsed. This failure has probably been caused by outflanking, which will lead to a progressive failure of the defence. Trial hole investigations in the front of both walls showed them to be very slender with no foundations at all. Serviceability limit state calculations of the walls as retaining structures show that the walls rely entirely on the presence of a good beach in front of them for stability. The calculations suggest that for stability, a beach level 0.77 metres below the promenade is needed for the East wall and 0.85m below the deck for the West wall. When the trial holes were done, the beach was 1.45 metres and 1.88 metres below the promenades of the East and West walls respectively. The defence condition rating for both walls is therefore very poor.

There are no hard defences in defence lengths 3 (Runtons) or 5 (East Runton / Cromer), however the beaches in both of these defence lengths are in good condition.

5.3 DEFENCE SUMMARY TABLES

The table below shows the minimum, most likely and maximum assessments of the residual life of the sea defences between Sheringham and Cromer. Both defence length 3 (Runtons) and 5 (East Runton / Cromer) are undefended and therefore have no residual life but will adapt due to coastal processes. The condition of the defences is summarised in more detail in the tables on the following pages. The defence lengths in RUN2, and their positions, are shown in Figure 5.1

Defence Length	Minimum (years)	Likely (years)	Maximum (years)
RUN2.01	0	0	0
RUN2.02	18	22	28
RUN2.03	-	-	-
RUN2.04	0	0	0
RUN2.05	-	-	-

The following table shows the assessment of minimum, likely and maximum residual lives of the groynes in RUN 2.

Groyne Numbers	Minimum (years)	Likely (years)	Maximum (years)
B2 to B5	4	6	7.5
Groyne B6	16	20	22.5

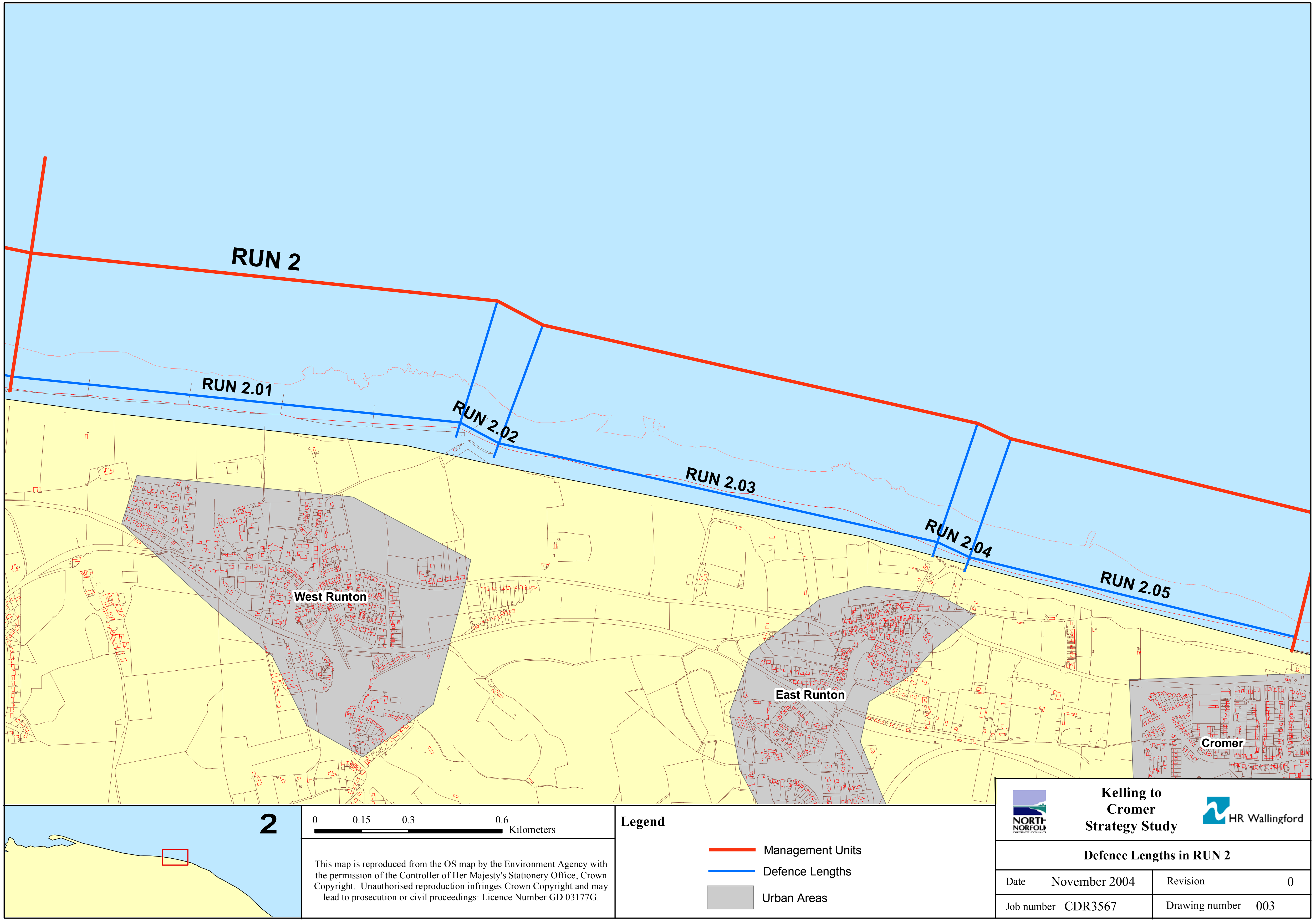

Figure 5.1 Locations of Defence Lengths in RUN 2

5.3.1 Defence Length RUN 2.01 – West Runton

Location: **West Runton**

Start / Finish NG Co-ordinates			**Survey Date:** April 2004
	Start	**Finish**	
Easting:	617107	618545	
Northing:	343337	343182	
Length:	1443m		

Management Unit: RUN2 — **Defence Length Reference:** 01

Description of Defences and Beach

Timber revetment with steel sheet pile toe. Shingle/ cobble upper shore to base of cliff. Sand lower shore on chalk platform. Occasional exposures of flint in lower shore

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Shallow beach generally. Little change observed over a period of time. Condition good.

Control Structures

Groynes B2, B3, B4, B5

Conditions and Performance of Backshore Defences

Type: **Built:** 1976 **Refurbished:**

Description: Timber revetment in various stages of dereliction. Still acting as a sill retaining beach material behind the structure.

Defence Condition Rating: Very poor

Updates to CPSE (1997):

Description of Hinterland and Development

Semi rural area, mixed use of land including residential properties with a number of Bed and Breakfasts, mobile home sites and agricultural land. Area includes part of the West Runton Cliffs SSSI

Photograph Log

Ref. No.	Description of View
A43	Groyne B3 seaward end
A48	Cliffs at groyne B2

Cause and Consequence of Failure

Likely Failure Mechanism: Failed

Consequence of Failure: Loss of land and amenity. Refreshment of the geological SSSI. Increasing supply of beach material

Groyne B2

Location **West Runton**

Groyne No. **B2**

Start / Finish NG Co-ordinates			**Survey Date:**
	Root		April/May 2004
Easting:	617365	617373	
Northing:	343315	343381	
Length:	67m		
Management Unit: RUN2			**Defence Length Reference:** 01

Conditions and Performance of Groyne

Type: Timber **Built:** 1976 **Refurbished:**

Defence Condition Rating: Fair

Updates to CPSE (1997):

Comment:

Groyne B3

Location **West Runton**

Groyne No. **B3**

Start / Finish NG Co-ordinates			**Survey Date:**
	Root		April/May 2004
Easting:	617688	617698	
Northing:	343289	343356	
Length:	68m		
Management Unit: RUN2			**Defence Length Reference:** 01

Conditions and Performance of Groyne

Type: Timber **Built:** 1976 **Refurbished:**

Defence Condition Rating: Fair

Updates to CPSE (1997):

Comment:

Groyne B4

Location West Runton **Groyne No.** B4	
Start / Finish NG Co-ordinates **Root** **Easting:** 617982 617995 **Northing:** 343258 343324 **Length:** 67m	**Survey Date:** April/May 2004
Management Unit: RUN2	**Defence Length Reference:** 01
Conditions and Performance of Groyne **Type:** Timber **Built:** 1976 **Refurbished:** **Defence Condition Rating:** Fair **Updates to CPSE (1997):** **Comment:**	

Groyne B5

Location West Runton **Groyne No.** B5	
Start / Finish NG Co-ordinates **Root** **Easting:** 618279 618285 **Northing:** 343217 343286 **Length:** 70m	**Survey Date:** April/May 2004
Management Unit: RUN2	**Defence Length Reference:** 01
Conditions and Performance of Groyne **Type:** Timber **Built:** 1976 **Refurbished:** **Defence Condition Rating:** Good **Updates to CPSE (1997):** **Comment:**	

Plate 5.1 Groyne B3 Seaward End

Plate 5.2 Cliffs at groyne B2

5.3.2 Defence Length RUN 2.02 – West Runton Gap (Old Woman Hithe)

Location: **Old Woman Hithe (West Runton Gap)**

Start / Finish NG Co-ordinates

	Start	Finish
Easting:	618545	618666
Northing:	343182	343117
Length:	137m	

Survey Date: April 2004

Management Unit: RUN2

Defence Length Reference: 02

<u>Description of Defences and Beach</u>

Concrete access ramp protected by concrete walls with steel sheet pile toe on the flanks. Sand, shingle and cobble beach on chalk platform.

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Extensive areas of chalk platform exposure. Eroding and no longer presents the consistently sandy beach the location was well known for.

Control Structures

Groyne B6

<u>Conditions and Performance of Backshore Defences</u>

Type: **Built:** 1976 **Refurbished:**

Description: Concrete ramp in serviceable condition. Flanking walls showing minor joint defects. Outflanking an issue to be resolved.

Defence Condition Rating: Good

Updates to CPSE (1997):

<u>Description of Hinterland and Development</u>

Mainly rural area with agricultural land on top of the cliffs, the village of West Runton is set back from the cliffs. Access to the beach is for fishermen and amenity use. This area includes part of West Runton Cliffs SSSI.

<u>Photograph Log</u>

Ref. No.	Description of View
A10	Gabions at eastern flank
A13	View along East wall

Cause and Consequence of Failure

Likely Failure Mechanism: Loss of beach resulting in steel pile failure or cliff failure

Consequence of Failure: Loss of important access for fishermen, amenity and maintenance. Loss of locally important sewerage pumping station with consequent pollution, in turn leading to serious threat to the Blue Flag status of adjoining resorts.

Groyne B6

Location **West Runton Gap**

Groyne No. **B6**

Start / Finish NG Co-ordinates			**Survey Date:**
	Root		April/May 2004
Easting:	618584	618468	
Northing:	343199	343244	
Length:	79m		

Management Unit: RUN2 **Defence Length Reference:** 02

Conditions and Performance of Groyne

Type: Timber **Built:** 1976 **Refurbished:**

Defence Condition Rating: Good

Updates to CPSE (1997):

Comment:

Since the completion of the condition survey in 2004, North Norfolk District Council (NNDC) has built an additional ramp onto the beach at the eastern side of the gap. The construction of this ramp, which is designed to facilitate beach access at low beach levels, provides additional protection against outflanking in the short to medium term.

The addition of this ramp has not improved the assessed condition rating of the defences here.

Plate 5.3 Gabions at eastern flank

Plate 5.4 View along east wall

Plate 5.5 View of new ramp at eastern side of the gap

5.3.3 Defence Length RUN2.03 – Runtons

Location: **Runtons**

Start / Finish NG Co-ordinates			**Survey Date:**
	Start	**Finish**	
Easting:	618666	620073	
Northing:	343117	342799	
Length:	1442m		
Management Unit: RUN2			**Defence Length Reference:** 03

Description of Defences and Beach

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Extensive areas of chalk platform exposure. Eroding and no longer presents the consistently sandy beach the location was well known for leaving the base of the cliffs undefended.

Control Structures

None

Conditions and Performance of Backshore Defences

Type: **Built:** **Refurbished:**

Description:

Defence Condition Rating:

Updates to CPSE (1997):

Description of Hinterland and Development

This area is predominantly rural, it contains parts of both East and West Runton SSSI's. Although land use is mainly agricultural, there are a few residential properties with a couple of Bed and Breakfasts and mobile home sites. There is a long sea treated effluent outfall within the area.

Photograph Log

Ref. No.	Description of View
E03	Beach looking west

Cause and Consequence of Failure

Likely Failure Mechanism:

Consequence of Failure:

Plate 5.6 Beach looking west

5.3.4 Defence Length RUN2.04 – East Runton Gap

Location: **East Runton Gap**

Start / Finish NG Co-ordinates	Start	Finish	Survey Date: May 2004
Easting:	620073	620176	
Northing:	342799	342751	
Length:	114m		

Management Unit: RUN2 | **Defence Length Reference:** 04

Description of Defences and Beach

Concrete ramp and steps to beach protected by flanking concrete sea walls. Sandy beach

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Shallow sandy beach in good condition.

Control Structures

None

Conditions and Performance of Backshore Defences

Type: **Built:** 1930 **Refurbished:**

Description: Concrete walls with extensive cracking. Failed at the centre of the western wall and the end of the eastern flank wall.

Defence Condition Rating: Very poor

Updates to CPSE (1997):

Description of Hinterland and Development

Urban area, residential properties in East Runton are close to the frontage. There are a number of Bed and Breakfasts and a few commercial properties. The area between the residential properties and the cliffs is filled with mobile home sites for holiday visitors. Access to the beach for fishermen and amenity use. Part of East Runton Cliffs SSSI.

Photograph Log

Ref. No.	Description of View
C17	Failure of end of West wall
C33	General view of East wall

Cause and Consequence of Failure

Likely Failure Mechanism: The walls to either side of the access ramp have already failed, the west wall failed by overturning due to low sea levels and the eastern end of the east wall collapsed due fill being washed away. Following these failures the cliffs behind are open to attacks from the sea, resulting in instability, slips and erosion. The existing failures will propagate and eventually the access ramp will be at risk of structural damage.

Consequence of Failure: Loss of important access

As noted in the Section 5.2, the west wall failed through overturning, due to low beach levels, during a storm early in 2005. At the same time, there were further failures of the east wall. The failed wall sections were subsequently demolished.

In 2006, the east wall was reconstructed in part and stabilised with the addition of a steel pile toe and concrete apron. Rock armour has been used to protect against outflanking. The west wall was completely demolished and replaced with rock armour. The work of rehabilitating the defences here took place concurrently with the extension of the concrete ramp, to take account of falling beach levels and other local improvements. Following completion of the rehabilitation works, the assessed condition rating is very good. See the updated defence condition survey below.

5.3.5 Residual Life

The following table shows the minimum, most likely and maximum assessments of the residual life of the flanking sea walls.

Defence Length	Minimum (years)	Likely (years)	Maximum (years)
RUN2.04	20	40	50

Location: **East Runton Gap**

Start / Finish NG Co-ordinates

	Start	Finish
Easting:	620073	620176
Northing:	342799	342751
Length:	114m	

Survey Date: November 2006

Management Unit: RUN2

Defence Length Reference: 04

Description of Defences and Beach

Concrete ramp and steps to beach protected on the east by a rock armour revetment and a concrete wall to the west. Sandy beach

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Shallow sandy beach in good condition.

Control Structures

None

Conditions and Performance of Backshore Defences

Type: **Built:** 1930 **Refurbished:** 2006

Description: East: Rock armour revetment in very good condition. West: Concrete seawall with steel pile scour protection, Rock armour against cliff as protection against outflanking.

Defence Condition Rating: Very good

Updates to CPSE (1997):

Description of Hinterland and Development

Urban. Band B. Access to the beach for fishermen and amenity use. Part of East Runton Cliffs SSSI. Mobile home sites and residential usage.

Cause and Consequence of Failure

Likely Failure Mechanism: Cliff failure causing instability.

Consequence of Failure: Loss of important access

Plate 5.7 Failure of end of west wall

Plate 5.8 View of the failure in east wall

Plate 5.9 View of rock armour revetment, east flank

Plate 5.10 Rock armour revetment, east flank

Plate 5.11 Sea wall and rock armour outflanking revetment, west flank

Plate 5.12 Sea wall, west flank

Plate 5.13 View from west flank wall

5.3.6 Defence Length RUN2.05 – East Runton/ Cromer

Location: **East Runton/Cromer**

Start / Finish NG Co-ordinates			Survey Date:
	Start	**Finish**	
Easting:	620176	621255	
Northing:	342751	342494	
Length:	1081m		

Management Unit: RUN2 | **Defence Length Reference:** 05

Description of Defences and Beach

Undefended. Sandy beach with exposed platform always showing east of East Runton Gap

Defences maintained by: North Norfolk District Council

Condition and Performance of Beach

Shallow slope, good condition

Control Structures

None

Conditions and Performance of Backshore Defences

Type: **Built:** **Refurbished:**

Description:

Defence Condition Rating:

Updates to CPSE (1997):

Description of Hinterland and Development

Semi urban on the west flank of Cromer. A few residential properties and a couple of Bed and Breakfasts. Mobile home sites and public open space. Part of East Runton Cliffs SSSI.

Photograph Log

Ref. No.	Description of View
E02	Beach looking east towards Cromer

Cause and Consequence of Failure

Likely Failure Mechanism:

Consequence of Failure:

Plate 5.14 Beach looking towards Cromer

Appendix

Appendix List of photos of defence lengths

Defence Length MU1/CU1.01 – Muckleburgh

Photograph Log	
Ref. No.	**Description of View**
E05*	View along beach to west
E06	Ditto
E07	Ditto
E06 E07	Perspective view
E08 to E10	View to east

* Photo inserted in report

Defence Length MU1/CU1.02 – Weybourne

Photograph Log	
Ref. No.	**Description of View**
E11	View to east
E12*	Ditto
E13	View to west
E14	Ditto
E15	Ditto

* Photo inserted in report

Defence Length RUN 1.01 – Sheringham

Photograph Log	
Ref. No.	**Description of View**
B01	General view looking west.
B02*	Groyne A1
B03	Groyne A1
B04	Groyne A2
B05	Sea wall
B06*	Seawall
B07	Rear of boat shed
B08	RNLI ramp

* Photo inserted in report

Defence Length RUN 1.02 – Sheringham

Photograph Log

Ref. No.	Description of View
B09*	Groyne A3
B10	Groyne A3
B11	Groyne A3
B12	Groyne A3 inshore end showing shingle gates
B13	Groyne A3
D02	Seawall
D03	Seawall
D04	Seawall (Crib wall behind)
D05*	Seawall and steps
D11	Crib/grass wall
D12	Promenade
D13	Crib wall turning bay
D14	Retaining wall behind promenade

* Photo inserted in report

Defence Length RUN 1.03 – Sheringham

Photograph Log

Ref. No.	Description of View
B14	Groyne A4
B15*	Groyne A4 inshore end note shingle gates
B16	Groyne A4 seaward end
B17	Groyne A4
B18	Groyne A5 seaward end
B19	Groyne A5
B20	Groyne A5
B21	Groyne A6
B22	Groyne A6
B23	Groyne A6 seaward end
B24	Groyne A7 seaward end
B25	Groyne A7
D01	General view looking east along beach
D06	Seawall
D07	Seawall
D08*	Seawall
D09	Seawall
D10	Seawall
D15	Retaining wall rear of promenade
D16	Promenade
D17	Promenade
D18	Maintained grass slope rear of promenade
D19	Seawall adjacent to derelict groyne
D20	Upcher seawall plaque (1895)
D21	Seawall
D22	Seawall
D23	Seawall
D24	Seawall
D25	Promenade
D26	Concrete at base of steps

* Photo inserted in report

Defence Length RUN 1.04 – Sheringham

Photograph Log

Ref. No.	Description of View
B26	Groyne A8
B27	Groyne A8 inshore end
B28*	Ditto
D27	Admiralty slip
D28	Refurbished seawall
D29	General view looking east
D30	Groyne A9
D31*	Rock revetment adjacent to groyne A9
D32	Seawall
D33	Retaining wall "Splash Corner"

* Photo inserted in report

Defence Length RUN 1.05 – Sheringham

Photograph Log

Ref. No.	Description of View
D34	Rock revetment at The Mo
D35	Rear retaining wall
D36	Ditto
D37	Crack/joint in rear wall
D38	Ditto
D39	Groyne A10
D40	Buttress – rear retaining wall
D41	Ditto
D42	Ditto
D43	Rear wall drainage inspection chamber
D44	Rear wall
D45	General view looking west
D46	General view looking east
D47	Rear wall drainage inspection chamber
D48	Rear wall note cracking/slight displacement
D49	Groyne A11
D50*	Rear wall/steps @ toilets
D51*	General view – rock revetment
D52	Cliff damage and repair
D53	Concrete damage
D54	Groyne A12
D55	General view to west

* Photo inserted in report

Defence Length RUN 1.06 – Sheringham

Photograph Log	
Ref. No.	**Description of View**
A90*	Looking east along line of seawall
A91*	Base of seawall

* Photo inserted in report

Defence Length RUN 1.07 – Sheringham

Photograph Log	
Ref. No.	**Description of View**
A68	Base of seawall looking west
A70	Rear of seawall
A71	Groyne A15
A72*	Base of seawall
A73	Ditto
A74	Root of groyne A14
A75	Groyne A14
A76	Ditto
A77	Ditto
A78	Rear of seawall looking east
A79	Rear of seawall looking west
A80*	Seaward end groyne A14
A81	Groyne A14
A82	Groyne A13
A83	Groyne A13
A84	Groyne A13
A85	Root of groyne A13
A86	ditto
A87	Seawall
A88	Base of seawall
A89	Crest of wall looking east

* Photo inserted in report

Defence Length RUN 1.08 – Sheringham

Photograph Log	
Ref. No.	**Description of View**
A51*	Derelict revetment at transition
A52	Derelict revetment
A53	Revetment steel sheet pile toe
A54	Concrete base to revetment
A55	Ditto
A56	Root of groyne B1
A57	View behind revetment
A58	Ditto
A59*	Root of groyne B1
A60	Groyne B1
A61	General view of revetment
A62	Seaward end groyne B1
A63	Detail groyne B1
A64	Seaward end groyne A15
A65	Groyne A15
A66	Root groyne A15
A67	Base of revetment with concrete footing
A69	Rear of revetment

* Photo inserted in report

Defence Length RUN2.01 – West Runton

Photograph Log	
Ref. No.	**Description of View**
A26	Timber revetment looking west from West Runton Gap
A27	General view of revetment
A28	Ditto
A29	Groyne B5 seaward end
A30	Ditto
A31	Groyne B5
A32	Groyne B5
A33	General view of revetment
A34*	Derelict revetment
A35	Root of groyne B4
A36	Groyne B4
A37	Groyne B4 seaward end
A38	Groyne B4
A39	Derelict revetment
A40	Steel piles at base of revetment
A41	Root of groyne B3
A42	Groyne B3
A43*	Groyne B3 seaward end
A44	General view of revetment
A45	Root of groyne B2
A46	Groyne B2
A47	Seaward end of groyne B2
A48*	Cliffs at groyne B2
A49	Ditto
A50	General view of revetment

* Photo inserted in report

Defence Length RUN2.02 – Old Woman Hithe (West Runton Gap)

Photograph Log

Ref. No.	Description of View
A01	Groyne B6 seaward end
A02	Groyne B6
A03	General view of Groyne B6
A04	Groyne B6 seaward end
A05	Edge of ramp
A07	Base of timber revetment
A09	General view of ramp and groyne
A10*	Gabions at eastern flank
A11	Eastern end of flank wall
A12	Ditto
A13*	View along East wall
A14	Steel sheet pile footing to East wall
A15	Joint in East wall
A16	View along East wall
A17	Joint in East wall
A18	Rear of East wall
A19	Rear of East wall showing outflanking
A20	General view of ramp
A21	Ditto
A22	Surface water drain outfall on ramp
A23	West wall
A24	Steel pile footings to West wall
A25	West wall

* Photo inserted in report

Defence Length RUN2.03 – Runtons

Photograph Log

Ref. No.	Description of View
E03*	Beach looking west
E04	Ditto

* Photo inserted in report

Defence Length RUN2.04 – East Runton Gap

Photograph Log

Ref. No.	Description of View
C01	Beach to west of Gap
C02	Concrete debris at end of East wall
C03	East wall
C04	Cracks in East wall
C05	View along East wall
C06	Cracks in East wall
C07	Crack close up
C08	Cracks in East wall
C09	Joint in East wall
C10	West wall at ramp
C11	Crack in West wall
C12	West wall
C13	Crack in West wall
C14	End of West wall
C15	Crack at failure at end of West Wall
C16	Failure of end of West wall
C17*	Ditto
C18	Ditto
C19	Beach from West wall
C20	Failure at rear of West wall
C21	Along crest of West wall
C22	Ditto showing cliff slump
C23	Crest of East wall
C24	Ramp
C25	Ramp
C26	Steps down to East wall
C27	View of West wall
C28	General view of ramp
C29	General view of ramp
C30	General view of ramp
C31	General view of ramp
C32	General view of ramp
C33*	General view of East wall
C34	Beach in front of East wall
C35	Gabions at junction of ramp and West wall
04061*	East flank: Rock armour revetment
04062*	East flank: Rock armour revetment
04063*	West flank: Sea wall and rock armour outflanking revetment
04064*	West flank: Sea wall
04065*	View from west flank wall

* Photo inserted in report

Defence Length RUN2.05 – East Runton / Cromer

Photograph Log	
Ref. No.	**Description of View**
E01	Beach looking east towards Cromer
E02*	Ditto

* Photo inserted in report

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EX 4985

Kelling to Cromer Strategy Study

Economic evaluation

Report EX 4985
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Summary

Kelling to Cromer Strategy Study

Economic Evaluation

Report EX 4985
November 2006

This report outlines the assumptions made regarding asset valuation, the likely impact of these assumptions, and the data sources that support these assumptions.

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Appendix Property Valuation

1. Introduction

1.1 BACKGROUND

The study area consists of soft cliffs, primarily composed of sand and gravel. Land use is predominately recreational and agricultural in nature, but includes the town of Sheringham. In Sheringham, coastal defence is provided by seawalls and groynes most of which were renewed in 1995. For the Management Units along this frontage, coastal erosion is an issue of primary importance, and the erosion rate is highly dependent upon management options adopted for adjacent Units. Thus, the methodology adopted to distil the potential economic loss and attribute that potential loss to a given management scenario is therefore necessarily complex and non-standard.

The methodology and calculations presented in this report are based on the DEFRA guidance published in 'FCDPAG3 – Flood and Coastal Defence Project Appraisal Guidance – Economic Appraisal' (MAFF 1999). MAFF (1993) sets out the principles of economic appraisal to establish the worthwhileness of any scheme.

This report was drafted in 2004 and the information contained is correct to that time. For the current issue, minor revisions have been undertaken. The monetary values quoted are correct at 2004 and have not been altered to 2006; however, updated values in line with the RPI and other relevant indices have been allowed for in the Do Nothing report and the Option Appraisal and Strategy Recommendations report.

1.2 OUTLINE OF REPORT

The report is outlines the assumptions made regarding asset valuation, the likely impact of these assumptions, and the data sources that support these assumptions.

2. Sources of economic data and assumptions

Assumptions and asset types within the study area fall into nine main categories:

- Selected base date
- Appraisal period
- Discount rate
- Residential property
- Transportation
- Agricultural land and production
- Commercial activities
- Recreation
- Environmental interests.

The evaluation of these assets is discussed below together with the underpinning assumptions.

2.1 BASE DATE

All costs and benefits have been converted to a Present Value (PV) assuming a base date of March 2004.

2.2 APPRAISAL PERIOD

An appraisal period of 100 years has been assumed.

2.3 DISCOUNT RATE

Test discount rates of 3.5% for years 0-30, 3.0% for years 31-75, and 2.5% thereafter have been adopted.

2.4 RESIDENTIAL AND COMERCIAL PROPERTIES

With over 1,100 properties sited within 200m of the cliff top, the potential damage to property from coastal erosion and cliff slides is large. The evaluation of these losses has been based on the following data:

- **Number of properties at risk –** Across the study area the number and location of properties has been obtained from digital OS Maps.

- **Property values – Write-off values –** The value of each property near the cliff top in the principal coastal settlements has been obtained through property valuations conducted by Keys Auctioneers and Estate Agents (March 2004), as given here in Appendix A. These values relate to the individual survey dates for the towns under consideration. The study area has many hotels, restaurants, and amenities; where relevant a value for the actual properties has been evaluated, however this does not include the potential cost of loss of business.

- **Future development –** Given the intensive tourism and recreational uses of the coastline here, there are will inevitably be development pressures in various locations along the frontage. Although it is impossible to consider future developments that may or may not happen, the economic evaluation presented should be updated in future to reflect any changes, and the options proposed should be sufficiently flexible to accommodate such change.

2.5 TRANSPORTATION

2.5.1 *Roads*

The main coastal road linking the principal coastal towns is the B1159. Norfolk County Council (NCC), the local highway authority, does not have a detailed analysis of traffic flows using the A149 through the study area. On the advice of NCC, annual traffic count figures for the A149 at Morston can be taken as representative of traffic on the A149. For the year 2003, the annual traffic count gave 2199 vehicles per day. The NCC five-year average is 2032 vehicles per day and the annual growth rate is predicted to be 3.7%. The A149 is not considered to be at risk during the study period.

2.6 SEWERAGE

2.6.1 *Overview*

Sewage from the communities of Sheringham, East and West Runton is pumped in a system of mains for treatment at a plant on the outskirts of Cromer. After treatment, the effluent is pumped to a long sea outfall, 2km in length, located just to the east of West Runton Gap where it is discharged into the North Sea. At the core of the system are the pumping stations and storm tanks that are located very close to the sites of the original short sea outfalls in each of the communities. Weybourne is an exception to this where a small local treatment facility was replaced with a pumping station.

2.6.2 *Pumping stations*

Sheringham: There is a storm tank and pumping station located under the amenity building at The Mo. The 3000 m^3 storm tank was built within a 25 metre diameter segmental shaft with the control and odour control equipment sited in the amenity building. The pumping station also has an emergency generator; located on what is known locally as the Tank (root of groyne A10) which itself was once the site of the town's short sea sewage outfall. The tank and associated sewers intercept all of the sewage that once discharged into the sea.

This terminal pumping station will be lost if the seawall fails. Given the topography of the town and the very high density of buildings, the facility cannot be simply moved inland away from the threat of erosion. Given the complexity of the town's sewerage system, the layout of the town and topography, the identification of the least cost replacement scheme would require a detailed study. The hypothetical least cost replacement scheme is likely to involve the provision of a major pumping facility and rising main located 100 metres inland. This would be slightly smaller in size to the existing facility but would, in addition, require the purchase and demolition of a large number of dwellings to create the site. An additional pumping facility would be built at the site of the existing 3,500 m^3 attenuation tank at the top of Beach Road. Together with a rising main to link it to the main transferring flows to treatment at Cromer. The estimated cost of this least cost replacement scheme is given in Table 2.1 below.

West Runton: The community here is served by a 364 m^3 storm tank and underground pumping station located adjacent to the road through the gap. Again, this tank intercepts all of the community's sewage at the site of what was once a short sea outfall and there is no existing alternative facility. As the pumping station and storm tank is remote from the community, it can be replaced by a similar facility inland with associated rerouting of sewers and pumping mains.

East Runton: The community here is served by a 295 m^3 storm tank and pumping station located under the toilet building in the public car park behind the gap. The building also houses the pumping station's controls and odour control equipment. Again, this tank intercepts all of the community's sewage at the site of what was once a short sea outfall and there is no alternative to this station. A replacement will involve the building of a similar sized pumping station inland, south of the A149, with diverted sewers and a diverted pumping main.

Table 2.1 Sewerage Replacement Costs

Sewerage – Least Cost Replacement Schemes (March 2004)	
Sheringham	£5,311,385
West Runton	£156,993
East Runton	£386,333

2.7 COMMERCIAL ACTIVITIES

Within the study area, there are no significant commercial activities apart from agriculture and tourism.

2.7.1 Manufacturing and distribution

There are no economically significant manufacturing or distribution businesses within the study area.

2.7.2 Commercial fishery activities

Both full time and part time inshore fishing boats operate from the beaches of Weybourne, Sheringham, West Runton and East Runton. The numbers of active boats are as follows;

Location	Number of Full-Time Boats	Number of Part-Time Boats
Weybourne	3	2
Sheringham	7	9
West Runton	3	2
East Runton	6	2

It is considered that the fishermen operating off the beaches at Weybourne, West Runton and East Runton will not be affected by ongoing erosion at those locations. As the resource used by the fishermen, the boats, will not be damaged and they can continue to operate, only a transfer payment is involved. The situation at Sheringham is slightly different in that the fishermen can only launch there using purpose built ramps. Hence, whilst the resource, the boats, can arguably relocate to another beach thereby only generating a transfer payment, the resources lost due to erosion are the two ramps and associated facilities. In the do-nothing option, the ramps would be periodically reconstructed in the 100 year study period with some degree of protection against damage by the sea. The least cost replacement value for each launch ramp is estimated to be £45,000.

2.7.3 Tourism

The tourist industry is extremely important to the economy of North Norfolk. The following points have been taken from a document prepared by the East of England Tourist Board for NNDC in 2001. The statistics give a very good indication of the significance of the tourist trade and the importance of the tourism infrastructure.

- The overall value of tourism to North Norfolk District in 1999 was an estimated £186.4 million.
- Of this, approximately £101.3 million (i.e. 54%) was generated by staying visitors and approximately £85.1 million (i.e. 46%) was generated by day visitors.
- In terms of staying visitors, there were approximately 844,000 trips, accounting for approximately 3.9 million nights and £101.3 million expenditure.
- In terms of day visitors, there were approximately 4.1 million tourist trips generating £85.1 million of expenditure.
- This expenditure supported an estimated 4,160 full time job equivalents (FTEs). Of these:
  - 68% were supported by direct expenditure, 23% by linkage (or indirect) expenditure and the remainder by multiplier expenditure
  - 40% were in the catering sector, 28% in accommodation and 14% in the attractions/entertainment sector. The remaining jobs were in the retail and transport sectors (13% and 5% respectively)
- When part time and seasonal jobs are considered, tourism expenditure in North Norfolk District supports a total of 5,690 actual jobs.

2.8 MINISTRY OF DEFENCE PROPERTY

2.8.1 Weybourne Camp: RAF Neatishead

The RAF maintains a small site at Weybourne, once used as a radar station but now used primarily as a camp for RAF cadets. The secure site is also the location of some very sensitive air quality monitoring equipment owned and maintained by the University of East Anglia (UEA). Apart from the UEA equipment and old military buildings, there is nothing at the site of any significant value

2.9 RNLI

2.9.1 RNLI Sheringham

The RNLI maintain an inshore lifeboat station at the western end of the promenade at Sheringham. The facilities there include a launch ramp, tractor shed, lifeboat shed with associated facilities, protection against damage by the sea (a sea wall) and a retaining wall supporting the cliff. Presently, access to the station is gained along the promenade that would be lost in the do-nothing scenario. The least cost replacement value of the lifeboat station is estimated to be £800,000, which includes the replacement of all existing facilities and permanent access to the replacement site down the cliff.

2.10 NATURE CONSERVATION

2.10.1 Environmental Assets

The study area is particularly rich in environmental assets including:

- Weybourne Cliffs SSSI

- Beeston Cliffs SSSI
- West Runton Cliffs SSSI
- East Runton Cliffs SSSI
- Kelling County Wildlife site
- Weybourne County Wildlife Site
- East Runton to Overstrand County Wildlife Site (Cliff and beach between East Runton SSSI and Overstrand Cliffs SSSI).

The study area with the exception of Sheringham is also part of an Area of Outstanding Natural Beauty which, together with the above designated sites, forms an area of high existence value.

2.10.2 Lower Bound Economic Value

In the DEFRA guidance note on Economic Appraisal (FCDPAG3) it is stated that the least contentious and lowest cost of deriving a proxy for the lower bound economic value of an environmental or heritage asset gained or lost as a result of a flood or coastal defence scheme can be taken to be the lowest of:

- the cost of creating a similar site elsewhere of equivalent environmental value
- the cost of relocating to another site (e.g. historic buildings or relocation of specially protected species)
- the cost of local protection.

This proxy approach has been adopted, where appropriate, in estimating the economic value of the environmental assets listed in 2.11.1 above.

2.10.3 Sites of Special Scientific Interest

All four of the SSSI in the study area have been designated in whole or in part because of their geological features which rely on continuing erosion to refresh the geological interest. In this respect, the use of a proxy value is not appropriate as the sites cannot be relocated nor protected. FCDPAG3, Section 4.2.2 suggests that in such cases, it may be necessary to obtain a valuation using other monetary based techniques such as contingent valuation. However, it is felt that the economic value of the SSSI, if determined, is unlikely to affect the result of any benefit cost analysis within the study area. Hence, it is not proposed to do a contingent valuation and no economic value has been estimated for the four SSSI.

2.10.4 County Wildlife Sites

The East Runton Cliffs to Overstrand cliffs County Wildlife Site (CWS) embraces a mixture of open eroding coast and, at Cromer, a defended frontage. Only the open coast section lies within the study area. The effect of this CWS is to extend the habitat protection offered by the flanking SSSI. As it is a coastal site, with eroding beach and cliff, it is not possible to relocate or reproduce it elsewhere. Hence, it cannot be assigned a proxy economic value.

The Kelling and Weybourne County Wildlife Sites differ in that they are shallow, swampy brackish pools offering a mixed habitat. These habitats, although unique, can plausibly be recreated elsewhere. The lower bound economic value for the sites includes the cost of land purchase, engineering works, planting and short term maintenance. The economic value does not include long-term maintenance nor management as these are continuing expenditure and are regarded as transfer costs. The lower bound economic value of these two CWS is given below.

County Wildlife Site	Lower Bound Economic Value
Kelling	£355,494
Weybourne	£163,318

2.11 AGRICULTURE

2.11.1 Agricultural production

The economic losses associated with the potential erosion of this land can be considered to be equivalent to land abandoned or lost for agricultural purposes for the foreseeable future. In this scenario, the value of the loss is assumed to be the risk-free market value of the land multiplied by a factor of 0.45. This factor reflects the inflated price of agricultural land resulting from Government subsidy (Annex G, PAGN 1993).

Based on the September 2003 DEFRA survey of land values for the eastern region (DEFRA 2003) the average risk-market value of agricultural land is £7,361/ha (2002).

2.12 RECREATION AND AMENITY

In addition to the recreational sports it supports, the study area has high amenity value in terms of its tourist attractions, tourist accommodation, cliffs, beaches, and promenades. Based on the baseline review, the principal recreational facilities and their importance (as determined by visitor numbers) are presented in Table 2.10.

At a strategic level, it is not appropriate to devote considerable effort towards establishing reliable economic values resulting from the loss of recreational resources. As demonstrated in Table 2.2 the study area is subjectively, and in certain areas demonstrably, of high recreational and amenity value.

The approximate tourist numbers given above and discussions with North Norfolk District Council indicate that a conservative (i.e. low) assessment of the total numbers of tourists visiting the North Norfolk area for recreation is of the order of 4,100,000 day visitors and 844,000 staying visitors. As shown in Table 2.2, 860,000 day visitors, 21% of the total number of day visitors, visit the coast for recreation and amenity purposes. The equivalent number of staying visitors, assuming that 21% of the staying visitors visit the coast, is 177,240. These visitors are primarily attracted to the sandy beaches the North Norfolk area offers. No statistics are available to quantify local visitors. However, an analysis of the very limited information available on car parking suggests that the study area receives 169,500 day visitors. Again assuming that a similar proportion of staying visitors go to the coast, the equivalent number is 35,000.

Using standard values presented in The Yellow Manual (MUFHRC 1990) (updated to March 2004) loss of this amenity in the study area would jeopardise an annual benefit of £641,420 in respect of day visitors and £310,670 in respect of staying visitors, totalling a loss of £952,090. Whilst it is accepted that these standard values tend to be rather high, it is indicative of the importance of recreation activities to the study area. Assuming the lower figure to be correct, an annual recreational benefit of £952,090 would yield a Present Value discounted over one hundred years of over £28.38 million. Without scheme specific Contingent Valuation Survey it is difficult to attribute these benefits to particular areas. Therefore, these benefits have been assumed to apply at a study wide scale.

Table 2.2 Key recreational and amenity resources – Day Visitors

Recreational Asset	Visitor numbers (x 1000)
City/Town	1,251
Coastal	860
Countryside	1,989
Total	4,100

2.12.1 Golf Courses

The Sheringham golf course is located in the western portion of the study area, to the west of Sheringham. This has significant local importance, attracting tourists and employing staff. A site specific valuation is not considered appropriate here, however for the purposes of the Strategy the value of the golf club land has been assumed to be five times agricultural value.

2.13 MOBILE HOMES

There are 1140 mobile homes approximately located within the study area distributed both within the study area. The national economic value of these has been estimated as follows.

The economic value associated with erosion of these assets is often considerably less than the risk-free market value as it is reasonable to assume that caravans may be moved to lower risk areas. Therefore, the national economic value of a caravan has been assumed equivalent to the cost of moving it to a new site and establishing the site. It is also the case that caravan parks are depreciating assets and, in accordance with MAFF guidance, should only be considered as worth half their replacement costs. Using this approach the following three items have been considered in estimating the likely damage associated with the write-off of inundation or erosion of a caravan park:

- The value of the land occupied by the caravan (risk-free market value of agricultural land factored by 0.45).
- The cost of removing and transporting each caravan to another hypothetical site.
- The installation of each caravan at that site: assumed 50% of the cost of pouring a concrete slab, fixing the caravan to the slab, and connecting main services.

Based on these considerations the value of each caravan has been estimated as £2000.

The difficulty of relocating large numbers of caravans is a potential problem, and for the purpose of this cost benefit analysis it is assumed that any caravan will be located to a ‘new hypothetical site’ within the study area. However, permanent facilities such as toilet/shower blocks, swimming pools bars, restaurants, etc. cannot be moved and, therefore, the write off costs associated with the permanent facilities has been considered under the Special Park land use category discussed previously.

2.14 HERITAGE

The study area contains many Listed Buildings, Schedule Ancient Monuments and archaeological features. For many of these features, there is a Statutory Duty to protect them.

Table 2.3 below is a listing of all identified heritage features together with their respective gradings.

Table 2.3 Heritage Features

Name	Location	Listed Building Grade	NGR
Barn at Abbey Farm	Weybourne	2	611153,343143
Abbey Farmhouse	Weybourne	2	611153,343153
Weybourne Priory	Weybourne	1	611168,343033
All Saints Church	Weybourne	2*	611168,343033
Old Farm Cottage	Weybourne	2	611234,342851
Weybourne Mill	Weybourne	2	611559,343128
Church of St. Joseph	Sheringham	2	615940,342913
Beeston Priory	Beeston	1	616759,342797
Abbey Farmhouse	Beeston	2	616755,342753
Church of All Saints	Beeston Regis	1	617964,342829
Flint House	East Runton	2	619944,342605
Incleborough House	East Runton	2	619875,342471
Mill	East Runton	2	620057,342296

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Appendix Property Valuation

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