Suffolk Coast and Estuaries

Coastal Habitat Management Plan

Final Report

October 2002

Department for Environment Food and Rural Affairs
Environment Agency
English Nature
Natural Environment Research Council

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PLEASE READ FIRST

Foreword to the Suffolk Coastal Habitat Management Plan (CHaMP)

This is one of seven pilots prepared as part of the *Living with the Sea LIFE Nature Project.* It has been developed as a pilot for the interim CHaMP guidance, which was the first output of the *Living with the Sea* project. Lessons learnt during completion of this document have helped develop the finalised CHaMP guidance, to be issued by Defra in 2003.

This CHaMP provides the first truly long-term evaluation of the implications of the Habitats Regulations for flood and coastal defence management policies in the Suffolk area.

This CHaMP places our actions in the context of obligations under the Habitats Regulations, taking account of coastal geomorphology. It does not take decisions, but rather it provides a science based forecast of the next 30 to 100 years of coastal change driven by sea level rise, the forces of nature and our coastal management decisions. It uses best available data in its evaluation and reinforces the importance of further coastal monitoring to better inform future reviews.

It is Defra policy, set out in the guidance to second generation Shoreline Management Plans, that the information provided in this CHaMP must be taken into account when the SMP is revised. This is to help ensure that, as far as possible, the revised SMP complies with the requirements of the Habitats Regulations. However, in doing so you should be aware of the following points:

- The full CHaMP mapped data is available on a separate CD ROM that uses a Geographic Information System. This should be viewed over licensed Ordnance Survey map data.
- Within the constraints of this project it has not been possible to confirm which freshwater coastal habitats can be sustainably protected in-situ. Further site-specific consultation with English Nature will be required during the SMP and strategy stages in combination with engineering and economic factors to confirm these details.
- The forecast habitat losses to sites designated under the Habitats and Birds Directives could be consolidated to provide a programme for compensation habitat in the Suffolk area covering the next 30+ years.
- A detailed schedule of habitat and feature monitoring could be developed to drive strategic monitoring programmes in the Suffolk area.

The *Living with the Sea* Project will be producing summary reports addressing some of the generic areas of further study identified above. It may also be helpful to refer to these when preparing SMPs. CHaMPs in combination with other project outputs such as 'Coastal Habitat Restoration-a Guide to Good Practice' will help us deliver our policies on sustainable coastal defences and habitats.

Stephen Worrall, Project Manager Living with the Sea

CONTENTS

GLOSSARY OF KEY TERMS AND ABBREVIATIONS

Accretion The accumulation of sediment through natural processes

Backshore Area above high water but which can be affected by coastal processes

Bathymetry Level of the seabed

Beach profile Cross section perpendicular to a beach. The profile can extend from any selected point from the backshore or top of the beach into the nearshore

Beach recharge The process of using sediment sourced from elsewhere to replenish or supplement the existing sediment volume of a beach

Breach The failure of a beach or defence structure by wave or tidal action

Coastal Defence The general term applied to coast protection and sea defence

Coast protection Protection of land from erosion by the sea

Community The species that occur together within a habitat in space and time

Downdrift The transport of sediment in the direction of nett longshore drift

Distribution The spatial range of a species, usually on a geographic but sometimes on a smaller scale, or the arrangement or spatial pattern of a species over its habitat

Disturbance In community ecology, an event that removes organisms and opens up space which can be colonised by individuals of the same or different species

Ebb Period over which the tide falls

Ebb tide delta Area of sediment deposition caused by a decrease in velocity of tidal currents where there is interaction with more open nearshore conditions. Typically such deltas form at the mouths of estuaries and restricted channels where they enter the sea

Ecology The study of the interactions of organisms with their physical environment and with one another

Ecosystem All of the organisms of a given area and the encompassing physical environment

Fine sediment (fines) Sediment with a particle diameter <0.063mm

Foreland Backshore area formed by the deposition of sediment which is no longer part of an active coastal process system

Groyne Coastal defence structure constructed perpendicular to the shore and designed to reduce the longshore transport of sediment along a beach

Habitat The environment of an organism and the place where it is usually found

Intertidal Area between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT)

Littoral drift The transport of beach sediment in the littoral zone by waves and currents

Longshore Applied to sediment transport and involving the area immediately adjacent to and parallel with the coastline

Longshore drift The movement of sediment parallel to the shore

Managed realignment The setting back of existing coastal defences in order to achieve environmental, economic and/or engineering benefits. Typically being undertaken in estuarine systems to combat the issue of coastal squeeze

Migration The movement of individuals and commonly whole populations from one area to another

Offshore Area to seaward of nearshore in which the transport of sediment is not caused by wave activity

Overtopping The process where water is carried over the top of an existing defence due to wave activity

Population Any group of individuals, usually of a single species, occupying a given area at the same time

Nearshore Area in which transport of sediment is driven by waves (including storm waves)

Saline lagoon An area of shallow, coastal saline water, wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks

Saltmarsh Saline tolerant vegetation which establishes and grows within the intertidal area

Sand Sediment with a particle diameter between 0.063-2mm

Sea defence Construction engineered to reduce or prevent flooding by the sea

Sea level rise The general term given to the upward trend in mean sea level resulting from a combination of local or regional geological movements and global climate change

Seawall Vertical structure constructed to provide flood and/or erosion protection to a backshore area

Shingle/gravel Sediment with a diameter between 2-75mm

Shingle ridge Feature of the upper beach, comprising built up deposits of shingle often fronting lower lying backshore

Spit Narrow accumulation of sand or shingle generally lying parallel to the coast with one end attached to the land and the other projecting seawards, often formed across the mouth of an estuary

Succession The orderly progression of changes in a community composition that occurs during development of vegetation in any area from initial colonisation to the attainment of the climax typical of a particular geographic area

Updrift Direction opposite to that of longshore transport of beach sediment

Vegetated shingle Plant communities on shingle ranging from pioneer plant species on fringing shingle beaches through to lichen-rich turf to gorse scrub on disturbed or marginal areas and where grazed to a species-rich turf.

BP Before Present
CD Chart Datum
EA Environment Agency
EN English Nature
LAT Lowest Astronomical Tide
MLW Mean Low Water
MHW Mean High Water
SPA Special Protection Area
SAC Special Area of Conservation
SSSI Site of Special Scientific Interest

1 INTRODUCTION

The coastline is a dynamic environment, where habitats and species, under natural conditions and functions, are able to respond to changes in physical processes (e.g. the balance between sediment provision and coastal form). Man's activities, particularly through the construction of coastal defence systems (flood defence and coastal protection) may interfere with and modify physical processes and, hence, the ability of habitats to respond to process change.

The Suffolk coastline and its associated estuaries clearly illustrate this classic cause and effect mechanism and the interaction between man's activities, process modification and habitat response. Significant areas of the Suffolk coastal inter-tidal area, particularly in the southern part of the CHaMP area (e.g. Alde-Ore and Deben estuaries) were subjected to extensive reclamation between the 15th and the 19th Centuries. Integral to this phase of extensive reclamation was the construction of coastal defences in order to protect the fertile agricultural land from flooding. The presence of these man-made defences and the decrease in the width of the estuarine channel (due to reclamation) has constrained the ability of intertidal habitats (notably saltmarsh) to move landward in response to sea-level rise. This inevitably results in habitat loss, the term 'coastal squeeze' has been coined for this effect. As an example of the scale of this change a recent survey by the University of Newcastle for the Environment Agency (University of Newcastle 2001) identified that 93ha of salt marsh from the Suffolk estuaries has been lost in the last 27 years, 80% of this loss due to erosion probably associated with coastal squeeze. With a predicted significant increase in sea-level due to climate change this process is likely to continue, resulting in the loss of greater areas of intertidal habitat.

In some locations habitats protected by man made coastal defences or natural beach systems are designated (under national and international legislation) for the freshwater and terrestrial features that are present (e.g. reedbed habitat at Minsmere, grazing marsh adjoining the Orwell Estuary). Potentially, in situations where internationally designated features are present to seaward and landward of the defences, options to remove coastal defences to enable coastal habitats to migrate landward may lead to direct conflict between the conservation of freshwater (i.e. terrestrial) and coastal designated habitats. This potential conflict between the maintenance of ecological interests either side of artificial boundaries (within an ecological context) is one of the key issues facing the conservation of habitats and species in the coastal environment and represents a significant area of consideration for the CHaMP.

1.1 International Directives

The coastal environment is an extremely important natural resource and supports a wide variety of habitats and species. Many sites around the UK coastline, including Suffolk, support significant assemblages of habitats and species which are recognised for their ecological and nature conservation importance through designation under the European Union Habitats (Council Directive 92/43/EEC) and Birds Directives (Council Directive 79/409/EEC) and the Ramsar International Convention on Wetlands (1971).

The Habitats Directive aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. It sets out measures to maintain or restore natural habitats and species of European Union interest at favourable conservation status. The Birds Directive protects all wild birds and their habitats within the European Union, and there are special measures for migratory birds and those that are considered rare or vulnerable.

Both Directives include requirements for the designation of conservation areas. In the case of the Habitats Directive these are Special Areas of Conservation (SACs) which support certain natural habitats or species, and in the Birds Directive, Special Protection Areas (SPAs) which support wild birds of European Union interest. These sites form a network of conservation areas across the EU known as “Natura 2000”.

Coastal Habitat Management Plans (CHaMPs) form an important link in the coastal planning process for managing European sites of nature conservation importance and Ramsar sites. The objective of this CHaMP is to take a strategic overview of the consequences of long-term (30-100 year) predicted shoreline changes for the Suffolk Coast and Estuaries frontage on designated habitats and species. The CHaMP identifies measures that could be undertaken to ensure that future Shoreline Management Plans (SMPs) and Flood and Coastal Defence Strategies are compliant with the Habitats and Birds Directives. This process is informed using the best available information on coastal defence issues, including that set out in the Lowestoft to Harwich (Subcell 3c) Shoreline Management Plan (SMP), together with the Suffolk Estuarine Strategies and open coast Coastal Defence Strategies (CDSs) that are currently in production.

The primary function of the CHaMP is to:

- To offer a long-term strategic view on the balance of losses and gains to habitats and species of European interest likely to result from sea-level rise, and the flood and coastal defence response to it;
- To develop a response to these losses and gains by setting the strategic direction for the conservation measures that are necessary to offset predicted losses, including the identification of suitable locations for new habitats that may need to be created and the flood and coastal defence works required to maintain protected habitats; and
- Make recommendations to SMPs to ensure flood and coastal defence options address the requirements of the Habitats and Birds Directives.

These plans will therefore contribute to maintaining the coherence of the Natura 2000 and Ramsar site network and provide a basis for the pro-active management of the variety and diversity of existing habitats.

1.2 CHaMP Content and Structure

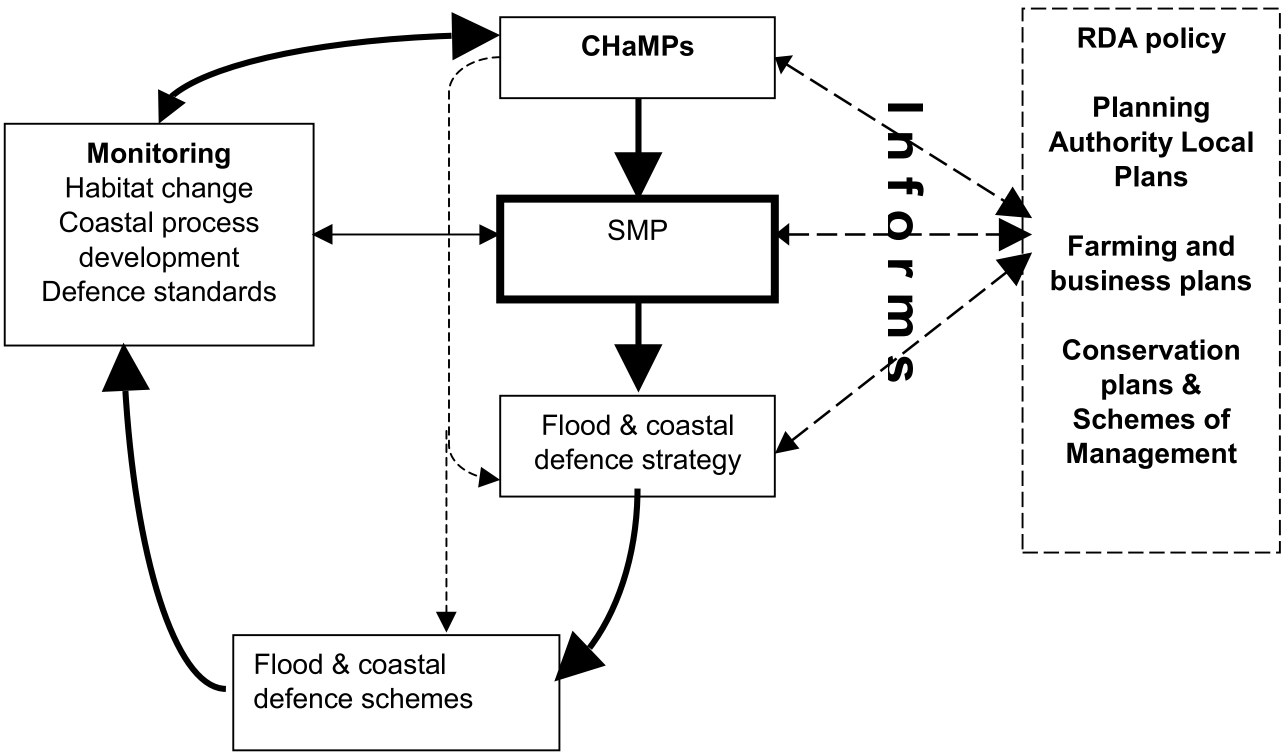
This CHaMP sets out the significance of the European designations and outlines the conservation objectives for the management of the designated interest features occurring in the area. An informed review of coastal process information contained in the relevant SMP, and other information, including strategic plans for flood and coastal defences, available scientific data and expert opinion has been undertaken to predict shoreline change likely to occur over the next 30-100 year period. The geomorphological analysis takes into account predicted climate change and sea level rise over the study period. An assessment has then been undertaken of the balance of European interests likely to be lost or gained (loss/gain accounting) in order to determine the effect of existing coastal defence policy on the integrity of the designated European interest features. Throughout this process, for designated features landward of a sea defence, there is a presumption in favour of maintaining the habitat *in situ*. Where this would be unsustainable (the sustainability of defences is normally considered over the probable design-life of a structure) or would cause damage to other features of conservation interest, the alternative option of habitat creation has been considered.

Where it is apparent that an adverse effect on the ecological integrity of a designated feature would occur, then the CHaMP sets out measures to either avoid an adverse effect or to compensate for it. Such measures include the review and testing of alternative flood and coastal defence options and the development of suitable replacement habitats. It should be appreciated that true coastal habitats cannot be 'protected' *in situ* and that a large element of their ecological interest derives from their dynamic nature. As such it may not always be possible to conserve designated interests in the same location. It must be borne in mind that it is not only important, in these cases, to recreate the habitat elsewhere, it is of paramount importance to ensure that the functionality of the habitat is of equal or greater value than that lost. It is therefore important that the conservation of coastal habitats, such as saltmarsh, shingle and mudflats are considered in the context of enabling all the components of the coastal system to function coherently.

1.3 The Suffolk CHaMP within the Shoreline Management Planning Framework

The CHaMP, once finalised, will be a non-statutory document setting out the best available scientific conclusions, advice and guidance to inform revisions of the Shoreline Management Plan and relevant CDSs. This process is represented graphically in Figure 1.1. It is intended that this CHaMP will focus on the need for the SMP and Suffolk Estuarine Strategies to re-examine preferred strategic defence options, within the CHaMP area, to ensure compliance with the integrity of all designated SAC, SPA and Ramsar features. This process will apply equally to CDSs, both retrospectively in the case of those that have been recently completed and to those that are undertaken in the future.

Figure 1.1 The CHaMP planning cycle



1.4 Area covered by the CHaMP

The Suffolk Coast and Estuaries CHaMP covers the area between Lowestoft in the north and the Stour Estuary in the south (see Figure 1.2). This area includes the following European sites, Ramsar sites and their constituent SSSIs:

- Benacre to Easton Bavents cSAC and SPA;
- Minsmere to Walberswick cSAC; SPA and Ramsar;
- Alde Ore and Butley cSAC;
- Alde Ore Estuary SPA and Ramsar;
- Orfordness to Shingle Street cSAC;
- Deben Estuary SPA and Ramsar; and
- Stour and Orwell Estuaries SPA and Ramsar

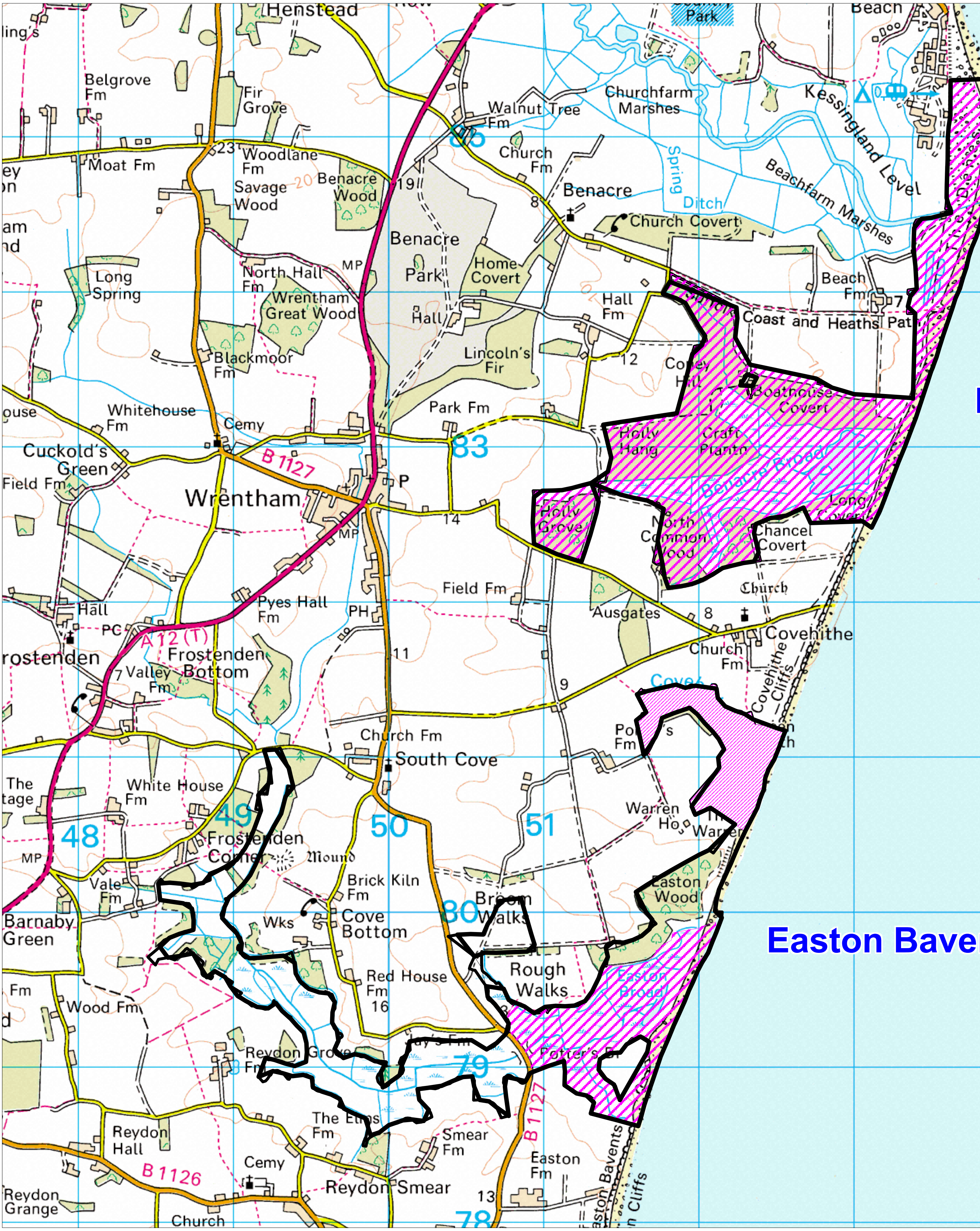
The locations of these SPA, and cSAC designations are shown in Figure 1.2. It should be noted that the boundaries of the Natura 2000 sites are not entirely coincident with the boundaries of the constituent SSSIs, as they have been drawn to include specific features of European interest. Landward components of Natura 2000 sites mostly coincide with SSSI boundaries while subtidal components of the marine SACs lie outside the boundaries of the SSSIs.

To provide comprehensive cover of the designated sites and allow scope for potential habitat mitigation measures, two areas within the CHaMP are identified as follows:

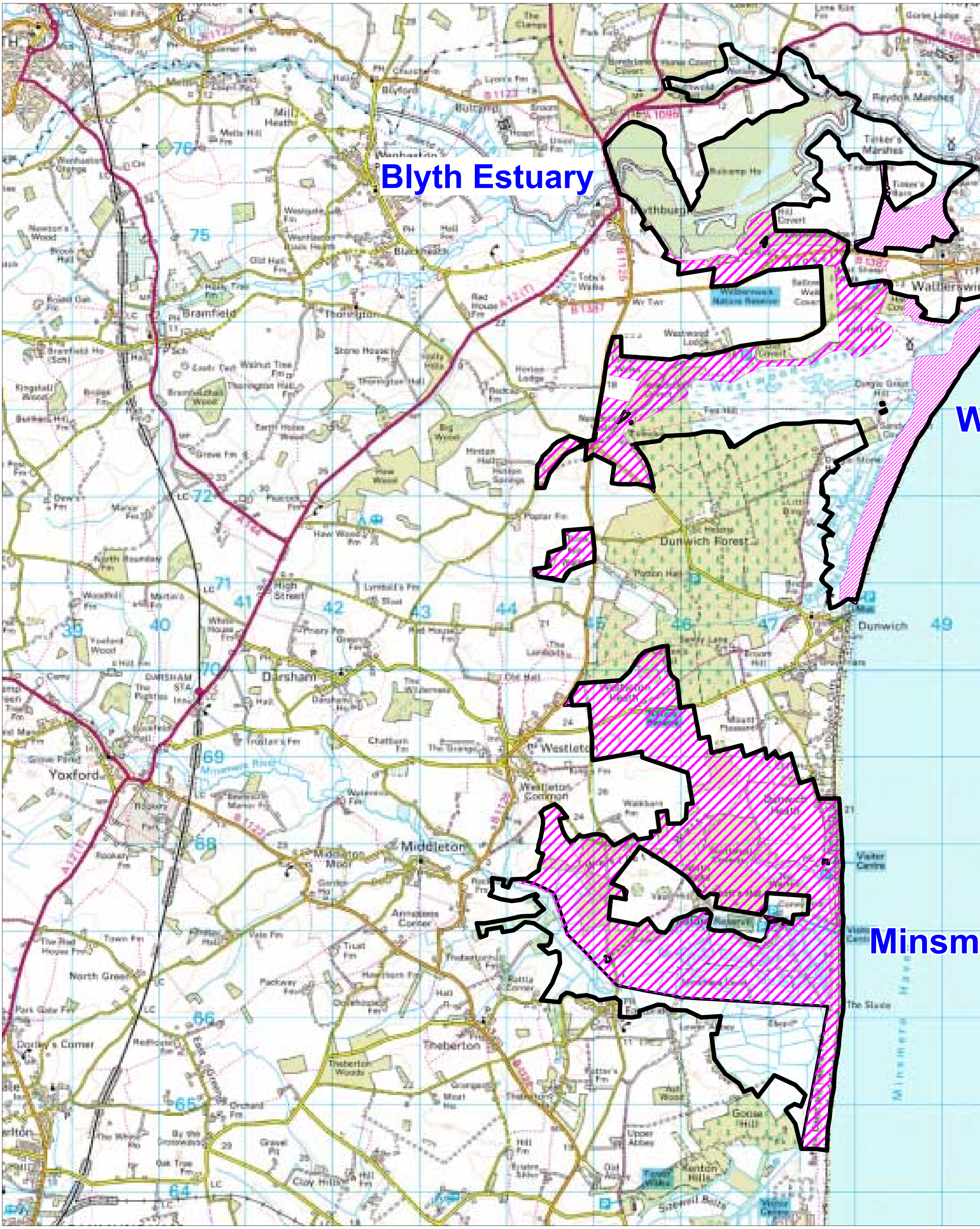
The Core CHaMP area extends from Kessingland in the north to the Stour Estuary to the south. This covers all of the European designated sites within an integrative “site complex” and defines the area within which the detailed assessments of the Plan will be completed. The Plan focuses on the mainland shoreline and seaward to the mean low water of spring tides. It also includes habitats immediately inland or seaward that influence, or are influenced by, the shoreline and its defence (e.g. areas of designated coastal grazing marsh).

In considering the future evolution of the coastline and potential impact on designated habitats and species it is important to ensure that the influence of coastal processes within the wider coastal area is fully taken into account. Clearly, geomorphological and ecological change play an important part in determining the overall areal extent covered by the CHaMP, particularly with respect to potential areas for habitat creation adjacent to or within close proximity to existing European sites. Such sites should not be viewed in isolation and as falling outside the CHaMP area, indeed it is important that such sites are ecologically functional within the wider coastal environment and, as such, need to be considered as part of a CHaMP. Therefore, an **Interactive Envelope** has been defined between Lowestoft and Hamford Water, which forms the northern boundary of the Essex Coast and Estuaries CHaMP area. This wider area comprises the adjoining physical coastal process systems that either interact with or have the potential to be affected by processes within the core CHaMP. It also defines the immediate zone within which compensatory opportunities (i.e. habitat creation) shall be sought in the event that this cannot be undertaken *in situ*, or immediately adjoining the designated habitats.

The aim of this approach is to ensure that attention is focussed upon the key designated sites whilst acknowledging the broader spatial interactions that are critical to the integrity of their sustaining physical and ecological systems.



Project	Title
Suffolk Coast and Estuaries Coastal Habitat Management Plan	**The Designated European Sites Covered by the CHaMP**

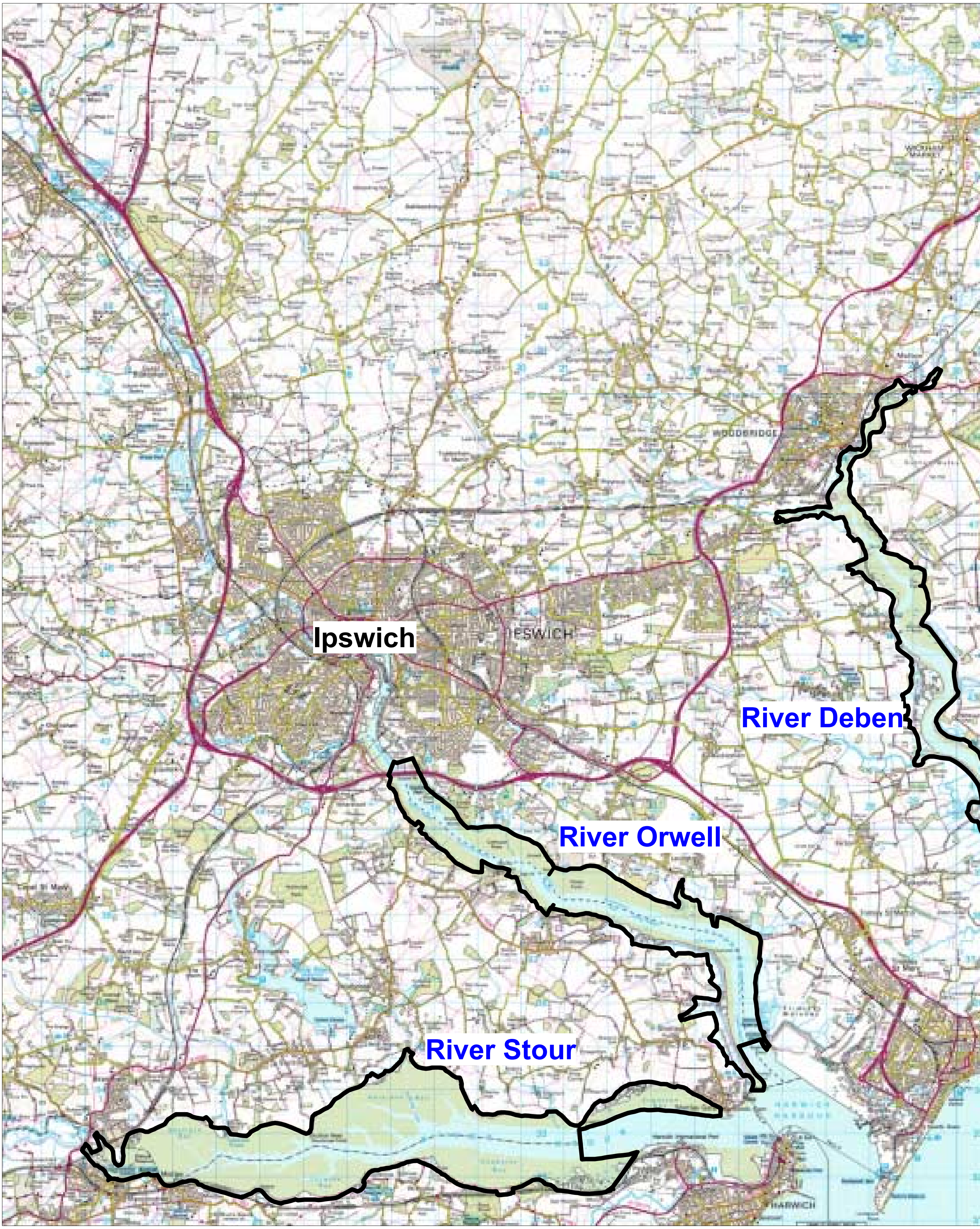


Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

The Designated European Sites
Covered by the CHaMP



Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

The Designated European Sites
Covered by the CHaMP

2 CHARACTERISATION OF SUFFOLK CHAMP AREA

2.1 Introduction

The approach taken in the development of the Suffolk CHaMP is set out and discussed in the previous section. While there is this recognition that the coast and its habitats must be approached at a systems level there is a need, within this, to focus on the particular designated, and associated, features if realistic management advice is to be developed.

The following sections describe this process of focussing in, starting with the characterisation of the whole Suffolk CHaMP Area. This provides the general context to identify key links at a regional scale, as well as providing the overview from which to define individual Habitat Behaviour Units (HBUs). Within each HBU individual elements are assessed for their sustainable competence under existing flood and coastal defence policy. Where there is concern that the integrity of features may be threatened then alternative management approaches (including the opportunity for habitat creation) are examined.

The conclusions from assessment at an individual element level is then re examined in relation to the HBU and in relation to the CHaMP area as a whole.

The information provided prior to the various levels of discussion and assessment is in a synoptic form, aimed merely at highlighting issues. Detailed information on each issue is presented in the following sections and in Appendix A (geomorphology).

2.2 Physical aspects of the CHaMP area

2.2.1 General description

The open shoreline comprises, predominantly, shingle backed beaches with sand to shingle foreshores. In areas, the upper beaches have a greater sand content, giving way, in a few specific cases, to a predominance of sand. Characteristically, the land above the beach or the backshore falls into three interspersed categories:

- Clay cliffs; such as at Easton, Covehithe, Sizewell and Thorpeness, Bawdsey Manor and Cobbles Point;
- Shingle ridges at Benacre and Covehithe but, more typically, in front of large areas of low lying land, such as at Easton Broad, Dunwich, Minsmere, Aldeburgh, the Alde-Ore valleys (i.e. Orfordness), and coastal frontages at Alderton, Felixstowe Ferry and Felixstowe itself; and
- Short sections of narrow dune such as to either side of Walberswick Harbour or at Minsmere, Sizewell and Thorpeness.

The frontage is typically characterised by a retreated drift shoreline[1] now draped and partially fixed between more resistant, but still eroding, high ground and dynamic estuary ebb deltas.

[1] Drift shoreline: A principal influence of movement (drift) of sediment along the shore is wave action. As the shore retreats and is molded by this action so it achieves equilibrium with the net direction of wave energy. The shore moves from being drift aligned to swash aligned (in tune with the wave action).

Within the estuaries, there is a different structure. The three main northern estuaries (the Blyth, the Alde/Ore and the Deben) are strongly constrained by man-made defences within quite broad flood plains. The Orwell is less constrained by man's intervention but is still generally restricted in its development by natural features. The Stour, in contrast, is relatively unrestricted and is constrained principally by estuarine processes within a wider open estuary.

The estuaries, therefore, may be characterised in different ways:

- The Blyth, by the locational disbalance between its large upper tidal prism of Bulcamp, Sandpit and Angel Marshes, reed beds and mudflats and its narrow restricting entrance channel, lying between large areas of defended low lands;
- The Alde-Ore, again by its inverted prism created by the area of the mudflats of Long Reach and the long channel down to Orford Haven. In the case of the Alde-Ore, however, there is a strong geological constraint imposed by higher ground and the coastal geomorphological influence of Orford Ness;
- The Deben, as with the other two estuaries, is constrained over its lower section but distinctively free in its upper reaches, except where offshoot valleys have been encapsulated by flood defences. The upper reaches have a relatively natural development of salt marsh. Within its lower channel the main constraint occurs at its mouth;
- The Orwell is dominated by the influence of high ground. Examples of this are the ridge to Fagbury cliff (now behind Felixstowe Docks), and at Sleighton Hill, with the more consistently steep slopes of the northern side to the estuary and with, on the southern flank, the high ground of Bourne Hill and Woolverstone down to Collimer Point. Finally, the estuary is guided on its eastern side towards its mouth by the ridges of Crane's Hill and Shotley Point before running out to sea behind Landguard. The only major areas of reclaimed land are at Trimley on the northern bank and opposite this area at Shotley; and
- The Stour, by contrast to the other estuaries is a classic widening trumpet shape from Mistley through to Shotley and Harwich; gently steered by high ground at Sutton Ness, Wrabness, Harkstead Point, Erwarton and Parkeston, and interspersed between these points by mudflats and saltings.

2.2.2 Processes

The following general points on coastal processes apply to the frontage. Further detailed information is provided in Appendix A.

The net wave energy direction to the coast is from the east, comprising principal components from the northeast and southeast to southwest. Tidal flows flood southward and return north.

The general sediment drift is to the south but with major sections of the coast in relative equilibrium.

To the north of Southwold the shoreline drift[2] is strongly south, with a weak supply being delivered past Benacre Ness. This frontage is subject to differential drift erosion[3] along its length.

[2] Shoreline drift: this is in reference to sediment movement along the shore (along the beach face). There is a recognition that this shoreline drift system may be only part of a more complex pattern of movement within nearshore and offshore areas.

Beyond Southwold, down to Thorpe Ness there is a weak southerly net drift[4] through the Blyth ebb delta, into the relative equilibrium of the shore of the main bay. Sediment drift, both north and south still occurs despite this equilibrium, with material moving from beneath Dunwich cliff and accumulating in front of the Sluice at Minsmere. The main potential change in this area is the stretching of the limited material over a retreating and lengthening shoreline, with the possibility of collapse and inundation of the low-lying land behind.

Little sediment moves south beyond Thorpe Ness and the shoreline of Aldeburgh Bay is again in relative, but dynamic equilibrium, differing only in the slight promontory created by Aldeburgh and in the increased southern drift along Orford Ness.

South of the Ness, the drift is strong, feeding off the bulk of shingle of the Ness itself, before material becomes retained within the banks of Orford Haven and the lurking stability of Hollesley Bay. Superficial sediment transfer across the shore of the bay feeds further south to the banks of the Knolls and the mouth of the Deben, from whence material is fed intermittently south to Felixstowe and Landguard Point.

Photo 1. Shingle banks at the southern end of Orfordness spit

On the Blyth and the Alde/Ore the artificial constraint of man made defences and the subsequent defence failures of the last fifty years, has led to an increasing conflict between defence and natural (or subsequent) evolution; placing many areas of estuary bank under stress. This change, or continuing adaptation to previous change, is of significance to the future behaviour of the shoreline.

Within the Deben, there is a slower underlying change, manifested in the loss of saltmarsh and in shifting pressure within the lower part of the estuary. Increasing tidal prism, due to sea level rise is expected to increase pressure at the mouth and along the retaining flood banks.

The dominant process within the Orwell is that of accretion, with finer sediments brought in on the dominant flood flows. Not withstanding this behaviour, the processes within the estuary do not appear to be in conflict with the existing flood defences; the main threat

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[3] Differential drift erosion: an important distinction is made in the cause of erosion. In this case erosion is caused not from an exclusion of sediment feed to an area but rather because the volume of sediment moving in to an area is less than that moving away. Such differential erosion areas can change quite rapidly due to temporal variation in wave climate. This can result in areas either eroding or accreting depending on the direction of an individual storm.

[4] Net drift: this is the numerical aggregating of sediment drift over a period of time. It is indicative of the overall movement of sediment along the frontage; it does not provide any definition of the level of movement under any specific condition. A net southerly movement may arise from a few severe storms during the year moving sediment south while the predominant movement under day to day wave conditions may be to the north.

to these defences being that of mere exposure and age, rather than stress associated with the overall estuarine processes.

Similarly the Stour shows little sign of stress, but is, in contrast to the Orwell, a net erosive estuary, resulting in the loss of saltmarsh and mudflats.

Detailed information on the geomorphology and coastal processes of the Suffolk coast and estuaries is provided in Appendix A. The information presented in the Appendix has been utilised in developing the predictions for coastal change described in the assessment of the HBUs in Section 4 of this report.

2.2.3 Control Structure

Along the length of the coast, and to a lesser extent within the estuaries, there are fundamental control features dictating the structure and therefore the behaviour, and potentially the future management of the area. The coastal features are identified in table 2.1 below.

2.2.4 Existing Defence Structures and Policy

On the open coast there is relatively little hard defence, the main activities being maintenance of otherwise natural features. Current SMP and Strategy policies are illustrated in Figure 2.1 and have been taken from the Subcell 3c SMP (Halcrow 1996) and the Lowestoft to Thorpeness Coastal Process and Strategy Plan (Halcrow 2001).

Work at present is undertaken to maintain the shingle banks across the Broads to the north of Southwold, in front of Corporation and Dunwich Marches and between Aldeburgh and Orford Ness. The preferred policy for all but the last of these areas is realignment and involves a continuation of the policy of rebuilding the shingle bank following a breach.

At Orford Ness, the policy changes between Slaughden (Hold the Line) and the Ness (Do Nothing). Until recently material has been transported north from the Ness to feed the south of Aldeburgh.

Fixed defences are at present at Kessingland, Southwold, Thorpeness, Aldeburgh, East Lane, the mouth of the Deben and from here to Landguard Point. The SMP policy (extended by the policies for agreed strategies where appropriate) in each of these areas is to Hold the Line.

The greater part of the coast is in effect unmanaged, including the clay cliffs to the north of Southwold, Dunwich cliffs and the shingle banks through Minsmere past Sizewell and down to Thorpeness, the Haven and the majority of Orford Spit, Hollesley Bay and Bawdsey cliffs. Defence policy varies across these sections of the coast. North of Southwold the policy is largely for realignment, as is the policy for the Dunwich and Minsmere sections. North of Thorpeness the policy is Do Nothing (apart from Sizewell, which is Hold the Line), while the policy for the Haven is Hold the Line. Orford Spit is again Do Nothing, while a Hold the Line policy for Hollesley Bay has been adopted.

A strategy has been developed for the three northern estuaries (Posford Duvivier 1999) but is as yet unadopted. For each the overall policy is to maintain as far as possible the existing shape of the estuaries but there are significant lengths of defence where the existing policy for individual frontages could be altered.

Table 2.1 Coastal Control Features within the Suffolk CHaMP area

	Feature	Nature of Feature	Nature of Control	Interaction and Comment	Status
1	Benacre Ness	Sand shingle nose	Sediment throttle, potentially more a response feature than a control feature.	Provides good local protection. Transient feature.	Primary
2	Southwold sea front	Protected high ground promontory	Anchors coast. Acts as a sediment throttle.	Provides a down coast headland. Reduces sediment drift south.	Primary
3	Blyth entrance	Harbour piers and ebb delta	Sediment barrier and coastal anchor.	Provides local protection. Efficiency dependent on flow volume and velocity. Up coast headland.	Secondary
4	Dunwich Cliffs	Eroding clay cliffs	Anchors coast.	Eroding cliff	Secondary
5	The sluice at Minsmere	Sand and shingle drift focal point	Anchor point and sediment throttle.	Potential down drift and up drift strong point.	Secondary
6	Thorpe cliffs and ness	Sand shingle ness and clay cliffs	Sediment throttle and coastal anchor	Down drift and updrift headland. Potential to erode.	Primary
7	Aldeburgh sea front	Protected high ground promontory	Anchors coast. Acts as a sediment throttle	Provides a down coast headland. Reduces sediment drift south	Primary
8	Orford Ness	Shingle promontory	Terminal sediment feature	Major source of sediment	Secondary
9	Orford Haven	Ebb delta	Sediment collector and coastal anchor	Provides local protection. Efficiency at transferring sediment depends on flow volume and velocity.	Primary
10	East Lane	Artificial hard point	Sediment throttle and coastal anchor	Retains coast to north.	Primary
11	Deben/ Knolls	Shingle banks at the river mouth complex	Sediment collector and coastal anchor.	Updrift head land. Regulates sediment passed step in the coast.	Primary
12	Cobbles Point	Protected high ground promontory	Sediment throttle and coastal anchor	Retains coast to north. Updrift head land.	Primary
13	Landguard	Reinforced shingle spit	Coastal anchor	Retains coast to the north. Influences the entrance to the estuary.	Primary

Key areas where potential changes are identified are the potential closure of the tidal system at the top end of the Blyth and possible realignment of the defences at Tinkers Marsh. On the Alde/Ore, the main recommendation includes for possible realignment at Hazelwood Marshes, Aldeburgh Town Marshes and Boyton. In addition, while recommending that the realignment is not undertaken over the marshes of Orford Ness there is an identified need to manage these areas differently from current practice. On the Deben, only limited change is envisaged with the main area of potential realignment being identified at Nursery Wood.

There is currently no strategy or defence management plan in place for the Orwell. The southern side of the Stour Estuary is covered by the Essex SMP. The adopted policy is to Hold the Line apart from the natural cliff sections where non-intervention (Do Nothing) is the preferred policy. The northern side of the estuary is not covered by the SMP. There is no overall strategy for the whole estuary.

2.3 Ecology

2.3.1 Overview of ecological interest

The following section provides a general account of the attributes, occurrence and distribution of specific designated European and international features within the area covered by the CHaMP.

Section 2.3.2 lists and describes the habitats designated as part of the suite of candidate SACs within the Suffolk coastal area. Section 2.3.3 presents information on the SPA designated bird populations, the habitats that support them and the Ramsar interests of the various sites. These two designations have been considered together as the Ramsar designation also includes the ornithological interest represented by the SPA designation and the wetland habitats that support the bird populations.

2.4 Description of cSAC interest features

The Suffolk CHaMP area incorporates four areas that have been designated as cSACs:

- Benacre to Easton Bavents Lagoons cSAC;
- Minsmere to Walberswick Heaths and Marshes cSAC;
- Alde-Ore and Butley cSAC; and
- Orfordness to Shingle Street cSAC

These cSACs contain the following seven Annex I habitat features listed under the EU Habitats Directive.

1. Annual vegetation of drift lines.
2. Perennial vegetation of stony banks.
3. Saline lagoons.
4. Saltmarsh.
5. Intertidal mudflats.
6. Estuaries.
7. Dry Heaths.

A general description of each of these key habitats is provided, based largely on information derived from the designated site description (JNCC.gov.uk/protected sites/sacselection). This is then followed by information on this habitat type within the CHaMP area, again based on information from JNCC, but also from other relevant sources. References to these are provided in the text where relevant. Figures 2.2-2.9 Provide an indication of the extent and distribution of the main habitat types within the CHaMP area.

2.4.1 Annual vegetation of driftlines

A shingle or sand/shingle beach fringes approximately one third of the UK coastline, only a small percentage of this has any vegetation. Many of the fringing beaches with driftline vegetation may exist in one year but not another. Therefore although widely spread in terms of total area, sites where the habitat type is persistent are rare. Many sites are naturally species-poor, and the range of ecological variation is very limited.

This habitat type occurs on deposits of shingle, at or above mean high water springs. Most shingle beaches have varying sizes of shingle and are mixed with varying amounts of sand. Vegetated shingle generally occurs when the shingle is in its lowest size range (2-200mm diameter). Vegetated shingle mostly occurs as a fringing deposit, prone to periodic displacement or overtopping by high tides and storms. This causes the ephemeral nature of this community of annual or short-lived perennial vegetation. The habitat supports a number of recognisable NVC communities but the vegetation is often difficult to classify because it is highly variable between sites and from year to year at the same site.

Colonising species are able to tolerate periodic disturbance (removal of surface) and saltwater inundation (during overtopping events or through wave spray). Level, gently sloping, mobile beaches, with little anthropogenic activity, support the best examples of the vegetation community.

Importance of the feature to the Suffolk CHaMP area.

Orfordness to Shingle Street cSAC

Orfordness is an extensive shingle spit some 15 km in length and is one of two sites selected to represent the habitat type on the east coast of England. Driftline vegetation occurs on the sheltered, western side of the spit, at the transition from shingle to saltmarsh. The driftline community is widespread on the site and comprises sea beet *Beta vulgaris* subsp *maritima* and orache *Atriplex* spp. in a strip 2-5m wide.

Minsmere to Walberswick Heaths and Marshes cSAC

Along the Walberswick to Minsmere frontage, driftline vegetation occurs on a well-developed beach strandline of mixed sand and shingle and is the best and most extensive example of this restricted geographical type. Species include those typical of sandy shores, such as sea sandwort *Honkenya peploides* and shingle such as sea beet. The main areas supporting this vegetation type are the Walberswick to Dunwich shingle ridge and the shoreline between the southern end of the Dunwich cliff section and Sizewell.

2.4.2 Perennial vegetation of stony banks

Vegetated stony banks are scarce. The UK hosts a significant part of the European resource of this habitat. Although there are only some 4,000 ha of stable or semi-stable vegetated shingle around the whole coast of the UK, the habitat is widely distributed and varied.

Perennial vegetation of stony banks occurs where a sequence of foreshore beaches is deposited at the limit of the high tide. More stable and more permanent ridges are formed as storm waves throw pebbles high up on the beach, from where the backwash cannot remove them. Several beaches may be piled against each other and extensive structures can form. Stability is the crucial determining factor in the ecology of these structures, along with the amount of fine material accumulating between pebbles, climatic conditions, width of the foreshore and past management of the site.

Photo 2. Flowering plant of sea pea *Lathyrus japonicus*

The less stable a structure is (i.e. spits and bars or the fringing beach associated with older, fossil beaches) the more it will be exposed to waves or salt spray. Unstable shingle, that is prone to movement by wave energy, generally supports communities that have affinities with the annual vegetation of driftlines. The presence of the rare sea kale *Crambe maritima*, sea pea *Lathyrus japonicus*, and the yellow horned-poppy *Glaucium flavum*, all species that can tolerate periodic movement, is significant. In more stable areas above the unstable zone, where sea spray is blown over the shingle, plant communities with a high frequency of salt-tolerant species such as thrift *Armeria maritima* and sea campion *Silene uniflora* occur.

The largest, most stable structures support a sequence of vegetation that includes scrub, notably broom *Cytisus scoparius* and blackthorn *Prunus spinosa*. Heath vegetation with heather *Calluna vulgaris* and/or crowberry *Empetrum nigrum* occurs on the more stable shingle structures, particularly in the north of the UK.

Importance of the feature to the Suffolk CHaMP area.

Orfordness to Shingle Street cSAC

Orfordness is an extensive shingle structure consisting of a foreland, a 15 km long spit and a series of recurves running from north to south on the Suffolk coast. This spit has been selected as it supports some of the largest and most natural sequences in the UK of shingle vegetation affected by salt spray. The southern extremity of the spit has an excellent series of undisturbed ridges, with zonation of communities determined by the ridge pattern.

Photo 3. Distal end of Orfordness spit and Havergate Island.

The vegetation of Orfordness tends to be restricted to the shingle ridges, associated with the presence of fine shingle rather than exposure or elevation. Newly accreted ridges are colonised by pioneer species such as sea kale, yellow-horned poppy, sea pea and yellow vetch *Vicia lutea*. Sea pea is one of the outstanding plants of the Suffolk flora and exists along the Suffolk coast in greater quantity and profusion than can be observed anywhere else in Western Europe (Simpson 1982). The most widespread pioneer species is sea campion *Silene uniflora*, which is abundant at Orfordness. The extensive woody, branched rootstock of this species makes it an important species in stabilising mobile shingle. Its wide distribution across Orfordness produces a microenvironment in which many less well adapted species can establish. Sea-campion, more than any other species, is responsible for shaping overall vegetation patterns at Orfordness (Randall and Fuller 2001).

Orfordness contains the second largest area of acid shingle heath in Britain. The best preserved section is within the old National Nature Reserve south of the former Atomic Weapons Research Establishment fenceline on the spit itself, but there are also good patches on Shingle Street and on the main bulk of the Ness where disturbance has been limited. The dominant flowering species are sea-campion and English stonecrop *Sedum anglicum*, with early hair grass *Aira praecox*, Common cat's ear *Hypochoeris radicata* and false oat-grass *Arrhenatherum elatius* being common. At the extremities of the heath, where maritime influences are greater, false oat grass is dominant, red fescue *Festuca rubra* and smooth meadow grass *Poa pratensis* are present with thrift *Armeria maritima*. Most of this vegetation is linear in pattern, coinciding with the finer shingle of the old ridge crests and cover is low or non-existent in the coarser shingle lows. Considerable amounts of bare ground are present over much of the site. The shingle heath has an extensive cover of lichens and mosses, in some parts dominating the vegetation. Most of the lichens are of the genus *Cladonia*, but a unique feature is the abundance on the ground of the normally epiphytic lichens *Parmelia caperata* and *Evernia prunastri*. At Shingle Street, the heathland is never far from the sea and false oat grass remains common throughout. Biting stonecrop *Sedum acre* replaces English stonecrop and the dwarf cushion form of *Geranium robertianum* is more common. Towards the riverside shore and on the longer stabilised western parts of Shingle Street, where there is a higher percentage of fine particles and humus within the shingle, a *F. rubra* turf has developed, often containing thrift and a wide range of clovers and vetches.

Ultimately, the successional development of the flora on the undisturbed areas is curtailed by the overriding maritime influence at Orfordness. Nowhere is there undisturbed shingle further than 250m from the sea. Wind and salt spray have limited the number of species which can colonise and establish. Probably, as a result, Orfordness has virtually no established communities of woody species on pure shingle in contrast to Dungeness which supports large quantities of gorse *Ulex europeaus* and broom *Cytisus scoparius*.

It is also worth noting that the shingle structures of Benacre Ness and Thorpeness also support a well developed perennial vegetation community. Although Benacre Ness is a designated cSAC, the perennial vegetation interest at this site does not form part of the designated interests. The shingle habitat at Thorpeness is not designated as SSSI or cSAC but supports a diverse plant community including sea kale, sea pea and yellow-horned poppy.

2.4.3 Saline lagoons

Saline lagoons are areas of typically (but not exclusively) shallow, coastal saline water, wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks or other hard substrata. They retain a proportion of their water at low tide and may develop as brackish, fully saline or hyper-saline water bodies.

Lagoons are localised in Europe and have a restricted distribution on the Atlantic coast. The habitat is complex, and a wide range of physical types and origins can be included in their definition. There is a wide range of geographical and ecological variation of the habitat type, and some of the types of lagoon found in the UK are rare elsewhere in Europe. This is a priority habitat type and is relatively uncommon in the UK.

Saline lagoons are split into five main sub-types dependant upon their physiography:

- **Isolated lagoons:** those completely separated from the sea (or estuary) by a physical barrier of rock or sediment. Groundwater seepage or overtopping events are the source of small amounts of seawater. The predominant inflow is from freshwater sources and predominant loss through evaporation, this balances so that in many cases salinity may remain fairly high. Tidal range is zero, longevity is brief.

- **Percolation lagoons:** those normally separated from the sea by a shingle bank. Seawater enters through the shingle by percolation or by occasional overtopping of the shingle bank. Tidal range is normally significantly reduced and may be unnoticeable. Longevity may be extended but this lagoon type is prone to rapid (if not immediate) extinction through movement of the surrounding sediment.

- **Silled lagoons:** those lagoons with an open connection to the sea in which water is retained at all tidal states by a horizontal barrier of rock. Seawater exchange is regular and frequent. Tidal range may be marked, although out of phase with the adjacent sea. These are potentially long-lived lagoons that tend to go extinct gradually, over extended time periods.

- **Sluiced lagoons:** those with an open connection to the sea, which is maintained or modified by anthropogenic mechanical structures such as valved sluices or sea-doors. Such lagoons restricted by culverts may fall into either this category or the previous one, although the latter is normally taken to refer to natural lagoons. These lagoons have a similar longevity to silled lagoons, but the tidal range will depend on the efficiency of the sluice, and may be very low.

- **Lagoonal inlets:** those with an open connection to the sea, where the sea connection is horizontally restricted. There is often a marked (but reduced) tidal range, commonly in phase with the adjacent sea. Longevity is similar to saline lagoons.

Only lagoons on natural substrates have been selected for SAC designation.

The floral and fauna assemblages in saline lagoons can vary according to the physical characteristics and salinity regime of the lagoon, and therefore there are significant differences between sites. Although a limited range of species may be present, compared with other marine habitats, the ones that are present are generally unique to lagoonal environments due to their adaptation to the varying salinity. The vegetation may include beds of eelgrass *Zostera* spp., tasselweeds *Ruppia* spp. and pond weeds *Potamogeton* spp. or stoneworts such as foxtail stonewort *Lamprothamnium papulosum*. In lagoons with a rocky substrate, communities of fucoid wracks *Fucus* spp., sugar kelp *Laminaria saccharina* and red and green algae are also found. The fauna is often characterised by mysid shrimps and other small crustaceans, burrowing worms, prosobranch and gastropod molluscs and some fish species. Species that are particularly found in lagoons and therefore have a restricted distribution in the UK include the starlet sea anemone *Nematostella vectensis*, lagoon sandworm *Armandia cirrhosa*, lagoon sand shrimp *Gammarus insensibilis* and foxtail stonewort.

Importance of the feature to the Suffolk CHaMP area.

Benacre to Easton Bavents Lagoons

This site includes four lagoons: Benacre Denes (1 lagoon), Benacre Broad, Covehithe Broad and Easton Broad.

There were, until very recently, three lagoons present at Benacre Denes, but erosion over the past two-three years has resulted in the loss of two of the lagoons. The lagoons here are old gravel pits situated on Benacre Ness which date back to World War II. The remaining lagoon is fed by seawater percolation and rainfall and supports a fauna including the crustaceans *Sphaeroma hookeri* and *Gammarus zaddachi*.

Benacre, Covehithe and Easton Broads, have formed behind shingle barriers and are a feature of the geomorphologically dynamic system. Seawater enters the lagoons by percolation through the barriers, or by overtopping them during high spring tides or storms. The lagoons display a wide range of salinities (both spatially and temporally), with Easton Broad periodically exhibiting low salinity due to significant freshwater flow into the lagoon (English Nature 1996). Salinity variation has produced a diverse assemblage of flora throughout the lagoons such as the narrow-leaved eelgrass *Zostera angustifolia* in fully saline or hyper-saline conditions, beds of spiral tasselweed *Ruppia cirrhosa* in brackish water and dense beds of common reed *Phragmites australis* in freshwater. The lagoons support a number of specialist lagoon species including the crustacean *Sphaeroma hookeri*.

In the last decade, significant overtopping and landward movement of the shingle bar in front of Benacre Broad has resulted in a reduction in the size of the lagoon and dieback of reed at its distal arms. To combat this loss, new lagoons and bunds to landward of the existing Broad were constructed in 1996. Easton Broad has also significantly reduced in size due to landward movement of the shingle barrier over the past few decades.

Orfordness – Shingle Street

Photo 4. Shingle beach, offshore banks and saline lagoon at shingle street.

There are three areas of saline lagoons within the Orfordness-Shingle Street site. Former clay extraction areas on the western side of Orfordness (Lantern Marsh and Kings Marsh) support a relatively diverse fauna and flora, although some are impoverished, possibly due to nutrient enrichment related to the presence of the very large breeding gull colonies. In those lagoons away from the main gull colonies the flora is dominated by the tasselweed *Ruppia*, with which many of the lagoonal animals are associated. Recorded species include the lagoon cockle *Cerastoderma glaucum*, lagoon winkle *Littorina saxatalis lagunae* and the spire shell *Hydrobia neglecta*. On the eastern side of the ness, a series of former gravel extraction areas which are now fed through percolation and rainfall support a varied and diverse fauna and flora with large populations of *N. vectensis*, lagoon cockle and lagoon winkle present.

The lagoons at Shingle Street are gravel-bedded with basal muddy sediments and have developed in the shingle bank adjacent to the shore at the mouth of the Ore estuary. Shingle movement in the vicinity of Shingle Street occurs on a regular basis and the lagoons are ephemeral in nature. Of the seven lagoons identified in Bamber (1989) only three were present in 1996 (English Nature 1996). A relatively large lagoon in front of the cottages at Shingle Street has recently developed (2001) as a result of shingle movement onshore from the tip of Orfordness. The salinity of the lagoons is maintained by percolation through the shingle with supplementary overtopping on extreme tides. The fauna of these lagoons includes typical lagoon species, such as *Cerastoderma glaucum*, the ostracod *Cypredeis torosa* and the gastropods *Littorina saxatillis tenebrosa* and *Hydrobia ventrosa*. The nationally rare starlet sea anemone *Nematostella vectensis* is also found at the site.

2.4.4 Atlantic salt meadows

Atlantic salt meadows (saltmarsh) occur on North Sea, English Channel and Atlantic shores. There are more than 29,000 ha of the habitat type in the UK, mostly in the large, sheltered estuaries of the south-east, south-west and north-west of England and in south Wales. These large sites provide the best examples of zonation. Historically, large areas of saltmarsh, especially the upper zones, have been lost by enclosure, usually involving the erection of a sea bank to exclude seawater.

Atlantic salt meadows develop when halophytic vegetation colonises soft intertidal sediments of mud and sand in areas protected from strong wave action. This vegetation forms the middle and upper reaches of saltmarshes, where tidal inundation still occurs but with decreasing frequency and duration. A wide range of community types is represented and saltmarshes can cover large areas, especially where there has been little or no enclosure on the landward side. The vegetation varies with climate and the frequency and duration of tidal inundation. Grazing by domestic stock may be particularly significant in determining the structure and species composition and its relative value for plants, invertebrates and wintering or breeding waterfowl. The upper saltmarsh is regarded as particularly important and there is considerable variation in different parts of the UK. Upper saltmarsh may show transitions to a number of habitats, including sand dune, coastal shingle, freshwater marshes and woodland. This part of the saltmarsh succession has been particularly vulnerable to destruction by enclosure, and remaining areas are particularly valuable.

At the lower reaches of the saltmarsh the vegetation is often species-poor and may form an open sward of common saltmarsh-grass *Puccinellia maritima*. Further up the marsh, the vegetation becomes herb-dominated and red fescue becomes more important. The upper saltmarsh shows considerable variation, particularly where there are transitions to other habitats.

There are marked regional variations in the Atlantic salt meadow communities of the UK. In east and south-east England low to mid-marsh communities predominate, owing to extensive reclamation of the upper marsh. In contrast, the salt meadows of north-west England and south-west Scotland are dominated by extensive areas of grazed upper marsh communities characterised by common saltmarsh-grass and saltmarsh rush *Juncus gerardii*.

Importance of the feature to the Suffolk CHaMP area.

Although saltmarsh vegetation is present within all of the Suffolk estuaries, only the Alde-Ore-Butley system has been selected as a cSAC for this feature. The following text therefore refers solely to this site. Saltmarsh is also an important habitat for waterfowl (feeding and roosting) and aspects of the habitat with respect to SPA interests are covered under the section describing the designated features of the various SPAs within the CHaMP area.

The Alde-Ore estuary system supports the largest area of saltmarsh in Suffolk, accounting for approximately 37% of the entire resource in the county. The saltmarsh survey undertaken by the Suffolk Wildlife Trust in 1993 identified nineteen saltmarsh communities and two swamp communities covering a total of 310 ha.

The total area of pioneer vegetation in the Alde-Ore is low, suggesting that little accretion is taking place. Along the River Ore, significant stands of two pioneer communities, annual *Salicornia* and *Suaeda maritima* occur. Although these only account for 5.5% of the total saltmarsh area within the estuary their presence may be an indication that more sediment accretion is taking place within the Alde-Ore than on the Deben or Blyth estuaries. Of significance is the presence of small stands of the nationally rare native species of cord-grass *Spartina maritima* and *Sarcocornia perennis* on the lower Butley estuary and the River Ore.

Three community types together make up the low-marsh on the Alde-Ore, which accounts for 30% of the overall saltmarsh. Significant stands of the *Aster tripolium* community occur on both sides of the Butley River, in similar situations to those found on the Deben and Blyth. The other main low-marsh community is the *Puccinella maritima* sub-community of the *P. maritima* community. Extensive blocks of this saltmarsh type are frequent along the lower stretches of the Butley and along the west side of the River Ore. The presence of such large areas of this sub-community may be associated with the past grazing regime on the Alde/Ore with the stands maintained by large numbers of wigeon *Anas penelope* grazing them during the winter.

Low-mid and mid-marsh communities make up the bulk of the well-established and stabilised saltmarsh blocks, accounting for 44% of the saltmarsh on the Alde-Ore. These communities are rather variable in composition and reflect local changes in sediment type and depth, extent of inundation and past management practices. Two basic communities dominate on the Alde-Ore. The low-mid marsh is dominated by communities of the *Atriplex portulacoides* (sea-purslane) saltmarsh. This vegetation type, as on the other estuaries, occurs as a linear community along creek sides. The mid-marsh is dominated by the *Limonium vulgare* (sea-lavender) sub-community of the *Pucinella maritima* community. Large blocks of this saltmarsh occur along the middle and lower sections of the estuary, reflecting the similar distribution found on the Deben and Blyth, and accounts for about 25% of the total area of saltmarsh on the estuary.

Upper marsh forms about 17% of the overall saltmarsh area on the Alde/Ore. The *Elytrigia atherica* community occurs mainly along the highest edge of the saltmarsh, the vast majority of this being on floodwalls. In the Upper Alde this community dominates on the old river walls in the middle of the estuary. Elsewhere it occurs on Orfordness in areas that have been extensively disturbed.

Saltmarsh vegetation is also present around the lagoons and borrowpits on Shingle Street, Havergate Island and Kings and Lantern Marshes on Orfordness.

2.4.5 Intertidal mudflats

Photo 5. Intertidal mudflat and fringing saltmarsh and reedbed habitat, Butley Estuary.

This is a widespread habitat type on the North Sea coasts of Atlantic Europe and occurs widely throughout the UK.

Intertidal mudflat and sandflats are submerged at high tide and exposed at low tide. They form a major component of estuaries and embayments in the UK but also occur along the open coast. The physical structure of the intertidal flats can range from the mobile, coarse-sand beaches of wave-exposed coasts to the stable, fine-sediment mudflats of estuaries and embayments. This habitat type can be divided into three broad categories: clean sands, muddy sands and muds, although in practice there is a continuous gradient between them. Within this range the plant and animal communities present vary according to the type of sediment, its stability and the salinity of the water.

Mudflats form in the most sheltered areas of the coast, usually where large quantities of silt derived from the open sea or from rivers are deposited in estuaries. The sediment is stable and communities are dominated by polychaete worms and bivalve molluscs. Such soft mudflats typically support very high densities of the snail *Hydrobia ulvae*. The high biomass of intertidal species in such sediments provides important feeding areas for waders and wildfowl. Within Suffolk only the Alde/Ore is designated for this habitat, a description of which is provided in the following section.

2.4.6 Estuaries

Estuaries are complex ecosystems interlinking the terrestrial and aquatic environments and are composed of an interdependent mosaic of subtidal, intertidal and surrounding terrestrial habitats. Many of these habitats, such as intertidal mudflats and sandflats, saltmarshes, sand dunes and reefs, are identified as habitat types in their own right in Annex I of the Directive (see description of intertidal mudflat and saltmarsh above). The UK has a particularly large number of estuaries. Indeed, more than a quarter of the area of north-western European estuaries occurs in the UK. The wide range of estuary types occurring in the UK is also unusual in a European context.

Estuaries can be defined as the downstream part of a river valley, subject to the tide and extending from the limit of brackish water. There is a gradient of salinity from fresh water in the river too increasingly marine conditions towards the open sea. Inputs of sediment from the river, shelter from wave action and, often, low current flows lead to the presence of extensive sediment flats. The structure of estuaries is largely determined by geological and physiographic factors. There are four main geomorphological types, defined by these physiographic features:

- Coastal plain estuaries: these estuaries have formed where pre-existing valleys were flooded at the end of the last glaciation. They are usually less than 30 m deep, with a large width-to-depth ratio. This is the main type of estuary, by area, in the UK.

- Bar-built estuaries: these characteristically have a sediment bar across their mouths and are partially drowned river valleys that have subsequently been inundated. Bar-built estuaries tend to be small but are widespread around the UK coast.

- Complex estuaries: these river estuaries have been formed by a variety of physical influences, which include glaciation, river erosion, sea-level change and geological constraints from hard rock outcrops. There are few examples of this type of estuary in the UK.

- Ria estuaries: ria estuaries are drowned river valleys, characteristically found in south-west Britain. The estuarine part of these systems is usually restricted to the upper reaches. The outer parts of these systems are little diluted by fresh water and are defined as Large shallow inlets and bays.

The intertidal and subtidal sediments of estuaries support biological communities that vary according to geographic location, the type of sediment, tidal currents and salinity gradients within the estuary. The parts of estuaries furthest away from the open sea are usually characterised by soft sediments and the water is more strongly influenced by fresh water. Here the sediment-living animal communities are typically dominated by oligochaete worms, with few other invertebrates. Where rock occurs, there are restricted communities characteristic of brackish flowing water, consisting of green unicellular algae, sparse fucoid algae and species of barnacle and hydroid. The silt content of the sediment decreases nearer to the mouth of the estuary, and the water gradually becomes more saline. Here the animal communities of the sediments are dominated by species such as ragworms, bivalves and sandhopper-like crustaceans. In the outer estuary, closer to the open sea, the substrate is often composed of fine sediment and supports communities of more marine bivalves, polychaete worms and amphipod crustaceans. Where rock occurs, a restricted range of species more characteristic of the open sea is found.

Importance of the feature to the Suffolk CHaMP area.

Of all of the Suffolk estuaries, only the Alde-Ore-Butley system has been selected as a cSAC representative of the range and types of estuaries found in the UK.

The Alde-Ore Estuary is a relatively complex estuary combining elements of the typical coastal plain estuary with that of a bar-built estuary. Over the last two thousand years the development of the estuary has been largely related to the evolution of Orford Ness. It has been postulated that at one stage the River Alde used to flow into the sea through a wide mouth at Slaughden. As a spit developed southwards from Slaughden, however, the estuary mouth was forced southwards with it. By the time Orford Castle was constructed in AD 1165 the spit had grown as far as the northern tip of Havergate Island, and by the late 1800's it had grown to its present length.

The estuary is fed by the rivers Alde and Butley and comprises in its upper part of a broad area of intertidal mudflat and saltmarsh through which the main estuary channel meanders. Here variable salinity sandy mud dominates and is characterised by the variable salinity bivalve *Macoma balthica* and *Manayunkia aestuarina* community, which is widespread throughout the estuary. At the head of the Alde, muddy substrate supports a typically upper estuarine community dominated by polychaete worms such as *Hediste diversicolor* and *M. aestuarina*. Beyond the broad, upper reaches of the Alde, the alignment and width of the main channel is restricted by the presence of flood defences and Orfordness, so that east of the basin the channel changes direction through 90^{o} and flows in a narrow channel for some 8km to its confluence with the Butley. Along this section the narrow intertidal comprises variable salinity muds with the polychaetes *Nephtys hombergii* and *Tharyx marioni*. The River Butley itself has its tidal limit adjacent to Butley Mills, and from here meanders downstream through extensive areas of reedbed, saltmarsh and inter tidal mudflats in its upper reaches. As with the upper part of the Alde, variable salinity sandy muds dominate in this area. Further downstream, as the river approaches the confluence with the Ore, the channel becomes more restricted by a continuous length of man made embankments on either side.

Downstream of the Butley/Ore confluence towards Orford Haven at the mouth of the estuary, the river is at its widest. It is also largely uncontrolled by man, running between the shingle spit to the south and the shingle and marsh frontage backed by set-back embankments to the north. The river flows into the sea past the shingle expanses of North Weir Point at the far southern end of Orfordness, and Shingle Street to the west. Coarser sediments at the mouth of the Ore provide a different substrate to the rest of the estuary and dense beds of the sandmason worm *Lanice conchilega* have been recorded from this area. As the spit continues to evolve, the position of these two points varies by up to 20m per year, with long periods of southwards movement and growth, followed by a dramatic breach of the spit before regrowth commences. Such a cycle of events is generally perceived to occur over a period 100 years or more.

2.4.7 Dry Heaths

Dry heaths typically occur on freely draining acidic soils, generally of low nutrient content. Ericaceous dwarf shrubs dominate the vegetation, the most common being heather *Calluna vulgaris*, gorse *Ulex* spp. and bilberry *Vaccinium* spp.

Importance of the feature to the Suffolk CHaMP area.

Minsmere to Walberswick Heaths and Marshes

Dry lowland heath occupies an extensive area of this site at the extreme easterly range of heath development in the UK. The heathland is predominantly NVC H8 *Calluna vulgaris-Ulex galii* heath, a type most characteristic of western parts of the UK, and is found in a mosaic with acidic grassland (NVC U1). Heather *Calluna vulgaris*, western gorse *Ulex gallii* and bell heather *Erica cinerea* dominate this type. The main area of heath vegetation relevant to the CHaMP is present along the cliff top between Dunwich village and Minsmere RSPB Reserve.

2.5 Interest features of the Special Protection Areas (SPAs) and Ramsar sites

The Suffolk CHaMP area incorporates six areas that have been designated as SPAs and Ramsar sites:

- Benacre to Easton Bavents SPA;
- Minsmere to Walberswick Heaths and Marshes SPA/Ramsar;
- Alde-Ore Estuary SPA/Ramsar;
- Orfordness-Havergate SPA/Ramsar;
- Deben Estuary SPA/Ramsar; and
- Stour and Orwell Estuaries SPA/Ramsar

2.5.1 Benacre to Easton Bavents SPA/Ramsar

Within the SPA there are a number of habitat types, which support the bird populations for which the SPA has been designated, the breeding birds being particularly associated with reedbed and shingle beach habitats. Benacre Broad is a natural brackish lagoon separated from the sea by a shingle bar, reed-fringed on the landward side and then grading into deciduous woodland on the rising ground behind with freshwater habitat dominating at the landward end of the distal arms of the lagoon. The fine sands and muds of the shallow broad support rich communities of bivalve molluscs and polychaete worms which provide a valuable food source for a large number of wintering waterfowl. The smaller Covehithe and Easton Broads have developed similarly, with fringing reedbeds. Upstream of Easton Broad, an extensive freshwater reedbed, together with a mosaic of wetland habitats including grazing marsh, ditches and wet woodland and scrub support rich plant and invertebrate communities. The reedbeds of the site support important numbers of breeding and wintering marsh harrier *Circus aeruginosus* and breeding and wintering bittern *Botaurus stellaris*.

The shingle bars fronting Benacre Broad and Covehithe Broad are utilised as a breeding site by little tern *Sterna albifrons*. This species is usually restricted to shingle areas and requires unrestricted views over greater than 200m with vegetation cover of less than 10% and the remainder bare during the breeding season. The shallow water of the intertidal area (within the SPA) is an important feeding area for little tern. This species will pick prey items (e.g. small fish, crustaceans, worms) from the surface of the water, with the majority of feeding occurring outside of the SPA in adjacent marine waters.

Benacre to Easton Bavents SPA qualifies under Article 4.1 of the EU Birds Directive by supporting:

- Populations of European importance of the following regularly occurring Annex 1 species (Table 2.1)

Table 2.1 Benacre to Easton Bavents SPA - populations for qualifying Annex I species

Species	Population[1]
Bittern	1 individual representing at least 5.0% of the breeding population in Great Britain (Count as at 1998); 2 individuals representing at least 2.0% of the wintering population in Great Britain (Count, as at 1998)
Marsh harrier	6 pairs representing at least 3.8% of the breeding population in Great Britain (5 year mean 1993-1997)
Little tern	53 pairs [1] (2.2% of GB population)

[1] JNCC SPA review data (2001) except where stated

Other Annex 1 species present at the site are breeding avocet *Recurvirostra avosetta* (up to 18 pairs), and a few pairs of common tern *Sterna hirundo* occasionally nest, red-throated diver *Gavia stellata*, black-throated diver *G. arctica*, great northern diver *G. immer*, Slavonian grebe *Podiceps auritus* and hen harrier *Circus cyaneus* winter within the SPA.

In addition to the species mentioned above the site supports a high diversity of breeding birds. These include bearded tit *Panurus biarmicus*, water rail *Rallus aquaticus*, gadwall

Anas strepera, wheatear *Oenanthe oenanthe*, redstart *Phoenicurus phoenicurus* and nightingale *Luscinia megarhynchos*. During the winter Benacre Broad is used by substantial numbers of mallard *Anas platyrhynchos* and teal *Anas crecca* as well as pochard *Aythya ferina*, wigeon *Anas penelope*, goldeneye *Bucephala clangula* and tufted duck *Aythya fuligula*.

2.5.2 Minsmere-Walberswick SPA/Ramsar

The Minsmere-Walberswick SPA contains a complex mosaic of habitats, notably areas of grazing marsh with dykes, extensive reedbeds, mudflats, lagoons, shingle, woodland and areas of lowland heath.

The sheltered estuary of the River Blyth supports a diverse wintering assemblage of waterfowl, notably wigeon, shelduck *Tadorna tadorna*, redshank *Tringa totanus* and dunlin *Calidris alpina*. The mudflats regularly support large flocks of avocet, with up to 750 being commonly recorded in recent winter months. Significant populations of pintail and black-tailed godwit *Limosa limosa* have wintered on the Blyth only during the past ten years, during which time numbers have generally increased annually. The Blyth now supports nationally important populations of these species and at times internationally important numbers of avocet. The site also supports wintering hen harrier.

Thirteen saltmarsh and two swamp communities have been identified (Suffolk Wildlife Trust, 1993) on the Blyth estuary covering a total of 86 ha. The majority of the saltmarsh fringes the southern side of Bulcamp Marshes and Angel Marshes. There has been very limited development of saltmarsh on the main bulk of the mudflats and northern side of these areas following breach of the estuary defences in the 1950-1960s. This suggests that the inundated land was at a low-level relative to mean high water and that, in addition, the overall rate of sediment accumulation is low. Pioneer saltmarsh accounts for approximately 13% of the total habitat, a relatively high component compared with the other estuaries. Low-marsh communities make up about 29% on the Blyth and are dominated by extensive stands of rayed sea aster *Aster tripolium* particularly on the southern side of the mid-estuary. Low-mid and mid-marsh communities make up the bulk of the well-established saltmarsh blocks. This is often a complex community comprising a variety of species, but on the Blyth tends to be dominated by species such as common saltmarsh grass *Puccinellia maritima* and sea lavender *Limonium vulgare*. The upper marsh community comprises various grass species, notably sea couch *Elytrigia atherica*.

There are extensive reedbeds at Walberswick (Westwood Marshes) and Minsmere RSPB Reserve, with the reedbed at Westwood being the largest continuous stand of common reed *Phragmites australis* in England. The reedbeds are of major importance for breeding and wintering bittern and marsh harrier, but also support large breeding populations of reed warbler *Acrocephalus scirpaceus* and bearded tit and breeding garganey *Anas querquedula*, Cetti's warbler *Cettia cetti* and water rail. The reedbeds also support a rich insect fauna, particularly moths, including white-mantled wainscot *Archanara neurica*, flame wainscot *Senta flammea* and Fenn's wainscot *Photedes brevilinea*.

The artificial lagoons and islands forming part of the RSPB reserve at Minsmere support a significant population of breeding avocet and also breeding shoveler, gadwall, teal and shelduck amongst others. Heathland vegetation within the SPA (Dunwich-Westleton) supports important breeding populations of Dartford warbler *Sylvia undata*, nightjar *Caprimulgus europaeus* and woodlark *Lullua arborea*.

The shingle beaches support important numbers of breeding little tern, with the shingle bank adjacent to Minsmere RSPB reserve being the main breeding site. Little terns and avocet (up to 20) also nest behind the shingle bank at Walberswick. The shallow coastal waters in front of the shingle ridge and of the Blyth Estuary provide an important feeding area for little tern, although they also feed further out to sea along the coast and in the scrapes of the RSPB bird reserve.

Grazing marsh occurs near Eastbridge, Southwold Town Marshes at the north-eastern end of the site and Tinkers Marsh on the southern side of the Blyth Estuary. Between them, these marshes support breeding waterfowl such as avocet, snipe *Gallinago gallinago*, redshank, gadwall and shoveler *Anas clypeata*. Dykes within the marshes contain very diverse aquatic plant communities, with brackish and freshwater types represented. Many nationally rare and scarce invertebrates such as the soldier fly *Odontomyia ornata* are found east of Eastbridge, as are a number of nationally scarce plants including sea barley *Hordeum marinum* and whorled water milfoil *Myriophyllum verticillatum*. The marshes west of Eastbridge support a mosaic of different unimproved wetland communities including fen meadow characterised by blunt flowered *rush Juncus subnodulosus* and marsh thistle *Cirsium palustre*, swamps dominated by lesser pond sedge *Carex acutiformis*, marshes dominated by meadowsweet *Filipendula ulmaria* and alder *Alnus glutinosa* woodland.

Minsmere-Walberswick SPA qualifies under Article 4.1 of the EU Birds Directive by supporting:

- Populations of European importance of the following regularly occurring Annex 1 species (Table 2.2)

Table 2.2 Minsmere-Walberswick SPA - populations for qualifying Annex I species

Species	Population[1]
Hen harrier	15 individuals representing at least 2.0% of the wintering population in Great Britain (5 year peak mean, 1985/6-1989/90)
Avocet	91 pairs representing at least 15.4% of the breeding population in Great Britain (RBBP 1996); 278 individuals representing at least 5.6% of the wintering population in Great Britain (5 year peak mean 1995/6 - 1999/00)[2]
Bittern	10 booming birds representing at least 14% of the booming males in Great Britain (3 year mean, 1999-2001)[3]; 14 individuals representing at least 14.0% of the wintering population in Great Britain (Count as at 1998)
Marsh harrier	16 pairs representing at least 10.0% of the breeding population in Great Britain (5 year mean, 1993-1997)
Nightjar	24 pairs representing at least 0.7% of the breeding population in Great Britain (Count, as at 1990)
Woodlark	20 pairs representing at least 1.3% of the breeding population in Great Britain (RSPB, 5 year mean 1995-99)

[1] JNCC SPA review data (2001) except where stated; [2] Source: WeBS data; [3] RSPB/EN data (average 1999/2001 booming males); [4] RSPB/EN data (2000 figure).

This site also qualifies under Article 4.2 by supporting in summer, in recent years, nationally important breeding populations of three regularly occurring migratory species and wintering populations of three migratory waterfowl: gadwall, teal and shoveler. The site also qualifies under Article 4.2 by supporting nationally important wintering populations of three migratory waterfowl: European white-fronted geese *Anser albifrons*, gadwall and shoveler.

2.5.3 Alde-Ore Estuary SPA

The Alde-Ore Estuary SPA habitat includes vegetated shingle, intertidal mudflats, semi-improved grazing marsh, saltmarsh and saline lagoons. The Alde-Ore Estuary comprises the estuarine complex of the rivers Alde, Butley and Ore, including Havergate Island and Orfordness. There are a variety of habitats including intertidal mudflats, saltmarsh, vegetated shingle (including the second-largest and best-preserved area in Britain at Orfordness), saline lagoons and semi-improved grazing marsh. The diversity of wetland habitat types present is of particular significance to the birds occurring on the site as these provide a range of opportunities for feeding, roosting and nesting within the site complex. At different times of the year, the site supports notable assemblages of wetland birds including seabirds, wildfowl and waders. As well as being an important wintering area for waterbirds, the Alde-Ore Estuary provides important breeding habitat for several species of seabird, wader and raptor. During the breeding season, gulls and terns feed substantially outside the SPA.

Saltmarsh provides an important habitat for breeding waders. A recent survey undertaken by the Suffolk Wildlife Trust established that the majority of breeding redshank and oystercatchers on the Alde-Ore were utilising saltmarsh rather than adjacent grazing marsh or fields. During the winter months saltmarsh also provides a feeding and roosting area for a large number of waterfowl, particularly wigeon and teal. The population of wigeon is of national importance and in some winters may up to 5000 birds may be present on and around the estuary.

The intertidal area of the Alde-Ore represents the most significant habitat type within the study area and is particularly important as a feeding and roosting area for waterfowl. The mudflats, particularly in the Iken area, regularly support large flocks of avocet, with up to 850 being recorded in some winters. This makes the estuary the most important wintering site for this species in the United Kingdom. The estuary supports an internationally important population of overwintering redshank, with over 2000 birds being regularly recorded feeding on the exposed mudflats during the winter months. Significant populations of other waders and wildfowl utilising the rich intertidal invertebrate food resource include, dunlin, black-tailed godwit, shelduck, curlew and oystercatcher.

On the Alde-Ore reed swamp forms extensive stands at the top of the tidal sections of the Alde and Butley rivers. The stands at the head of the Alde estuary are rather species-poor, although there is a small amount of the nationally rare marsh sow-thistle *Sonchus palustris* at Snape Bridge. Lower down, at Iken Cliff, the reed stands are fragmented and botanically impoverished, probably due to regular inundation by high tides. They do however, stabilise the substrate and provide some protection against erosion. The reed-beds at the head of the Butley are cut regularly and are botanically richer with some small areas of herb-fen present. The presence of a good population of brookweed *Samolus valerandi* is of interest as this species is in decline in Suffolk.

Although much of the land adjacent to the Alde-Ore is in arable production there are still relatively large areas of grassland remaining. Much of this area has been entered into the Environmentally Sensitive Area (ESA) scheme and comprises semi-improved, cattle or sheep grazed pasture with improved drainage and low field surface water levels. These areas are generally of little ecological interest, although they may be used by low numbers of breeding oystercatcher *Haematopus ostralegus* and lapwing *Vanellus vanellus*. Where water levels have been raised, under the ESA scheme, or have been maintained through traditional agricultural practices, these grassland areas provide excellent habitat for a range of breeding waterfowl and in addition often have an important freshwater/brackish dyke flora and fauna. Notable areas include Boyton Marshes, the old airfield site on Orfordness, Stanny Farm (opposite Aldeburgh marshes) and Hazelwood Marshes.

The Alde-Ore Estuary SPA qualifies under Article 4.1 of the EU Birds Directive by supporting populations of European importance of the following Annex I species (see Table 2.3) in any season:

Table 2.3 Alde-Ore Estuary SPA - populations for qualifying Annex I species

Species	Population[1]
Marsh harrier	3 pairs representing at least 1.9% of the breeding population in Great Britain (5 year mean, 1993-1997)
Avocet	104 pairs representing at least 17.6% of the breeding population in Great Britain (5 year mean, 1990-1994); 766 individuals representing at least 15.3% of the wintering population in Great Britain (5 year peak mean 1995/6 - 1999/00)[2]
Sandwich tern (*Sterna sandvicensis*)	169 pairs representing 1.2% of the British breeding population[3]
Little tern	48 pairs[1] (2% of the British breeding population)

[1] JNCC SPA review data (2001) except where stated
[2] Source: WeBS data
[3] RSPB data (average 2000/2001 figures)
[4] RSPB data (2000 figure)

The site also qualifies under Article 4.2 of the Directive by regularly supporting populations of European importance of the following migratory species (Table 4).

Table 2.4 Alde-Ore Estuary SPA - qualifying internationally important bird populations

Species	Population
Lesser black-backed gull (*Larus fuscus*)	21,700 pairs representing at least 17.5% of the World breeding population (Count as at 1998)[1]
Redshank (*Tringa totanus*)	2957 individuals representing at least 1.9% of the wintering Eastern Atlantic - wintering population (5 year peak mean 1995/6 - 1999/00)[2]

[1] JNCC SPA review data (2001) except where stated.
[2] Source: WeBS data

In addition, the area also qualifies under Article 4.2 of the Directive as a wetland of international importance by regularly supporting at least 20,000 birds. Over winter, the site supports a recorded 16,252 individual waterfowl (5 year peak mean 1995/6 -

1999/00)[2] including: black-tailed godwit *Limosa limosa islandica*, dunlin, lapwing (*Vanellus vanellus*), shoveler, teal, wigeon, shelduck, European white-fronted goose, redshank and avocet. During the breeding season, the area regularly supports 59,118 individual seabirds (count period ongoing) including: herring gull *Larus argentatus*, black-headed gull *Larus ridibundus*, lesser black-backed gull, little tern and Sandwich tern.

2.5.4 Deben Estuary SPA/Ramsar

The Deben Estuary SPA mainly consists of saltmarsh and intertidal mudflats with some areas of reedswamp, unimproved neutral grassland and scrub. The estuary is largely surrounded by agricultural land.

Photo 6. Upper saltmarsh vegetation on the Deben Estuary.

The Deben estuary supports approximately 28% of Suffolk's area of saltmarsh and displays the most complete range of the vegetation's community types in the County. A saltmarsh survey undertaken by the Suffolk Wildlife Trust in 1993 identified sixteen saltmarsh communities and two swamp communities covering a total of 238 ha. Low marsh communities, which are mainly situated towards the head of the estuary, are characterised by communities dominated by sea aster, annual seablite *Suaeda maritima*, saltmarsh grass and sea purslane. In places, particularly where steep cliffs abut the mudflats, virtually pure stands of common cord grass occur. Where former sea-walls have been breached (e.g. near Waldringfield on the western side of the Estuary) a saltmarsh community that is typical of formerly disturbed sites has become established. This is characterised by a mosaic of species such as sea milkwort *Glaux maritima*, sea lavender, sea arrow-grass *Triglochin maritima* and sea plantain *Plantago maritima*. Varying proportions of these species are also found in the more typical mid-marsh communities which become prevalent towards the lower end of the Estuary. Swamp communities occur in several places along the Estuary, usually as relatively narrow fringes but occasionally forming large stands. Such areas may be dominated by sea club-rush Scirpus maritimus or, most frequently, common reed.

The Estuary supports four nationally scarce plant species, namely: dittander *Lepidium latifolium*, marsh mallow *Althaea officinalis*, shrubby seablite *Suaeda fruticosa* and small cordgrass. The Estuary also supports a population of Endangered British Red Data Book mollusc *Vertigo angustior*. Martlesham Creek is one of the only fourteen sites in Britain where this species occurs. The nationally scarce *V. pusilla* has also been recorded.

A breeding wader and wildfowl survey (1997) undertaken by Suffolk Wildlife Trust found that the salt marsh of the Deben estuary is by far the most important habitat along the estuary for breeding waterfowl with 100 pairs of redshank, 98 pairs of oystercatcher and 75 pairs of shelduck recorded. The saltmarsh at Falkenham Creek was found to support the highest density of breeding redshank of any site on the Suffolk estuaries (30 pairs).

In comparison with the Alde-Ore and Blyth estuaries there are no appreciable areas of grazing marsh habitat along the Deben estuary. The only significant area is at Shottisham Creek, where there is approximately 80ha of semi-improved cattle grazed grassland. Water levels over parts of the site have been raised under the ESA scheme and now provide suitable habitat for breeding waders and wildfowl such as redshank, lapwing and shelduck. Small areas of semi-improved pasture are also present to the west of Ramsholt and at Kirton Creek. In the last couple of years the outfall sluice for the marshes at Ramsholt has been blocked leading to extensive winter and spring flooding of the grassland. This has proved to be an attractive feeding area to a number of waterfowl species, particularly shelduck, when mudflats are covered at high tide.

The Deben Estuary SPA qualifies under Article 4.1 of the EU Birds Directive by regularly supporting populations of European importance of the following Annex I species (see Table 2.5) in any season:

Table 2.5 Deben Estuary SPA - populations for qualifying Annex I species

Species	Population (5 yr mean 1995/6-1999/00)[1]
Avocet	310 individuals representing at least 6 % of the British wintering population

[1] Source: WeBS data

Other Annex 1 species wintering on this site include golden plover *Pluvialis apricaria*, hen harrier and short-eared owl *Asio flammeus*.

In addition, the site supports nationally important numbers of breeding and wintering wetland birds. Breeding species include shelduck, gadwall, teal, shoveler, Redshank, oystercatcher, ringed plover *Charadrius hiaticula* and snipe. Wintering species include teal, pintail *Anas acuta*, wigeon, goldeneye, oystercatcher, dunlin, curlew *Numenuis arquata* and twite *Carduelis flavirostris*. Nationally important numbers of dark-bellied brent goose *Branta bernicla bernicla*, shelduck and black-tailed godwit occur during the winter months.

2.5.5 Stour and Orwell Estuaries SPA/Ramsar

The Stour and Orwell Estuaries SPA is a wetland of major international importance comprising of extensive mudflats, low cliffs, saltmarsh, and small areas of vegetated shingle on the lower reaches. It provides wintering habitats for important wetland bird species, particularly wildfowl and waders. Agricultural land outside the SPA provides a feeding area for dark-bellied brent geese and roosting area for waders. The site has close ecological links with Hamford Water and the Mid-Essex Coast SPAs, lying to the south.

On the Orwell, extensive mudflats border the channel and support patches of eelgrass *Zostera marina* and dwarf eel grass *Zostera noltii*. The saltmarsh tends to be sandy and fairly calcareous with a wide range of communities. Glasswort and cord grass are the principal colonisers of the mud and sea aster is very abundant on the lower marsh. The central areas of marsh are dominated by common saltmarsh grass, sea purslane and sea lavender. There are small areas of vegetated shingle on the foreshore of the lower reaches, but most of the saltmarsh is fringed by sea couch *grass Elymus pycnanthus* or by common reed. The wetland complex of the Suffolk Wildlife Trust at Trimley supports wintering and breeding avocet, amongst many waterfowl species, and is an important feeding and roosting area for dark-bellied brent geese. The grazing marshes at Shotley form an integral part of the ornithological interest of the site especially for feeding brent geese and wigeon and breeding redshank and lapwing.

The Stour Estuary is the largest of the Suffolk estuaries and straddles the Suffolk-Essex border. It is a broad estuary characterised by extensive intertidal flats that are sandy in the outer section and muddier towards the inner part of the estuary. The five main bays at Seafield, Holbrook and Erwarton on the north and Jacques and Copperas on the south encompass most of the intertidal flats. The mud is extremely rich in invertebrates and this factor, coupled with its relative freedom from disturbance, enables the Estuary to support a large number and diverse range of waterfowl. Saltmarsh vegetation is present at various locations within the Estuary. Higher saltmarsh is dominated by saltmarsh grass and sea purslane with sea aster and sea lavender scattered throughout. Adjoining lower areas are colonised by clumps of sea lavender, glasswort and cord grasses which grade through pure stands of cord grass into large expanses of mud. These are colonised by algae such as *Enteromorpha* and eelgrasses.

During the winter the main concentration of birds tends to be in Holbrook Bay with roosts along the more protected northern shore (e.g. Brantham, Stutton Mill and Netherall). The inner, muddy section of the estuary favours birds such as redshank, dunlin and black-tailed godwit, whereas most of the oystercatcher, grey plover and knot congregate towards the outer, sandier section of the Estuary. Wigeon graze on *Zostera* and *Enteromorpha* beds and winter in large numbers on a par with nearby Hamford Water. Pintail congregate with the wigeon after arrival in Holbrook Bay reaching peak numbers in mid-October and then again in January-February. Shelduck breed in the estuary and are present throughout the year. They favour areas of high invertebrate density and concentrate in the upper reaches roosting on the saltmarsh with other dabbling ducks. Wintering dark-bellied brent geese feeding on *Z.angustifolia* prefer the lower reaches of the Essex shore of the Estuary.

The Stour and Orwell Estuaries SPA qualifies under Article 4.1 of the EU Birds Directive by supporting populations of European importance of the following Annex I species (see Table 2.6) in any season:

Table 2.6 Stour and Orwell Estuaries SPA - populations for qualifying Annex I species

Species	Population[1]
Hen Harrier	10 individuals representing at least 1.3% of the wintering population in Great Britain (Count as at 1996/7)

[1] JNCC SPA Review data (2001) except where stated.

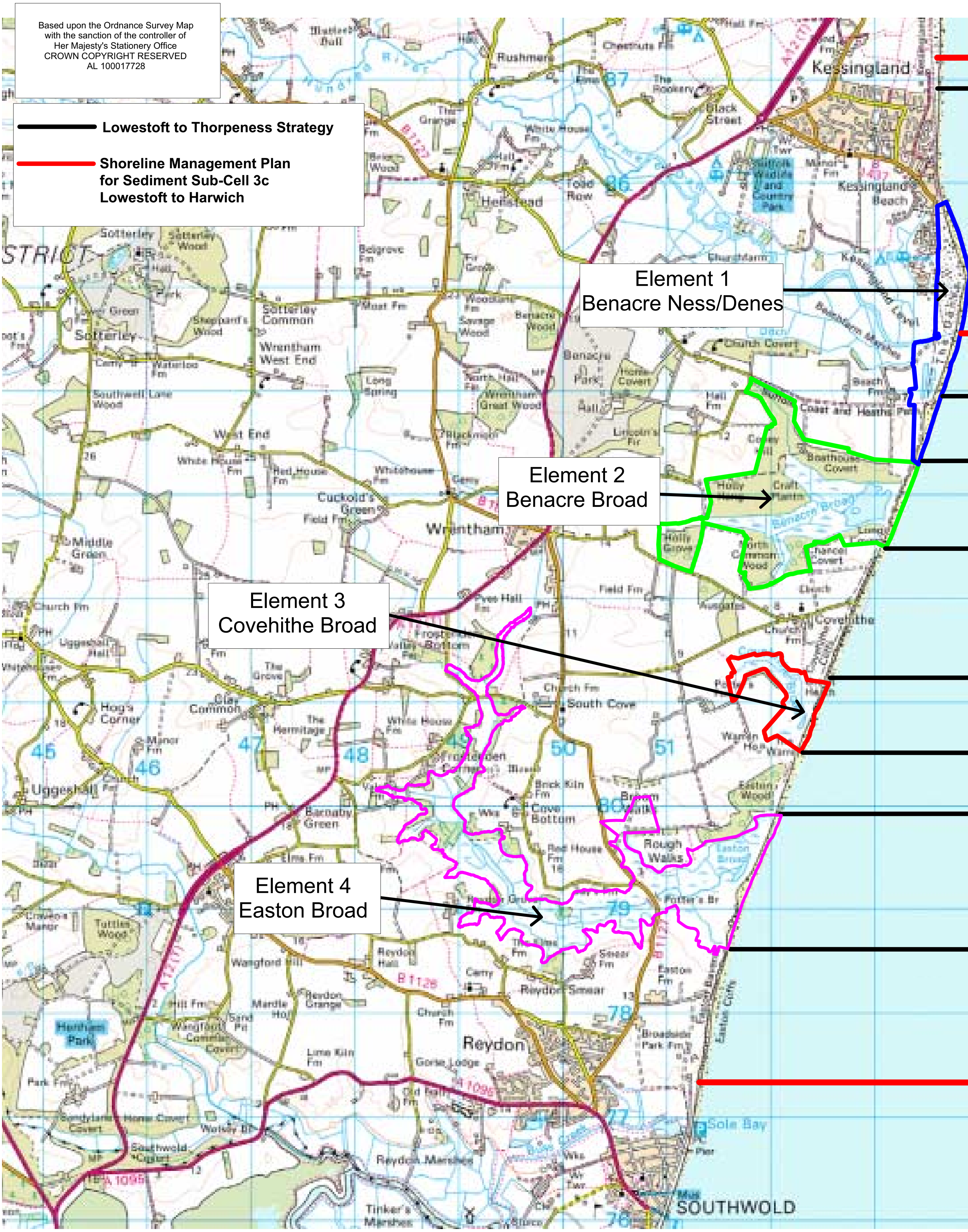
The site also qualifies under Article 4.2 of the Directive by regularly supporting populations of European importance of the following migratory species (Table 2.7) in any season.

Table 2.7 Stour and Orwell Estuaries SPA - qualifying internationally important bird populations

Species	Population (5 yr peak mean 1995/6-1999/0)[1]
Dark bellied brent goose	3140 individuals representing at least 1% of the wintering Northwestern Europe population
Shelduck	2800 individuals representing at least 1% of the wintering Northwestern Europe population
Pintail	735 individuals representing at least 1.2% of the wintering Northwestern Europe population
Ringed plover	531 individuals representing at least 1% of the wintering Europe/Northern Africa - wintering population
Grey plover	3049 individuals[2] representing at least 2.4% of the wintering Eastern Atlantic - wintering population
Dunlin	18,799 individuals representing at least 1.3% of the wintering Northern Siberia/Europe/Western Africa population
Black-tailed godwit	2626 individuals[3] representing at least 3.7% of the wintering Iceland - breeding population
Redshank	3580 individuals representing at least 2.3% of the wintering Eastern Atlantic - wintering population
Turnstone	861 individuals representing at least 1.2% of the wintering Western Palearctic - wintering population

[1] Source: WeBS data;
[2] Incomplete count winter 1997/8;
[3] Incomplete count winter 1996/7.

In addition, the area qualifies under Article 4.2 of the Directive (79/409/EEC) as a wetland of international importance by regularly supporting at least 20,000 waterfowl. Over winter, the area supports 58,851 individual waterfowl (5 year peak mean 1995/6 - 1999/00)[1] including: cormorant, pintail, ringed plover, grey plover, dunlin, black-tailed godwit, redshank, shelduck, great crested grebe, curlew, dark-bellied brent geese, wigeon, goldeneye, oystercatcher, lapwing, knot and turnstone.



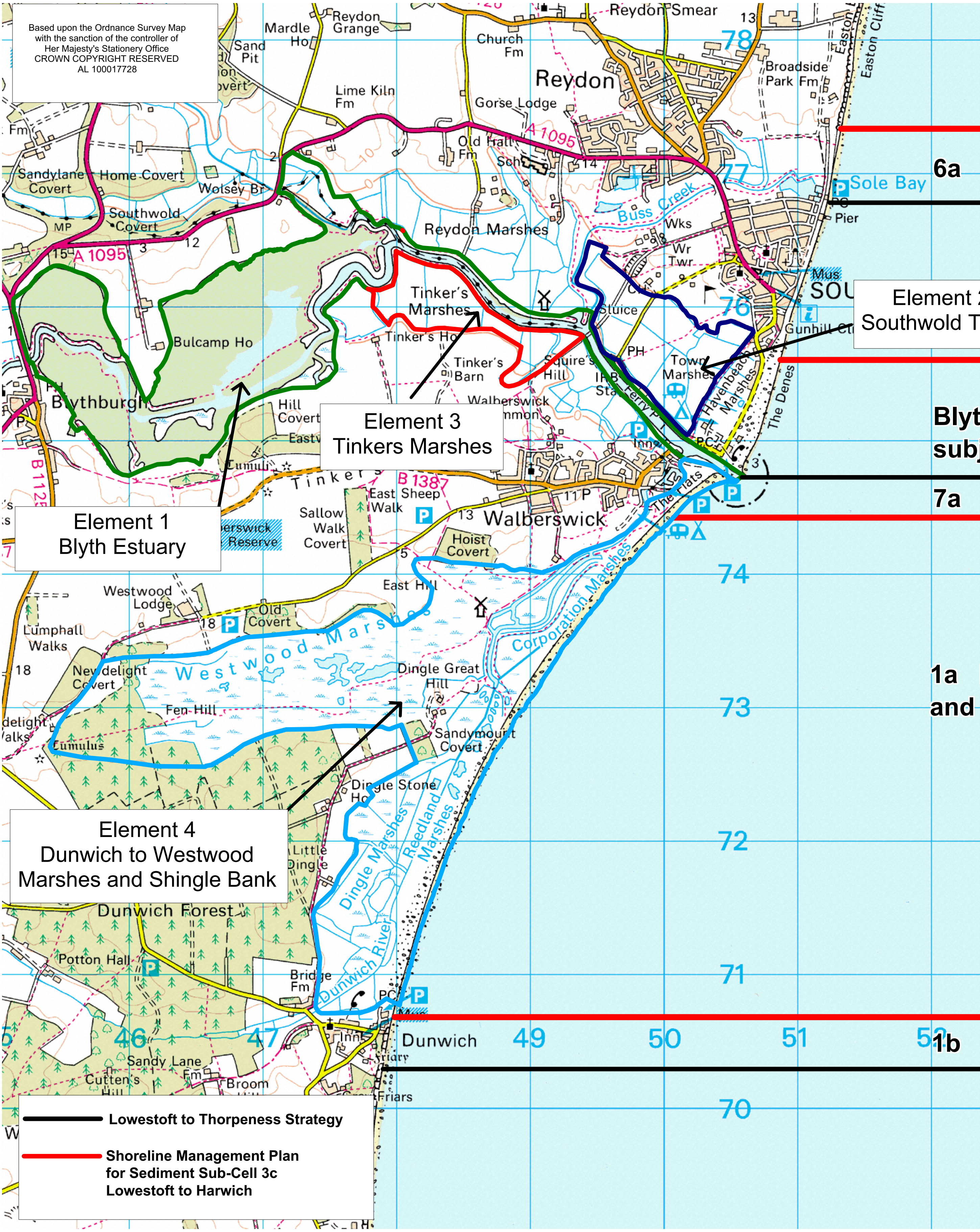
Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Shoreline Management Strategies for Kessingland to Easton Cliffs and Location of Benacre and Easton Elements

G: G5472/Suffolk CHAMP/ Mapinfo/ Elements Benacre.wor



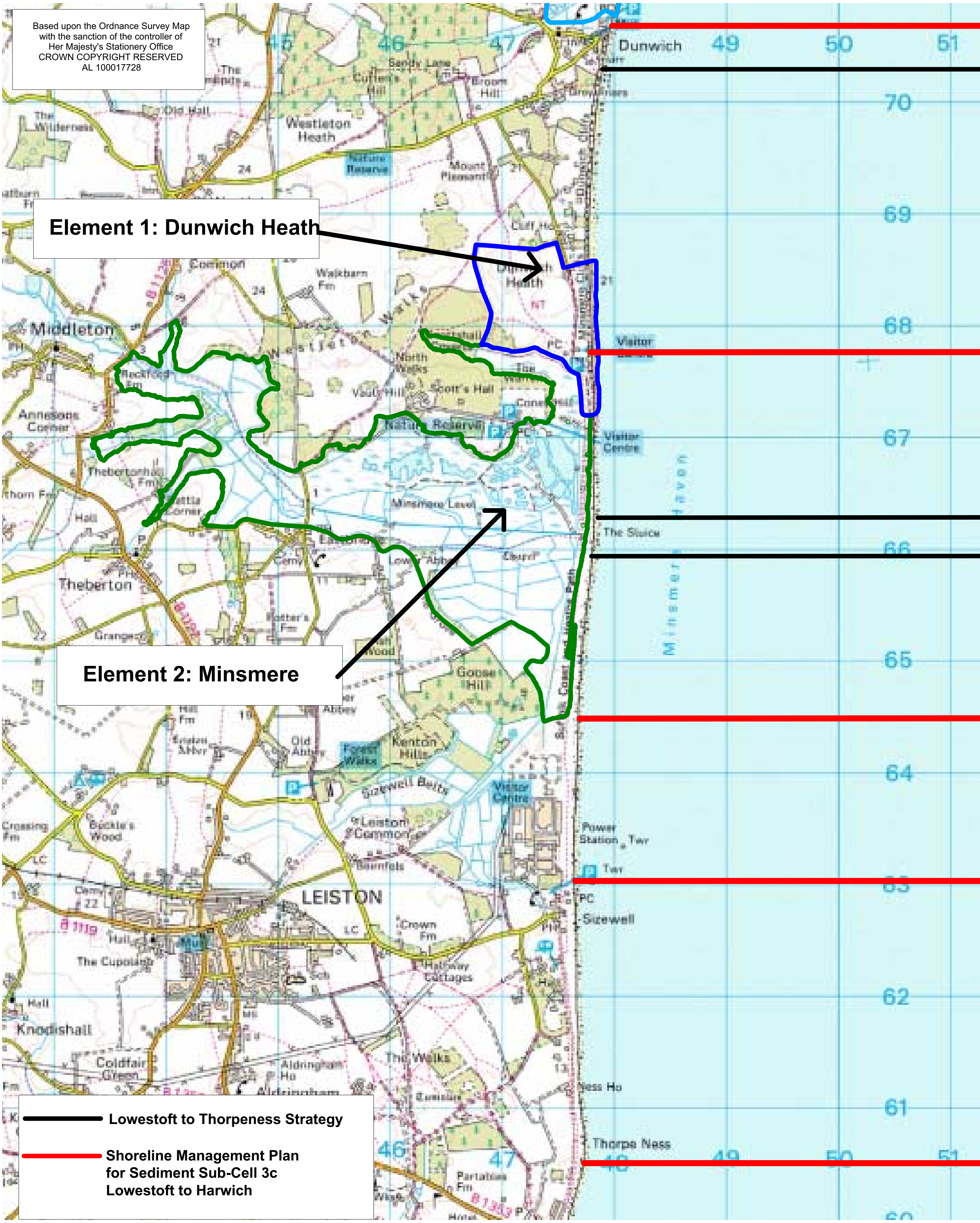
Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Shoreline Management Strategies for
Easton Cliffs to Dunwich and
Walberswick/Minsmere Elements

G: G5472/Suffolk CHAMP/ Mapinfo/ Elements Benacre.wor



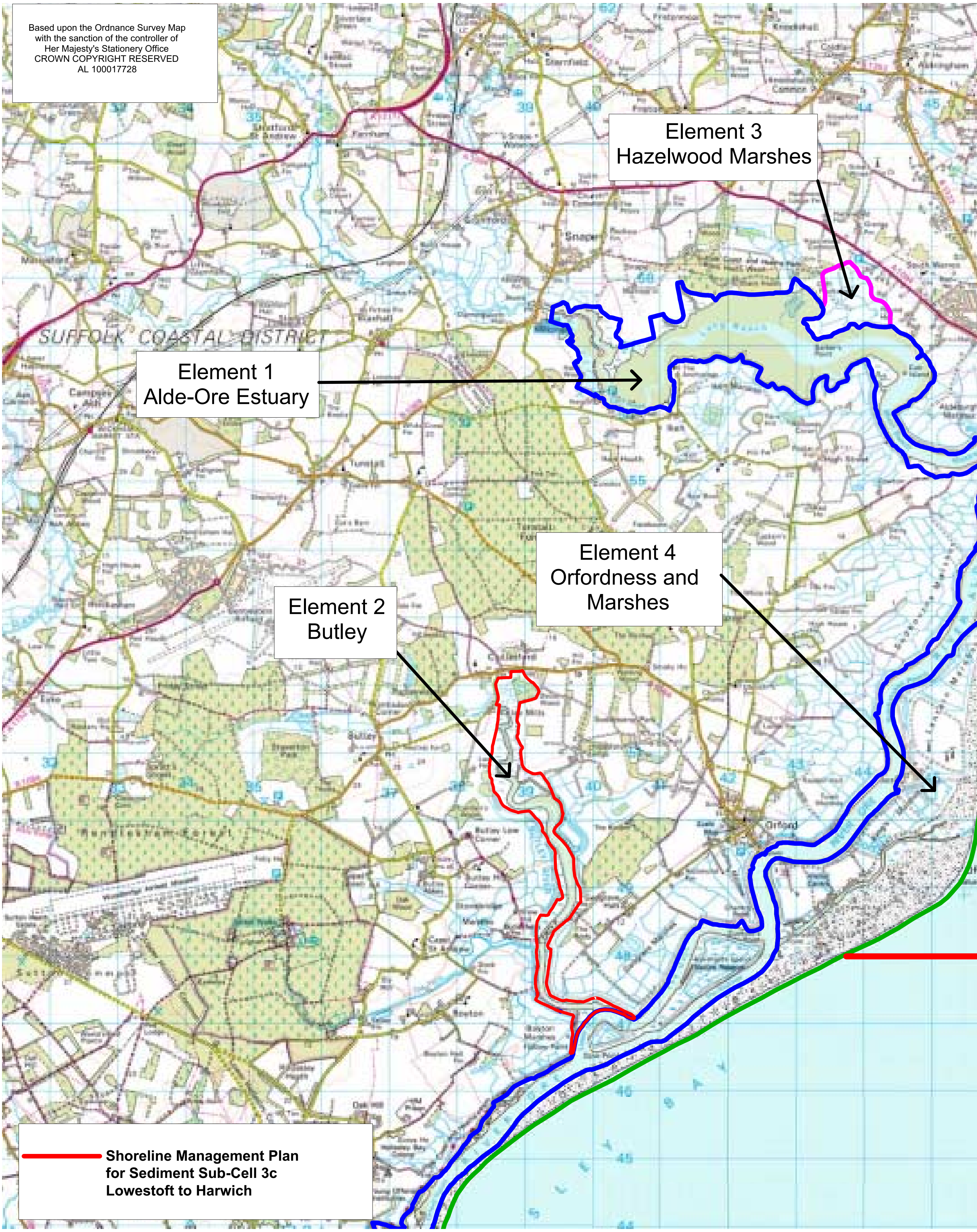
Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

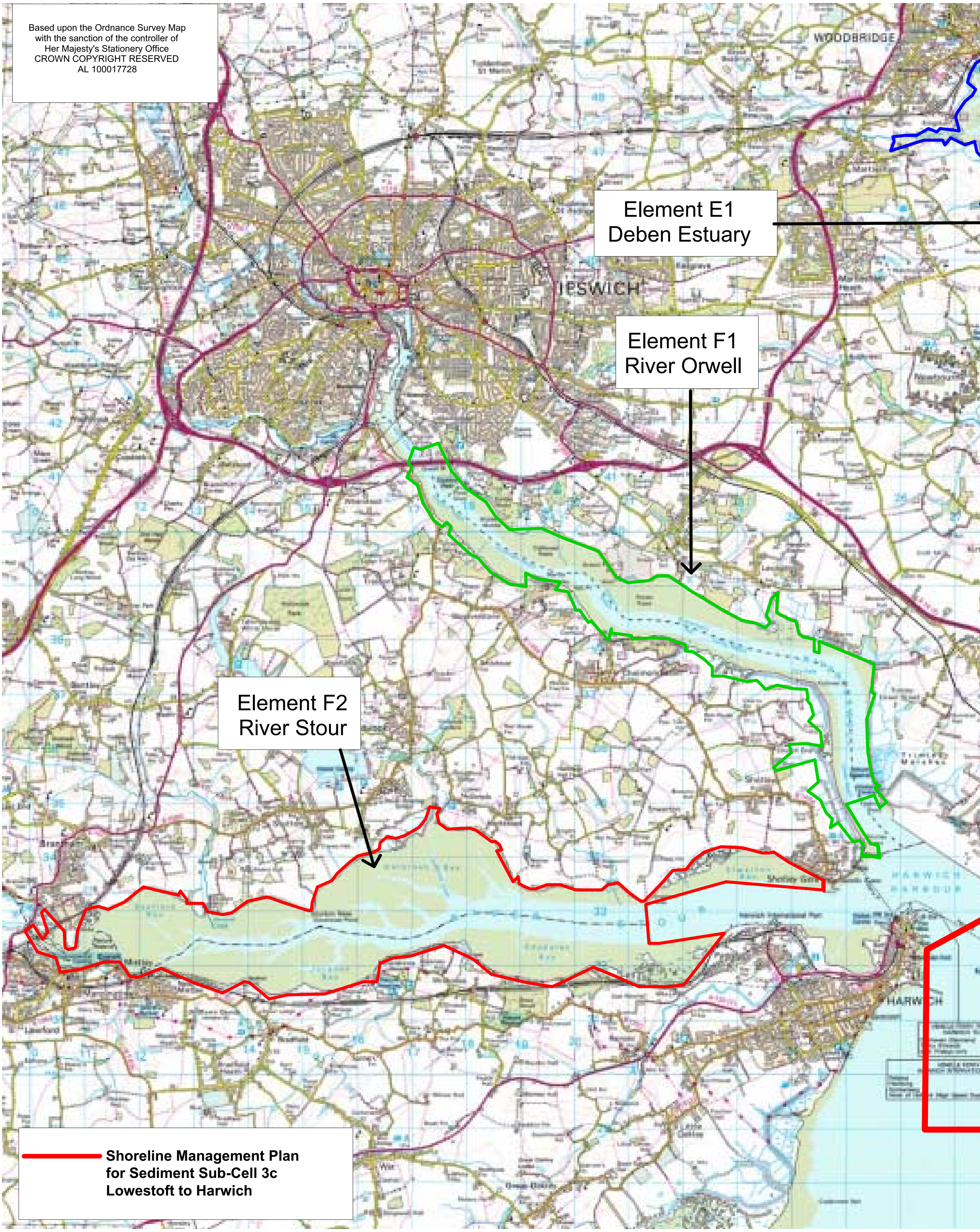
Shoreline Management Strategies for
Dunwich to Thorpe Ness and Blyth Elements

G: G5472/Suffolk CHAMP/ Mapinfo/ Elements Benacre.wor



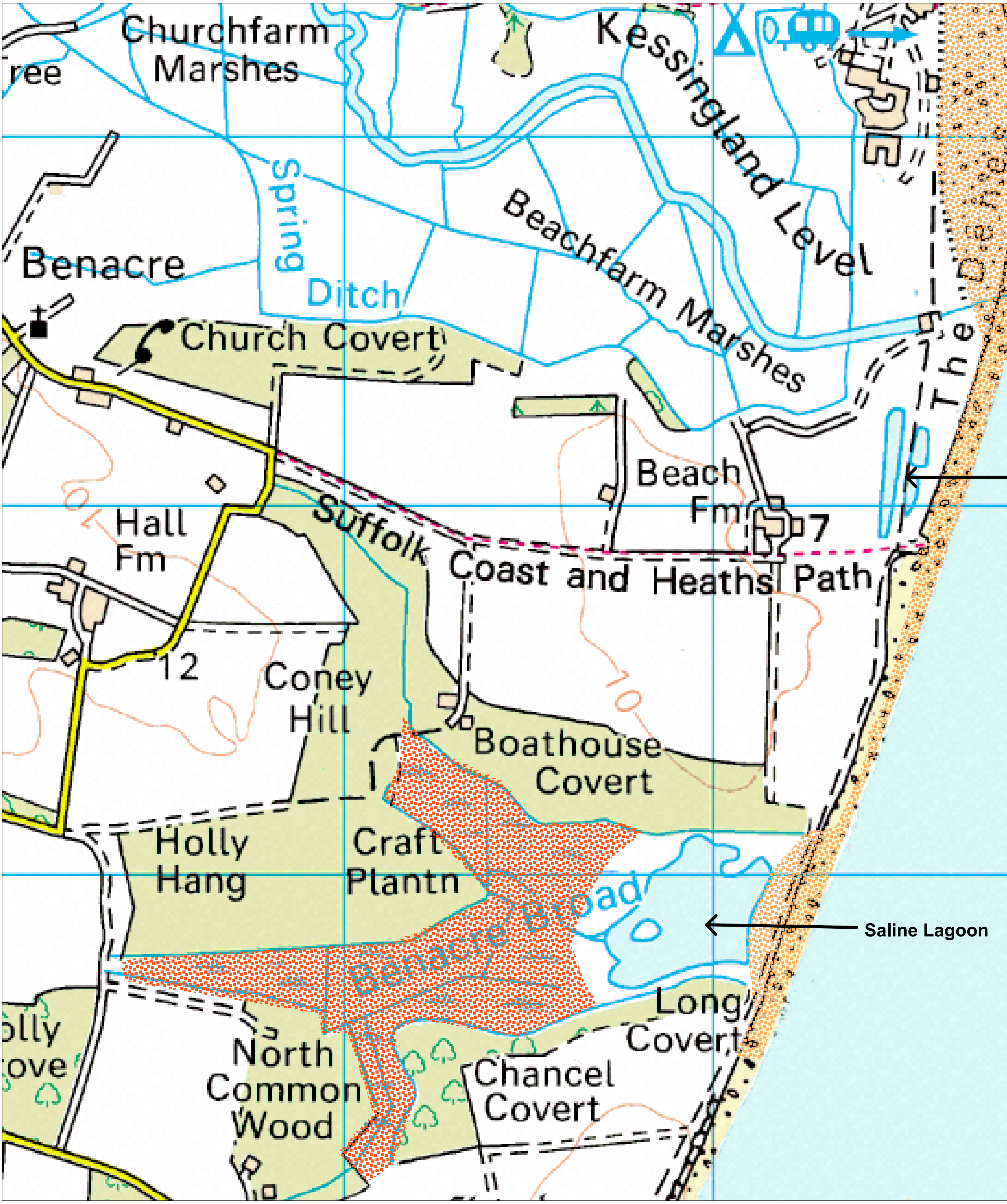
G: G5472/Suffolk CHAMP/ Mapinfo/ Elements Benacre.wor

Project	Title
Suffolk Coast and Estuaries Coastal Habitat Management Plan	Shoreline Management Strategies for Thorpeness to Shingle Street and Location of Alde/Ore Elements



G: G5472/Suffolk CHAMP/ Mapinfo/ Elements Benacre.wor

Project	Title
Suffolk Coast and Estuaries Coastal Habitat Management Plan	Shoreline Management Strategies for Shingle Street to Felixstowe including Alde/Ore, Deben and Stour/Orwell Elements

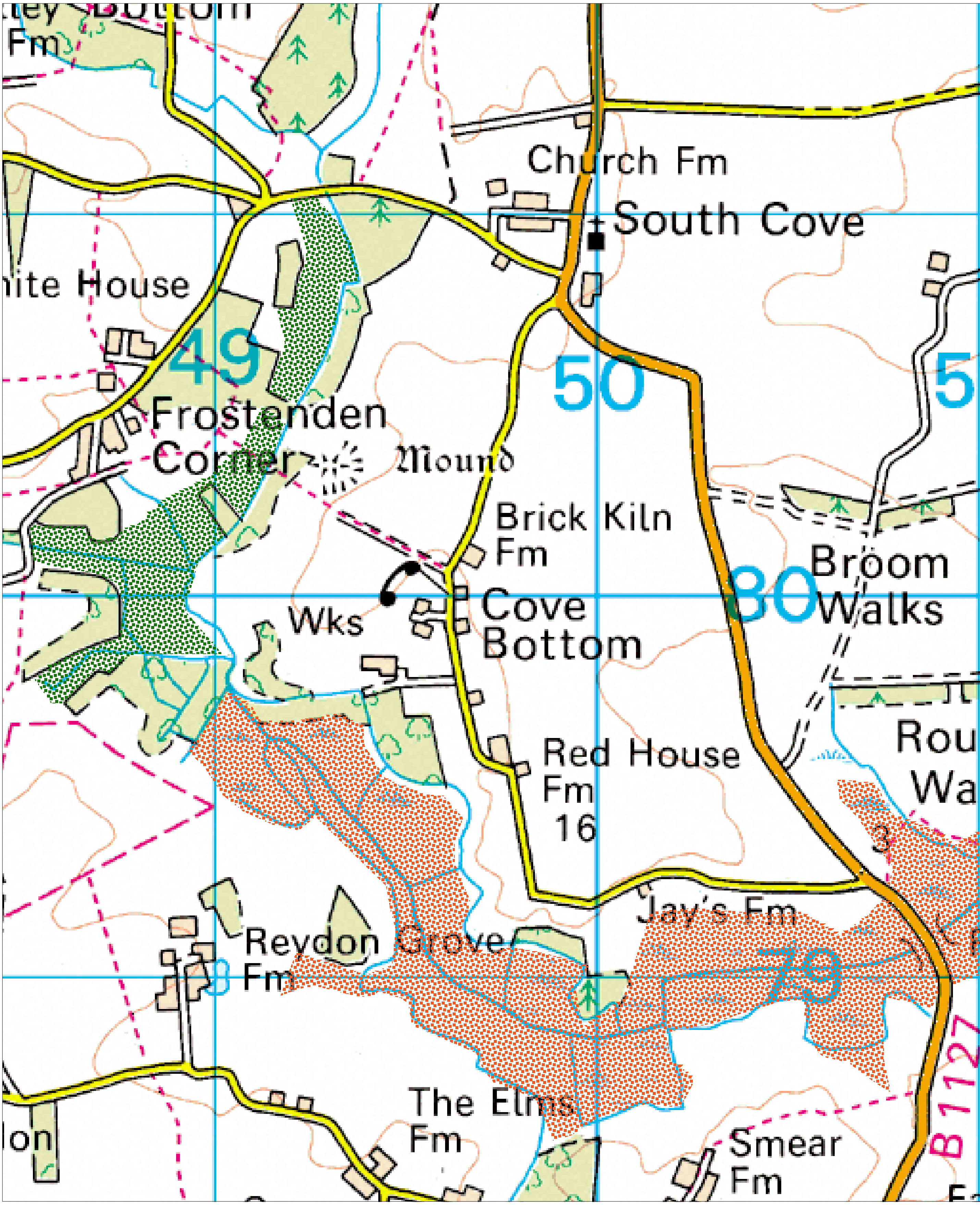


Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Indicative Map of Designated Habitats
of Benacre and The Denes

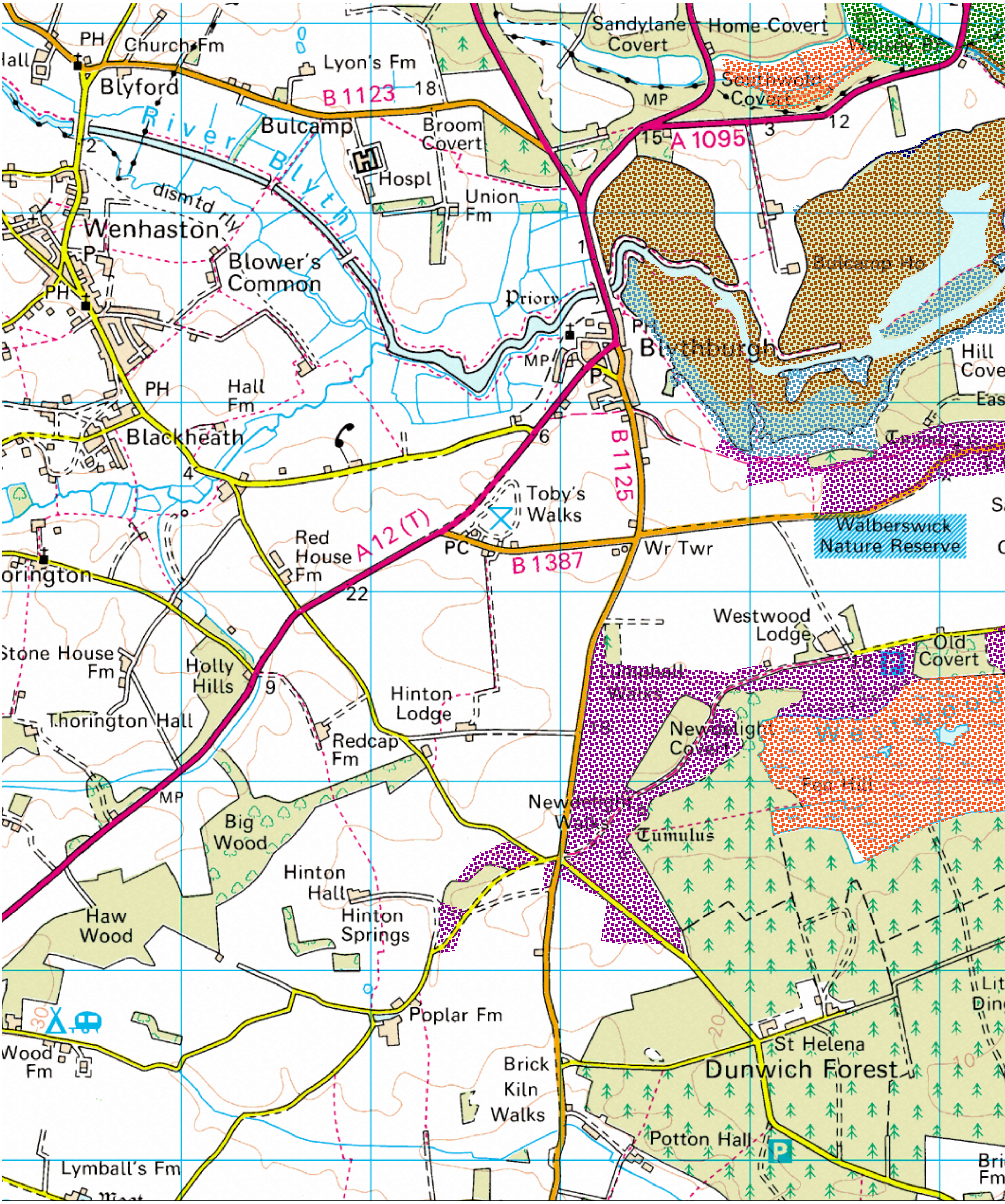


Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Indicative Map of Designated Habitats
from Covehithe Cliffs to Easton Bavents

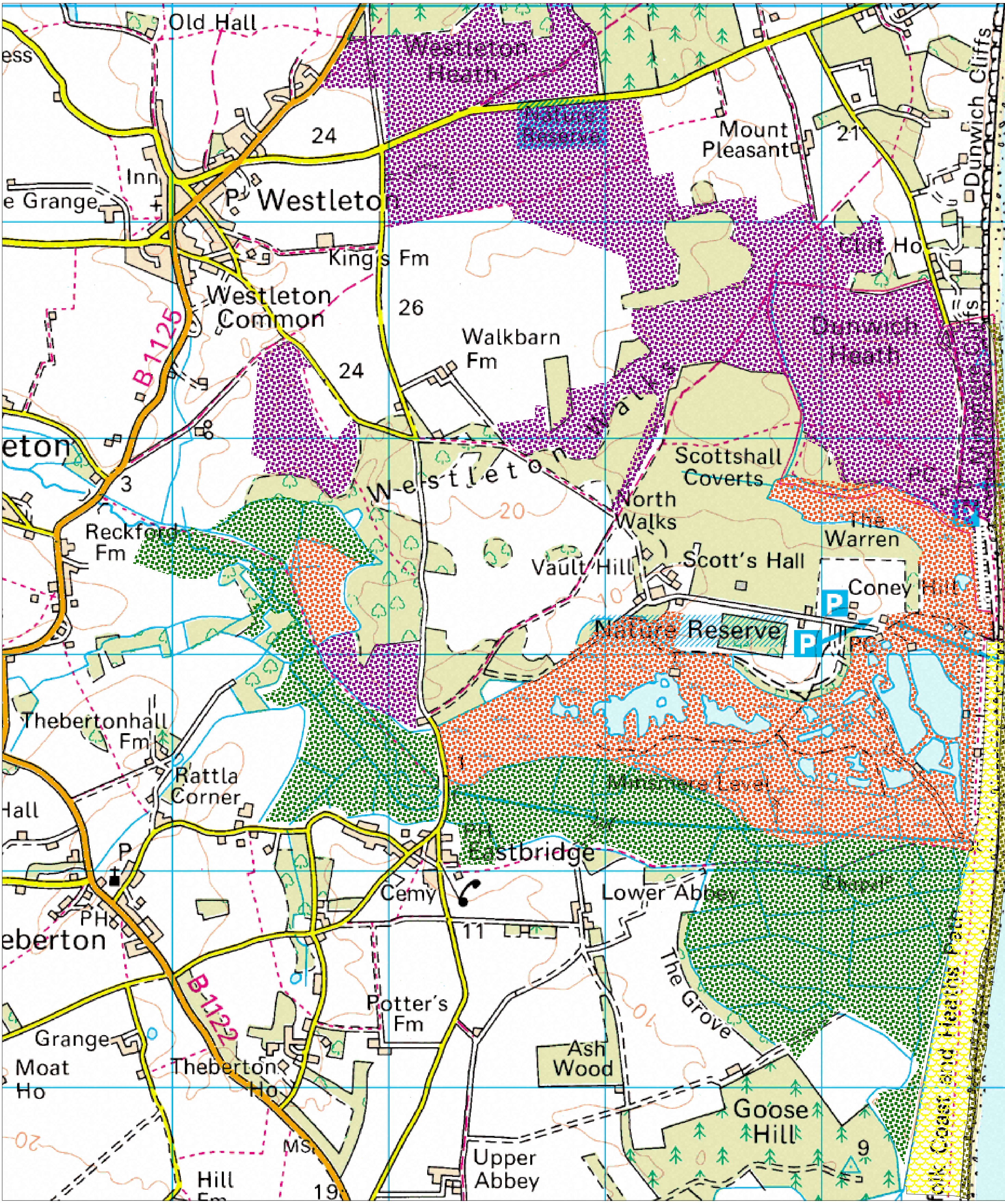


Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Indicative Map of Designated Habitats of Minsmere and Walberswick

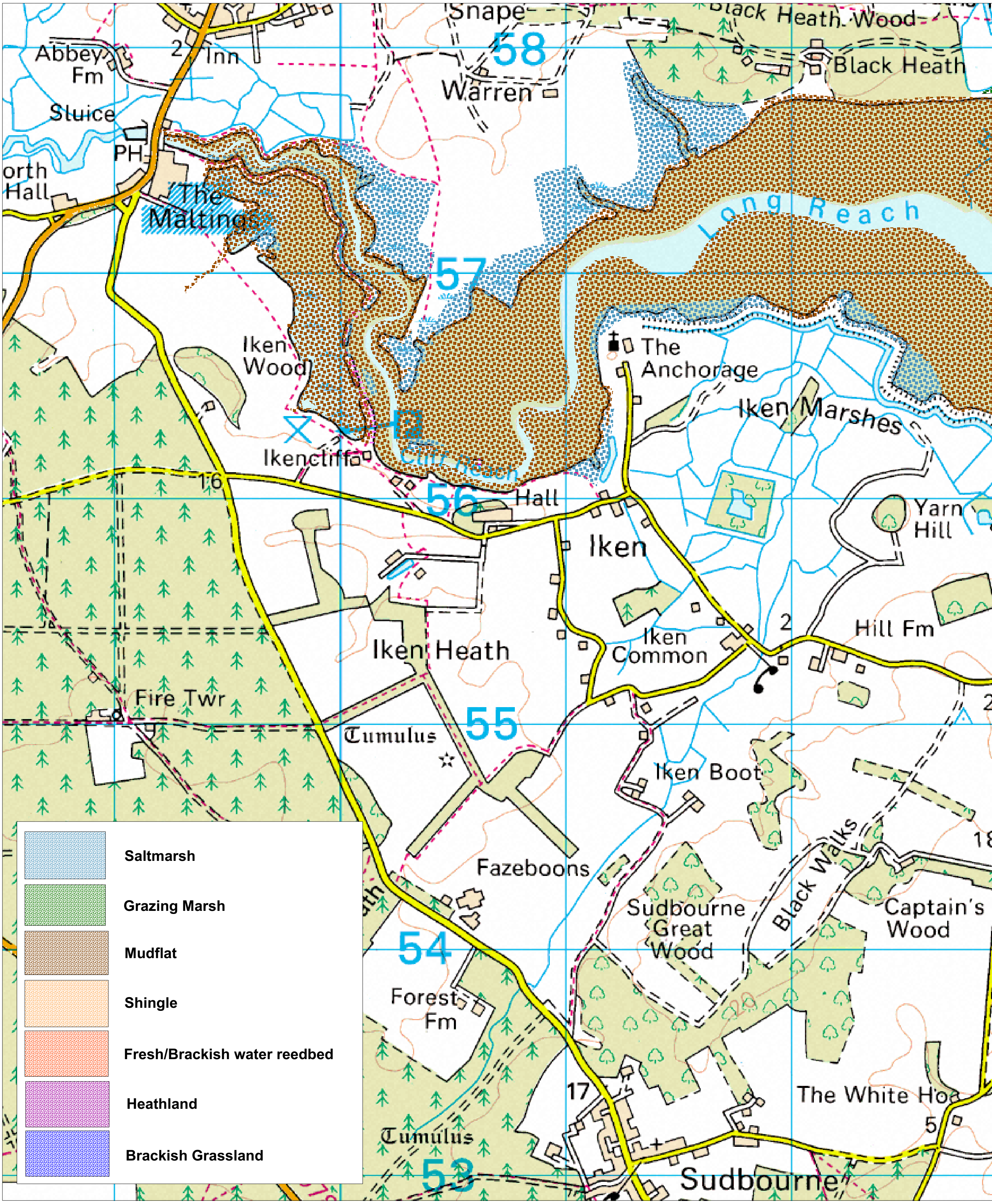


Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plans

Title

Indicative Map of Designated Habitats of Dunwich to Minsmere



Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Indicative Map of Designated Habitats of the River Alde

Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

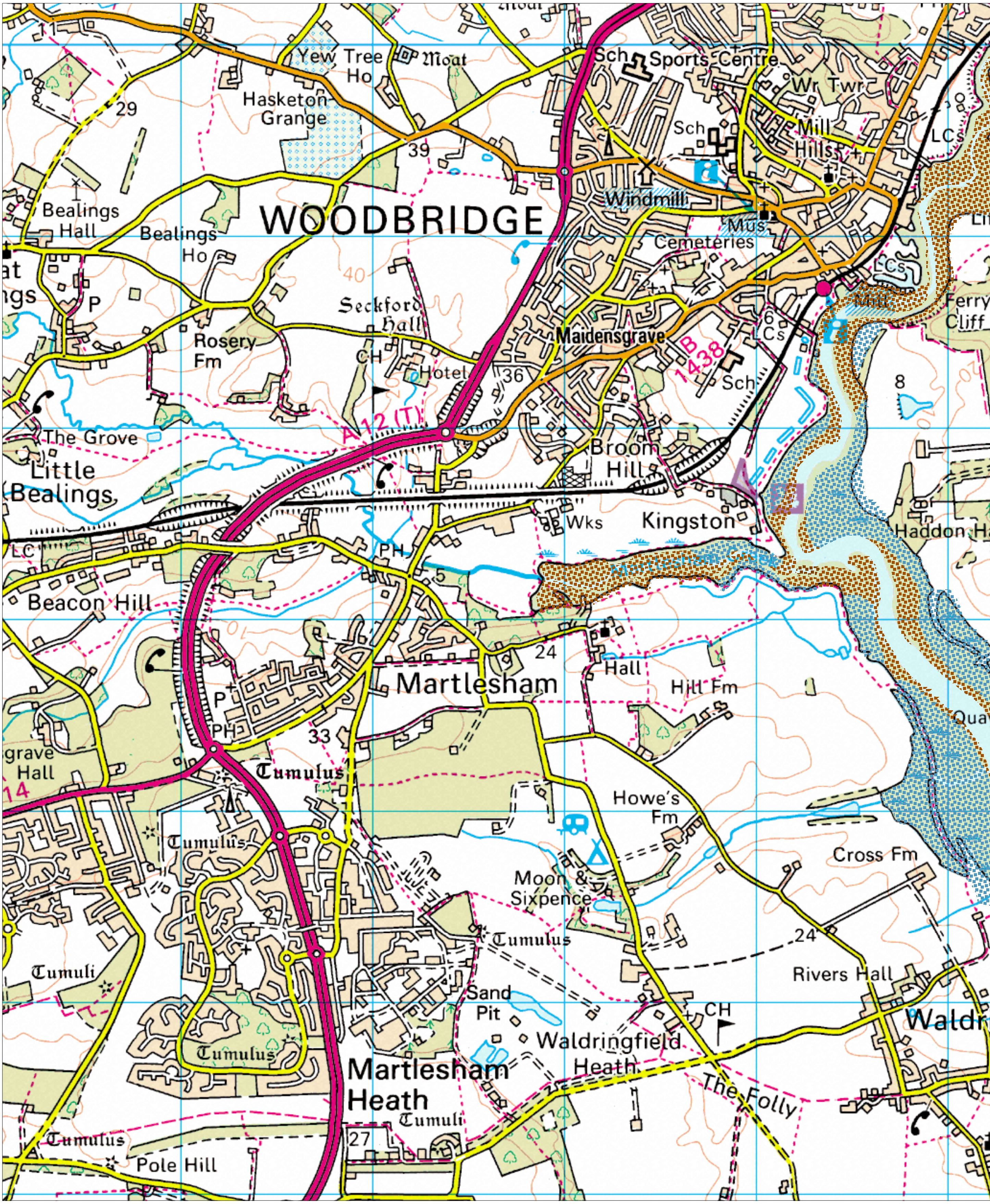
Indicative Map of Designated Habitats of the River Ore, Orfordness and the Butley River

Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Indicative Map of Designated Habitats of Shingle Street

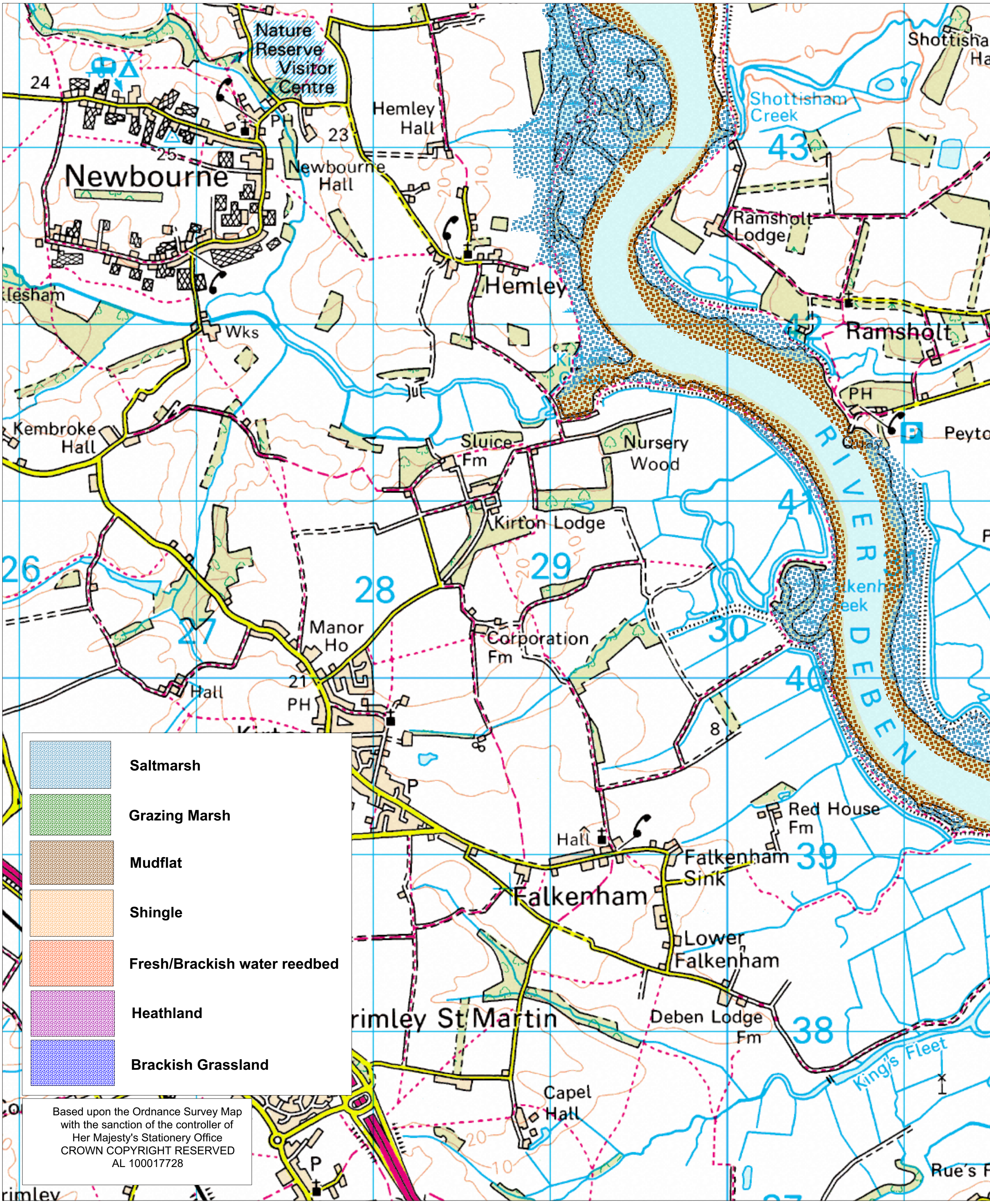


Project

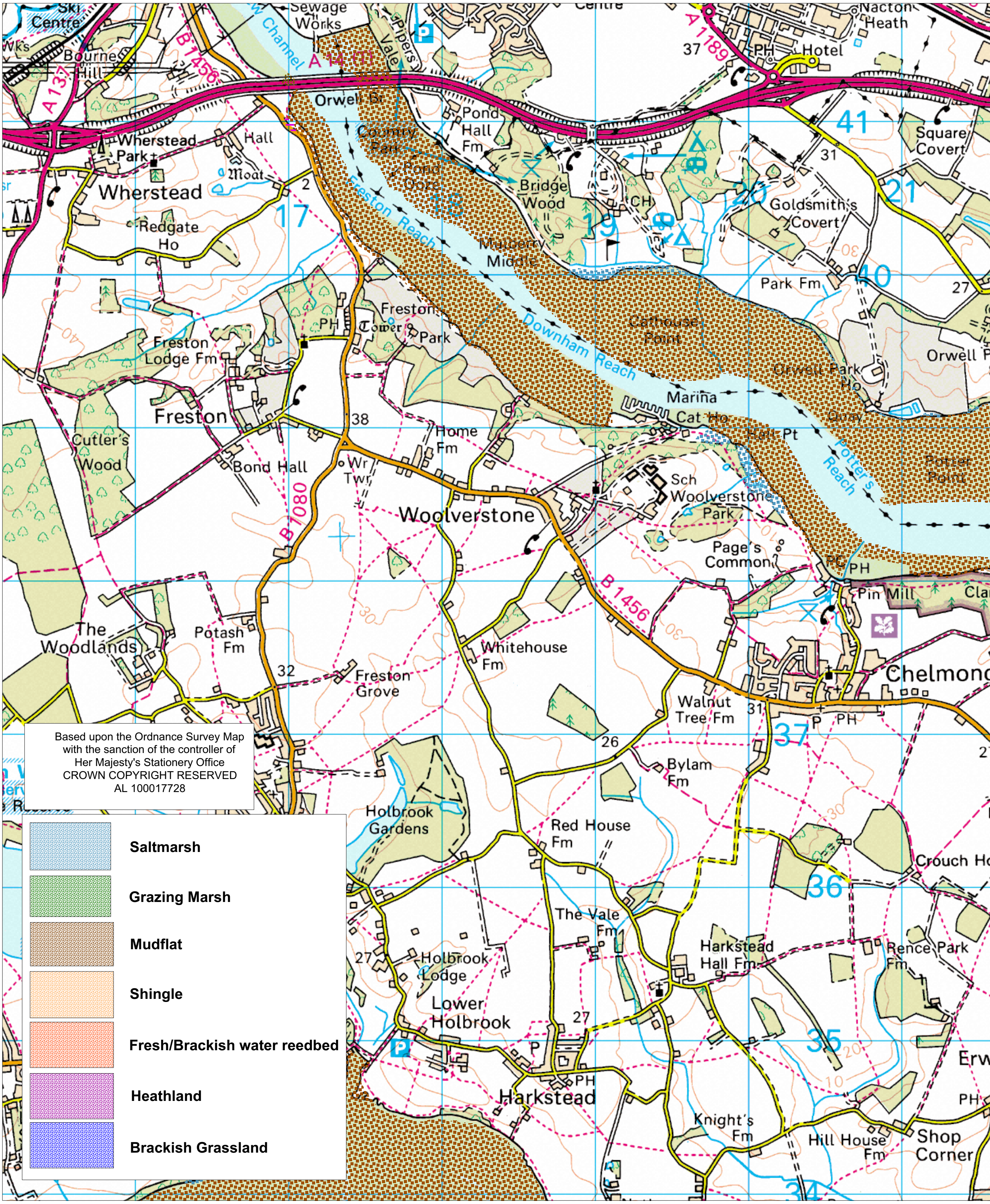
Suffolk Coast and Estuaries
Coastal Habitat Management Plans

Title

Indicative Map of Designated Habitats of the Upper Deben Estuary



Project	Title
Suffolk Coast and Estuaries Coastal Habitat Management Plan	**Indicative Map of Designated Habitats of the Lower Deben Estuary**

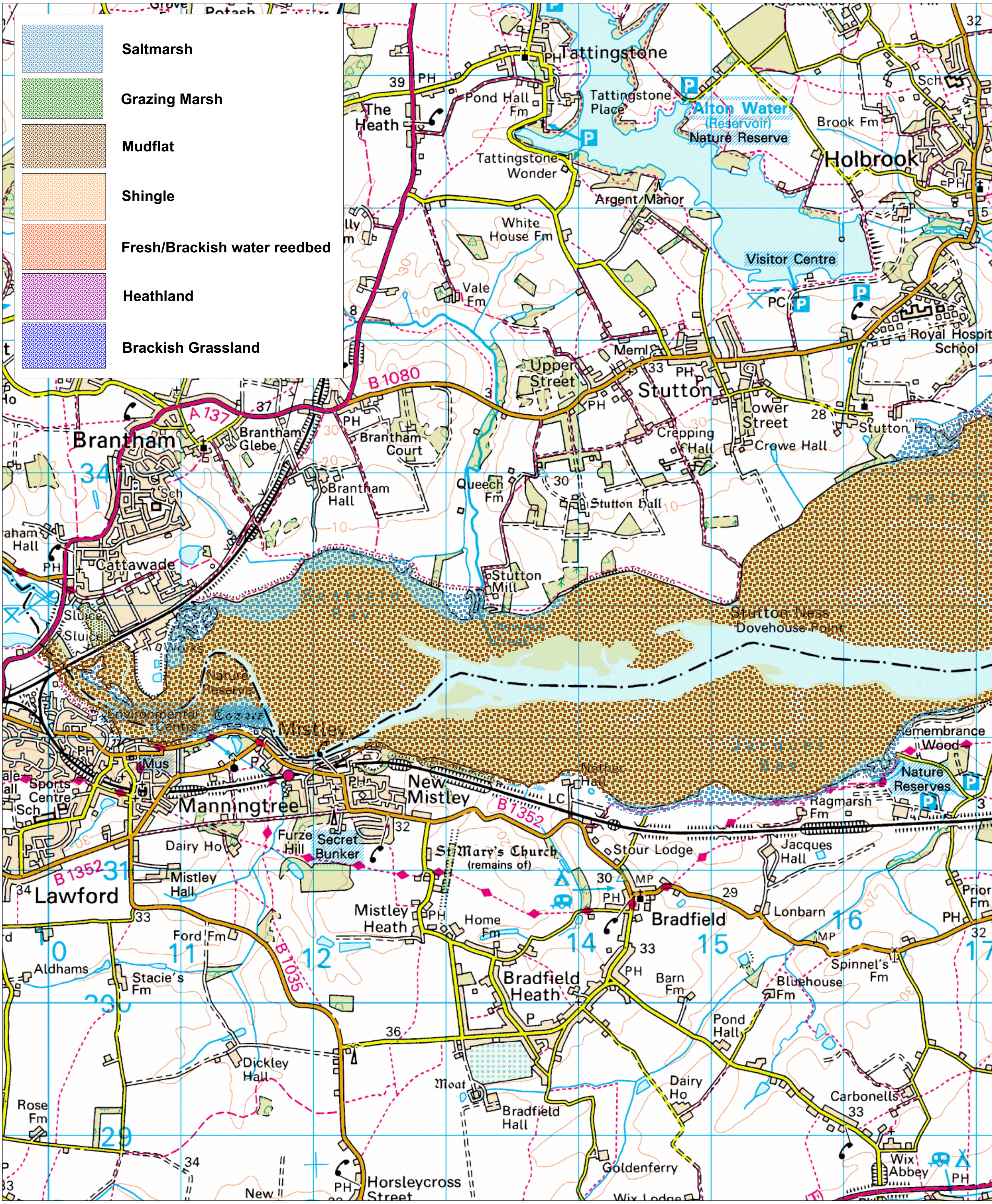


Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Indicative Map of Designated Habitats of the Orwell Estuary



Project

Suffolk Coast and Estuaries
Coastal Habitat Management Plan

Title

Indicative Map of Designated Habitats of the Stour Estuary

3 CONSERVATION OBJECTIVES

This section provides a summary of the conservation objectives that have been developed for the designated European interest features of the cSACs and SPAs within the CHaMP area. For all of the features, maintenance implies restoration if the feature is not currently in favourable condition. Further information on the development of the Conservation Objectives and associated Favourable Condition Tables can be gained from English Nature. Information and FCTs for marine designated features is also available in the Regulation 33 packages which have been produced for designated areas with a marine component to them.

3.1 Candidate Special Areas of Conservation

3.1.1 Benacre to Easton Bavents cSAC

Subject to natural change, to maintain, in favourable condition:

- Saline lagoons.

3.1.2 Minsmere to Walberswick cSAC

Subject to natural change, to maintain, in favourable condition:

- Annual vegetation of drift lines
- Perennial vegetation of stony banks.

To maintain in favourable condition:

- Dry heaths

3.1.3 Alde Ore and Butley cSAC

Conservation objectives for this cSAC are not yet available. However, on the basis of the features for which the site is being considered the following objectives would apply. This has to be confirmed by English Nature.

Subject to natural change, to maintain in favourable condition

- Atlantic saltmeadows; including the following subfeatures: low/mid-marsh communities, upper marsh communities and upper marsh transitional communities;
- Mudflats and sandflats not covered by the sea at low tide, including the following subfeatures: mud communities, muddy sand communities and sand and gravel communities; and
- Estuaries, including the following subfeatures: Saltmarsh communities**,** intertidal mudflat and sandflat communities, subtidal mud communities, subtidal muddy sand communities and subtidal mixed sediment communities

3.1.4 Orfordness cSAC

Subject to natural change, to maintain in favourable condition:

- Saline lagoons,
- Annual vegetation of drift lines
- Perennial vegetation of stony banks.

3.2 Special Protection Areas, Ramsar Sites and Sites of Special Scientific Interest

The conservation objectives for the designated SPAs and SSSIs are given in the following sections. Conservation objectives for the Ramsar sites have not yet been developed, however, the integrity of Ramsar designated features has been considered throughout the CHaMP process. With respect to the bird element of the Ramsar designation it is likely that the conservation objectives for the SPA would be applicable. For all SPAs the conservation objectives apply to the habitats present within the site that are utilised by the bird populations for which the SPA has been designated.

3.2.1 Benacre to Easton Bavents SPA/Ramsar

The conservation objectives developed for the above site state that, subject to natural change, the habitats listed in Table 3.1 should be maintained in favourable condition. Objectives have been set out for bird species of European importance within the following categories: Annex I species. For the SSSI, only habitats in addition to those covered by the European Marine site (i.e. objectives stated in the Reg. 33 guidance) are listed.

Table 3.1 Habitats to which the Conservation Objectives for Benacre to Easton Bavents SPA and SSSI are applicable.

		Annex I (little tern)	**Annex I** (marsh harrier & bittern)
Designated Site/Area	**SPA (Reg. 33)**	- Shingle - Shallow coastal waters	
	SPA/ SSSI		- Swamp - Marginal and inundation - Standing water

3.2.2 Minsmere to Walberswick SPA and SSSI

The conservation objectives have been set out for bird species of European importance and they state that, subject to natural change, the habitats listed in Table 3.2 should be maintained in favourable condition. For the SSSI, only habitats in addition to those covered by the European Marine site (i.e. objectives stated in the Reg. 33 guidance) are listed.

Table 3.2 Habitats to which the conservation objectives for the Minsmere-Walberswick SPA and SSSI are applicable.

		Annex I (Little tern)	**Annex I** (Avocet , bittern, marsh harrier, nightjar and hen harrier)	**Migratory Waterfowl Assemblage** (Gadwall, teal, shoveler European white-fronted goose)
Designated Site/Area	**SPA (Reg. 33)**	- Shingle - Shallow coastal waters		
	SPA/SSSI		- swamp, - marginal and inundation - standing water - grassland - coastal lagoons - marsh - heathland.	- grassland, - marsh - standing water**.**

The bird species named in Table 3.2 are those specified by English Nature in their original conservation objectives for SPAs and SSSIs. Analysis of the most recent information on bird usage of the site (see Section 2.3.3) indicates that the Annex I species, woodlark is also present within the Minsmere-Walberswick SPA in numbers of European importance. Specific conservation objectives have not yet been developed for this species.

3.2.3 Alde-Ore Estuary SPA and SSSI

Conservation objectives have been set out for bird species of European importance within the following categories: Annex I species, migratory waterfowl and wintering waterfowl. The conservation objectives state that, subject to natural change, the habitats listed should be maintained in favourable condition. For the SSSI, only habitats in addition to those covered by the European Marine site (i.e. objectives stated in the Reg. 33 guidance) are listed.

Table 3.3 Conservation Objectives for the Alde Ore Estuary SPA and SSSI.

		Annex I (Avocet, little tern, sandwich tern, ruff)	**Annex 1** (Marsh harrier)	**Migratory Species** (Lesser black-backed gull, redshank)
Designated Site/Area	**SPA (Reg. 33)**	- Shingle - Shallow coastal waters - Saltmarsh - Intertidal mudflats and sandflats		- Shingle - Saltmarsh - Shallow coastal waters - Intertidal mudflats and sandflats
	SPA/SSSI	N/A	- Grazing marsh	- Shingle areas above MHW

3.2.4 Deben Estuary SPA and SSSI

Conservation objectives have been set out for bird species of European importance within the following categories: Annex I species. The conservation objectives state that, subject to natural change, the habitats listed in Table 3.4 should be maintained in favourable condition. For the SSSI, only habitats in addition to those covered by the European Marine site (i.e. objectives stated in the Reg. 33 guidance) are listed.

Table 3.4 Conservation Objectives for the Deben Estuary SPA and SSSI.

		Annex I (Avocet)
Designated Site/Area	**SPA (Reg. 33)**	- Shallow coastal waters - Saltmarsh - Intertidal mudflats and sandflats

3.2.5 Stour and Orwell Estuaries SPA/Ramsar

Conservation objectives have been set out for bird species of European importance within the following categories: Annex I species, migratory waterfowl and wintering waterfowl. The conservation objectives state that, subject to natural change, the habitats listed in Table 3.5 should be maintained in favourable condition. For the SSSI, only habitats in addition to those covered by the European Marine site (i.e. objectives stated in the Reg. 33 guidance) are listed.

Table 3.5 Conservation Objectives for the Stour and Orwell Estuaries SPA, Ramsar and SSSI.

		Annex 1 (Marsh harrier)	**Migratory Species** (Dark bellied brent goose, shelduck, pintail, ringed plover, grey plover, dunlin, black-tailed godwit, redshank and turnstone)	**Wintering waterfowl assemblage**
Designated Site/Area	**SPA (Reg. 33)**		- Saltmarsh - Intertidal mudflats and sandflats - Shallow coastal waters	- Saltmarsh - Intertidal mudflats and sandflats - Shallow coastal waters
	SPA/SSSI	- Grazing marsh	- Grazing marsh	- Grazing marsh

The bird species named in Table 3.5 are those specified by English Nature in their original conservation objectives for SPAs and SSSIs. Analysis of the most recent information on bird usage of the estuary (see Section 2.3.3) indicates that the Annex I species, golden plover, no longer reaches population levels of European importance for the Stour and Orwell estuaries, while the site supports an important population of wintering hen harrier.

4 ASSESSMENT OF HABITAT BEHAVIOUR UNITS

4.1 Introduction

4.1.1 Division of the area

The main aim behind the way in which the CHaMP area has been divided is to assist the process of assessing the impact on the internationally designated sites as a consequence of both natural and manmade change to the way in which the coast works and to its management. The division process has to both allow proper assessment of the interrelation interests and effects at a sensible scale of coherent management, while ensuring that the broader scale linkage is recognised.

The area is divided into six HBUs. These units focus on the designated sites but are defined broadly enough to take in supporting areas of habitat and or land. The HBUs are set out in Table 4.1 (and shown in Figure 2.1) which also highlights the key associations and distinctions used in making the division. This is not seen as a rigorous, hard line division of the coast; there is, rather, a recognition of issue leakage across all boundaries (e.g. sediment transfer or movement of species is not curtailed by a line on a map). It is merely intended as a convenient management tool to allow for a more reasoned and considered analysis of the overall and complex system.

The manner in which this analysis is presented and the procedure triggering consideration of alternative management scenarios is discussed below.

4.1.2 Decision Process

The decision diagram for the analysis is shown in Figure 4.1. This is reflected in the layout of the following pages within this section; this process is laid out as a series of sheets, containing a synopsis of information presented in full detail either in earlier sections of the report or in the appendices, with a fuller discussion of different scenarios as necessary. The general format is explained below:

Sheet 1. Description of the Habitat Behavioural Unit (HBU). This sheet sets out an overview of the whole HBU. It comprises:

- Identification of the basic elements making up the behavioural unit, with a summary of key features and designations.
- A summary of the shoreline management, identifying future trends in the behaviour of the coast, an overall description of the way in which the unit is managed at present and a description of the overall policy for future management.
- A brief discussion of the issues considered pertinent to the integrity of the designated features and their interrelationship, both internal and external to the behavioural unit.

This sheet sets the scene. Subsequent sheets focus in on the individual elements making up the HBU. For each element there is a summary sheet followed by a discussion

Sheet 2. Description and summary for individual element contained within the HBU.

This sheet aims, in the first place, to identify how the element functions, highlighting the way in which this function depends on the physical processes. The sheet provides, then, a simple synopsis of the findings of the analysis for that specific ecological element. This is set out as follows:

- *A preliminary assessment of physical management of the element.* Taking the two primary scenarios, of non-intervention or that of following existing policy[5], the sheet highlights whether either scenario is likely to deliver a sustainable and practical[6] approach to maintaining the internationally important features. In providing this initial assessment, a long term view is also taken in identifying whether adopting either policy may be regretted in the future[7]. Where, in the case of the existing policy, the physical management is felt to be unsustainable, this triggers consideration of alternative approaches. Where either approach would require some form of mitigation, this is identified and, as above, in the case of the existing policy, triggers the need to consider an alternative approach[8]. Finally, within this initial assessment, any potential opportunities for habitat enhancement or development are flagged up.

- Following on from the above (if necessary, or triggered as such) is a *consideration of alternatives*, as a result of the existing policy being unsustainable, impracticable or requiring mitigation. A range of alternative approaches are highlighted and, as with the primary scenarios, assessed in terms of sustainability, practicality, regret and need for mitigation. This section of the table is intended merely as a synopsis of the subsequent discussion.

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[5] Existing Policy: as defined by the SMP (updated by subsequent strategies) or inferred by, as yet un-adopted (formally), strategy plans.

[6] Sustainability: A very practical attitude is taken to the use of the word “Sustainable” in the sheets. In the purely physical sense; can the management approach sensibly be maintained over a period of time (typically 50 to 100 years)? If so it is sustainable. In the case of a hard defence such as a sea wall this implies that once built it will remain over that period of time; it will not suffer from such excessive erosion as to require continual repair and underpinning. Obviously, in this sense the ultimate sustainable action is non-intervention; no action is taken and therefore there is no need to take action to continue the policy. Other forms of defence may also be sustainable, in that they work with or modify the coastal processes such that they require little maintenance. This use of “sustainable” makes no judgement on such issues as whether the outcome is desirable or whether the ecological interest is sustainable.

[7] Potential regret: This term puts forward another aspect of sustainability, that of attempting not to impose conditions on future generations or attempting not to un-necessarily limit options of response. The term is again referring to the physical behavior of the coastal system. The most obvious situation of potential regret occurs where an irrevocable change results from an action: realignment of defences or causing fundamental switching of the geomorphological behaviour. Less obvious, is where an action builds stress in the system, potentially delaying actual change but none the less imposing an irrevocable change in behaviour when, for example, a structure fails. In some cases it is possible to create a situation which is sustainable over a period of time but which still dictates development of the coast and limits future response: a potential regret situation. In the sheets, the use of the term potential regret does not in itself imply judgement as to whether the impact of an action is positive or negative.

[8] Mitigation required: there is a presumption under the directive in favour of maintaining habitat in situ.

Sheet 2, therefore, provides a preface to the discussion of management of the element, highlighting the key considerations and issues and identifying the range of, and reason for discussing, various approached.

- *Discussion.* Each approach, as identified in sheet two, is discussed; drawing in information from the appendix on geomorphology and from sections 2 and 3 on the ecology, considering how each international feature may be affected by a specific management approach to the physical aspects of the shore and how well that approach might deliver the conservation objectives[9]. The discussion concludes with a summary table for the element, identifying which alternatives management scenarios are considered viable; in effect identifying which alternatives should be considered further when looking at the management of the HBU.

  This local summary table is followed by a table setting out, in approximate terms, a baseline[10] assessment of the physical extent of habitat and features. For each management alternative, considered to be sensible (i.e. not for alternatives which are considered inappropriate to the frontage), a revised assessment is made of the extent of habitat that will result. The change in habitat is recorded in the table. This table helps focus on approaches, which in conjunction with the management of other elements considered within the HBU, deliver the conservation objectives.

  Each element of the HBU is assessed in the above manner, on an individual element by element basis[11]. This element assessment is drawn together, finally, to provide an assessment of the HBU as a whole. This is set out as a discussion and tables after the final element assessment.

- *Overall Assessment for HBU*. As with the individual element assessments the initial discussion considers first a non-intervention policy for the whole unit and subsequently an assessment based on the existing or current policy. The results of this, based on the previous assessments of individual elements, are presented in

[9] Objectives: CHaMPs aim to on the implications shoreline management has on the designated habitats. As such, the assessment of alternative management scenarios focus on the conservation objectives. No specific account is taken of economic or socio-economic factors beyond that of common sense limitations.

[10] Baseline Assessment:

[11] Individual element assessments: It is essential that, in doing the assessments, double counting is avoided. This becomes particularly problematic when addressing the estuaries. The elements are necessarily an artificial division of the overall unit. They cannot provide the complete picture of interaction, but do allow focus on the detail within the unit. The elements have to be strictly defined. For example, where an element is defined as the estuary channel, the assessment of the international features are those defined lying seaward of the defences, within or adjacent to the channel. Loss of saltmarsh along the edge of the channel, as a result of realignment of defences, might be what is being considered and, from the perspective of the element, would not, therefore, be compensated by the gain in saltmarsh area within the flood compartment being realigned over. If the area of retreat is within the international designated area, it would be considered as another element of the unit and, as such, the gain in saltmarsh would be identified within that second element. If the retreat area lies outside the internationally designated boundary then the gain in specific habitat would be recorded as a potential mitigation site.

This clear distinction of element boundaries is essential to the way in which each element is assessed but also means that it is only when the elements are put together in the overall assessment of the HBU is the true picture revealed.

tabular form of change to the physical extent of the habitat features. This is then discussed.

Where, as is always the case on this section of the coast, neither non-intervention nor the existing policy adequately maintains the internationally important habitats, a discussion of alternative management is presented. This focuses, logically, on a blend of alternatives for each element aimed at addressing the specific deficiencies associated with non-intervention or the existing policy. It is not felt necessary to revisit all the alternatives for each element in combination (such a matrix approach would be unwieldy and is felt to be unnecessary).

In particular the issues of mitigation and of in situ protection of habitat are considered with respect to the whole HBU. The final table of each HBU section considers the proportion of habitat (in terms of extent) which could be retained by in situ protection.

Unlike the SMP process, the CHaMP assessment process does not set out to prescribe a single preferred option for the HBU. The CHaMP aims to provide advice and guidance to the SMP and coastal managers; defining, and explaining, the consequence of different alternatives of management, identifying where these run counter to the conservation objectives or to the wish to maintain sustainable internationally designated features. Where appropriate, the assessment identifies what actions may be realistic in addressing such issues.

4.1.3 Definitions

In setting out this process of assessment certain terms have been used to summarise, in some cases, relatively complex concepts. These terms and the concepts, intended by the terms used, have been generally covered in the footnotes over the previous pages. Other terms, not covered by the footnotes, are described below in Table 4.2.

Table 4.2 Terms and concepts adopted in the assessment process.

Term	Specific use within text and tables
Non-intervention	No action taken in terms of influencing coastal response or behaviour.
Realignment	Management of the natural retreat of the coast.
Beach nourishment	Actively providing supply of sediment from outside the local system.
Erosion control	Creating artificial physical features (such as hard points) to influence the dynamic behaviour of the coast under natural forces.
Direct protection (or hard protection)	Focussed protection works (normally linear) to defend specific assets or areas from physical loss or flooding.
Retired Defence	Construct or retreat existing defence line to a specific defence line further in land.
Viable	A management action or policy that can be realistically be undertaken and delivers objectives (subject to caveats).
Inappropriate	Technically or pragmatically inappropriate course of action.

Table 4.1 Distinguishing Features of Habitat Behaviour Units

HBU	A. Covehithe	B. Blyth	C. Minsmere	D. Orford and Alde	
Extent	Kessingland Levels to Southwold	The Denes to Dunwich including the Blyth Estuary	Dunwich to Thorpeness	Slaughden to East Lane including the Alde/Ore Estuary	The Baw the
Designations	cSAC/SPA/Ramsar	cSAC/SPA/Ramsar	cSAC/SPA/Ramsar	cSAC/SPA/Ramsar	SPA
Morphology	Open shingle and sand coast controlled by Benacre Ness /Kessingland and Southwold	Principally estuary with open shingle coast with low land contiguous to estuary behind	Open shingle coast, part of larger Bay structure. Held partially by Dunwich Heath cliffs and by Thorpe Ness	Principally estuary constrained over its lower end by massive shingle ridge of Orford Ness	Estu inter
Sediment transport	Weak input from north.	Weak input from north	Weak input from north.	Little input from north	Inpu
	Differential net drift to south.	Weak net drift south. Marine sediment input and internal redistribution within estuary.	Differential north and south movement converging at Minsmere and Sizewell	Weak then strong southerly drift. Principally redistributed sediments within estuary	Som estu sedi with
	Weak outdrift to south	Weak outdrift south		Intermittent input to south	Inter estu
General features under threat	Fresh/ brackish habitats		Fresh water habitats	Fresh/ brackish habitats	
		Saltmarsh		Saltmarsh	
	Shingle loss		Shingle dunes	Shingle loss	
			Heath erosion		
				Brackish/ saline lagoons	
Opportunity habitat	Brackish/ saline lagoons	Freshwater habitat Brackish/ saline habitats Saltmarsh	Brackish/ saline habitats Saltmarsh	Freshwater habitats Brackish habitats Saltmarsh	Fres Salt

4.2 HBU A: Covehithe, Kessingland to Southwold

Elements:

1. Benacre Ness	*Designation*	Part of the Benacre to Easton Bavents cSAC and SPA
	Key Features	Saline lagoons (cSAC), also supporting shingle habitat of the Ness (Not designated as part of the cSAC interest, but included within the SPA)
2. Benacre Broad	*Designation:*	Part of the Benacre to Easton Bavents Lagoons cSAC and SPA
	Key Features:	Saline lagoons (cSAC), Brackish/freshwater reedbed and shingle beach (SPA).
3. Covehithe Broad	*Designation:*	Part of the Benacre to Easton Bavents Lagoons cSAC and SPA
	Key Features:	Saline lagoons (cSAC), Shingle beach (SPA)
4. Easton Broad	*Designation*	Part of the Benacre to Easton Bavents Lagoons cSAC and SPA
	Key Features	Saline lagoons (cSAC), Brackish/freshwater reedbed and associated wet fen grassland habitats up the Easton Valley.

Management

Trends	*Constraints:*	The unit is an eroding shoreline (average 350m over 150 years) with clay cliffs interspersed by small valleys fronted by shingle banks. The frontage runs between Kessingland and Benacre Ness to the north and Southwold to the south. The alignment of both these areas is likely to be held in the future.
	Evolution:	The frontage is predicted to continue eroding until a more stable shoreline shape develops (up to 800m landward of the existing shoreline in places). This will result in the loss of the lower sections of each of the tributary valleys to the frontage with the new shoreline lying across the upper spur valleys. Gradual reduction of sediment to supplement attrition of banks
Current Practice	*Description*	No works are carried out to the clay cliffs and they continue to erode. The shingle ridges fronting Benacre and Easton Broads breach occasionally and are repaired and reprofiled following such events.
	Implications	Regular influx of saline water into the brackish and freshwater lagoons during breach of the fronting single banks. Erosion of the cliffs gradually exposes the tributary valleys to greater saline influence. There is a continuing, but small loss of sediment to the south with resulting loss to the foreshore.
Policy	*Description*	Retreat; allowing the shoreline to move back while maintaining the integrity of the shingle banks.
	Intent	To allow natural erosion to continue, fixed by the Hold the line policy to north and south. Provide continuity of sediment supply to the coast to south.

HBU issues: Continuing erosion, coupled with an increasing attrition of material to shingle ridges would result in a reduction and potential complete loss of the designated saline lagoons (cSAC interest features). Intermittent, but potentially more frequent breaching and overtopping of the shingle ridges at Benacre and Easton would lead to the loss of brackish and freshwater reedbed habitats and the SPA designated bird populations (bittern and marsh harrier) that these areas support. Changes to the foreshore may result in loss of open coast shingle habitat, potentially leading to the loss or reduction of suitable habitat for breeding little tern (designated SPA interest).

The sites form part of a habitat chain for mobile species such as marsh harrier and bittern linking areas to south with the Norfolk Broads.

4.2.1 Benacre Denes (Abstract and Assessment of HBU A. Element 1)

Description of environmental feature

Inventory
- The Denes – saline lagoons, designated cSAC and SPA

Key function The lagoons of The Denes are old gravel pits situated on Benacre Ness, which date back to World War II. The lagoons are fed by seawater percolation and rainfall. Recent erosion has led to the loss of all but one of the lagoons. The remaining lagoon supports elements of a typical fauna including the crustaceans *Sphaeroma hookeri* and *Gammarus zaddachi*.

Dependency The remaining lagoon is effectively isolated within the shingle fabric of the ness, but is dependent on the percolation of saltwater through the shingle in order to maintain brackish conditions although occasional overtopping does occur.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain integrity of existing ecological interest Loss of saline lagoons due to erosion of surrounding shingle. *Opportunity:* None	**- Sustainable - Potential regret - Mitigation required ?**
Retreat (existing policy)	*Integrity:* Fails to maintain integrity of existing ecological interest Progressive loss of saline lagoon. *Opportunity:* None	**- Sustainable - Potential regret - Mitigation required:**

Protect in-situ alternatives

Beach recharge Import material to maintain ridges	*Integrity:* Fails to maintain integrity of element Difficulty in maintaining feature. *Opportunity:* Increases static shingle. Maintains sediment supply to south	**- Unsustainable - Mitigation required:**
Erosion Control Fix coast to south of element and retain shingle frontage	*Integrity:* Maintains integrity of element Maintains integrity of feature. *Opportunity:* Assists in maintaining shingle habitat of Benacre Ness and in protecting Kessingland Levels	**- Sustainable**
Direct protection Replace shingle with artificial defence (revetment or wall)	*Integrity:* Partially maintains integrity Loss of mobility of shingle and artificial percolation to saline lagoon *Opportunity:* Acts to protect Kessingland levels	**- Sustainable**

4.2.2 Discussion

As Benacre Ness has progressively moved northwards so the protection provided by the structure to this area has decreased. To the north, the SMP has defined a Hold the Line policy, to the south, including this element of the HBU, the policy is retreat.

Under a **non- intervention (A1a)** policy there is likely to be further erosion of the shingle in front of the lagoon, reducing remoteness from regular overtopping and finally resulting in loss to the sea; despite the defences further to the north being maintained and the line held. Under this non- intervention scenario the remaining saline lagoon would not be maintained.

The adopted SMP **retreat** policy **(A1b)** for this section of the coast is similar in consequence to the non-intervention policy as there is no active management of the retreat process. In reality, there would need to be some transition from the Hold the Line Policy further north and the management of this section although from the SMP it is implied that the main strong point would be at the main outfall flume for the Kessingland Pumping Station. Under the retreat scenario the remaining saline lagoon would not be maintained.

The eventual loss of the remaining saline lagoon to erosion under a policy of non-intervention or retreat may be deemed to represent natural change. Saline lagoons are typically ephemeral natural features, particularly on mobile shingle shorelines where dynamic erosional and accretionary processes lead to changes in the distribution and extent of shingle and the enclosement of waterbodies. The erosion of the shingle at Benacre can be viewed as a ‘natural’ process and the loss of the lagoons at the Denes a consequence of this process. Under current interpretation of the Habitats Directive, and as highlighted in the Favourable Condition Table for the saline lagoon features at Benacre, then there would not be a requirement to replace the designated habitat lost. This view is, however, dependent on agreement that the erosion of the shingle and loss of lagoon represents natural change. The overall management of the coastline and disruption to coastal processes to north and south of the site suggests that modified natural change may be occurring. If this view is taken, then the loss of the saline lagoons could be partially due to human activity and as such some form of mitigation for their loss may be required. Alternatively, human management of the Benacre coastal section may have reduced the rate of potential loss of these features and under a purely natural scenario the lagoons could have been lost entirely some years ago.

Due to the relative lack of significant dynamic shingle movement along this frontage the potential for the ‘natural’ creation of new lagoons is considered to be limited. New lagoons would therefore have to be artificially created within the fabric of the Ness if this feature were to be maintained *in situ*. If the line were taken that the loss of the lagoons is not a consequence of natural change (despite the artificial nature of the lagoons) then the adopted SMP policy would not fulfil obligations under the Habitats Directive, without mitigation. With respect to this and as highlighted as part of the CHaMP process, alternative defence and management options have therefore been considered, as outlined below.

As the coast evolves so this section may erode relatively rapidly, even though the actual landward retreat of the shore is likely to be less than further south. Attempting to hold this point by **recharge (A1c)** is likely to be problematic, either in leaving the frontage vulnerable to breaching or requiring such substantial volumes of recharge sediment as to threaten swamping the saline lagoon (or at least isolate it so completely from saline percolation so as to diminish its intrinsic ecological value). Management of beach recharge for this section of the coast would, therefore, be difficult as it would require an on-going and increasing volume of material to provide the down drift bulk necessary to ensure protection to the lagoon. Due to this aspect this approach is not seen as being sustainable.

Benacre Ness has moved north as the tail of the Ness has been eroded to the south. By retaining the material in the tail of the Ness, protection of the remaining lagoon would be maintained. This could be achieved by creating a hard point, **controlling erosion (A1d)** to the southern end of the lagoon frontage. The position of the lagoon is such that there would be little scope to allow roll back and deformation of the shingle banks in response to changes in the overall energy climate or a rise in sea level. This approach would be likely to result in some damage to the ecological interest of the site and would also result in some loss of sediment feed to the southern coastline.

Existing policy is to hold the line of the defence from Kessingland Sluice to the north. To protect the lagoon it would be necessary to extend this **direct protection (A1e)** to the end of the Benacre Denes. Although technically achievable and quite sustainable (from a technical perspective) for the next one hundred years, the defences, particularly at the southern end, would come under increasing pressure due to the northwards movement of Benacre Ness. It is therefore considered that this option could protect the integrity of the designated features, although in doing so intervention and management of the existing processes would be required.

Local Summary for Element A1

Approach		Comment	Local Conclusion
A1a	Non-Intervention	Loss of saline lagoon interest. Allows natural processes and maintains sediment supply south.	Viable, but may require mitigation to offset loss
A1b	Retreat	In effect as non- intervention.	Viable, but may require mitigation to offset loss
A1c	Re-charge	Not sustainable in the long term. Potentially damaging to remaining interest.	Difficult to manage and may require habitat mitigation.
A1d	Erosion Control	Maintains part interests in situ. Reduces drift south	Viable subject to impact to south.
A1e	Local Protection	Extends Hold the Line policy south. Reduces drift south.	Viable subject to impact to south.

Initial Accountancy Table

Feature	*Baseline*	A1a	A1b	A1c	A1d	A1e
Saline/ brackish lagoon	*1ha*	-1ha	-1 ha	-1ha	-1ha	0
Brackish/freshwater reedbed	*na*	-	-	-	-	
Wet fen grasslands	*na*	-	-	-	-	
Shingle beach	*na*	-	-	-	-	

Note figures for different approaches are in terms of loss or gain from the baseline.

With respect to all of the above options, it is apparent that consideration has to be given to the overall ideal of dealing with the integrity of the remaining saline lagoon. For any of the options promoting intervention, the question of overall sustainability needs to be addressed. It is debatable whether undertaking works to protect the lagoon could be justified, particularly from an ecological perspective. However, it is important to recognise the role that defence of this frontage could provide in protecting Kessingland Levels from inundation and preventing loss of a potential area for freshwater habitat creation.

4.2.3 Benacre Broad (Abstract and Assessment of HBU A. Element 2)

Description of environmental feature

Inventory

- Benacre Broad – saline lagoon (cSAC).
- Shingle barrier fronting the lagoon – habitat supporting SPA designated populations.
- Brackish to freshwater reedbed and associated wetland habitats – SPA designated interests.

Key function

Benacre Broad has formed behind a shingle barrier and is a feature of the geomorphologically dynamic system. Seawater enters the lagoon by percolation through the barrier, or by overtopping during high spring tides or storms. Salinity variation within the lagoon is an important physical component of the ecological interest of the site. The lagoon supports typical lagoon species including beds of the spiral tasselweed *Ruppia cirrhosa* in brackish water and dense beds of common reed *Phragmites australis* in freshwater.

The shingle barrier fronting the lagoon supports breeding little tern while the reedbeds surrounding the site provide habitat for breeding marsh harrier. The shallow waters of the lagoon provide feeding habitat for wintering waterfowl. Bittern make use of the reedbed for breeding and feeding.

Dependency

The ecological integrity and interest of the site depends on the balance between the influx of fresh and saline water, the width of the lower valley in maintaining the extent and morphology of the Broad, and the landward extent of the system (i.e. ability to support fresh water habitats such as reedbed).

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain ecological integrity of element Loss of existing ecological interest due to landward transgression of the shingle barrier and reduction in extent of the lagoon. Increased inundation and frequency of overtopping would lead to further losses of freshwater and brackish reedbed and wetland habitats, resulting in the loss of habitat supporting SPA designated populations and other wetland bird species. Long term loss of length of fronting shingle and therefore adverse impact on potential breeding area for little tern. *Opportunity:* Transient creation of saline lagoons, potentially, salt marsh and eventually static shingle banks.	**- Sustainable** **- Potential regret** **- Mitigation required ?**
Retreat (existing policy)	*Integrity:* Fails to maintain ecological integrity of element Reduces rate of landward transgression of shingle barrier fronting the lagoon and therefore maintains ecological interest over a longer time period that non-intervention. Long term reduction in the extent of the saline lagoon and under climate change the potential for increased overtopping and/or breaching of the shingle barrier leading to the loss of freshwater and brackish habitats adjacent to the lagoon. *Opportunity:* Managing a reducing asset. As for non-intervention in the longer term.	**- Sustainable** **- Potential regret** **- Mitigation required:**

Protect in-situ alternatives

Beach recharge Import material to maintain ridges and protect cliffs	*Integrity:* Fails to maintain ecological integrity of element Regular and major disruption to the shingle barrier fronting the lagoon and therefore impact on the breeding little tern which utilise this habitat. Build up of the barrier could significantly reduce the potential for overtopping and/or breach reducing the loss of area of the saline lagoon and inundation of brackish and freshwater habitats around the lagoon by saline water. *Opportunity:* Increases mobile shingle. Maintains sediment supply to south	**- Not sustainable** **- Mitigation required:**
Erosion Control Fix coast to south of element and retain shingle frontage	*Integrity:* Maintains integrity of ecological interests Slight reduction in the overall area of saline lagoon habitat, but diversity and extent of associated habitats could be retained. Reduces dynamic nature of system and associated ecological change. *Opportunity:* Increases area of shingle	**- Sustainable**
Direct protection Replace shingle with artificial defence (revetment or wall)	*Integrity:* Partially maintains integrity Loss of shingle habitat and therefore area available to breeding little tern. Artificial means to provide saline incursion to the lagoon would be required. Retention of reedbed and wetland habitats around the lagoon and associated SPA/Ramsar interest. *Opportunity:* Increases management opportunity within lagoons	**- Sustainable** **- Potential regret** **- Mitigation required**

4.2.4 Discussion

During the early part of the 20th Century, Benacre Broad was situated behind Benacre Ness, held in position by the high ground of Covehithe cliffs. The area of lagoons was more extensive, continuing southwards behind the Ness. With erosion of the cliffs and movement north of the Ness, Benacre Broad has been retained within the broad valley base between Long Covert and Boathouse Covert. The Broad is contained in this area by a relatively natural broad-crested bank of shingle and sand. The width of the frontage is some 600m and the area of the lagoon itself is some 12 ha, within the larger area of the Broad and reed beds of some 60ha.

Lateral erosion of the frontage has been in the order of 500m over the last 150 years. The present bank is held in position by the cliff section at Covehithe to the south. As these cliffs erode, the bank will tend to roll back and erode. The ultimate position of the coast, assuming in particular that Southwold and Kessingland would be held in their present locations, would be some 900m further inland (after approximately 75 years, as advanced in the SMP), with the coast impinging on the spur of higher land occupied by Craft Plantation. This would divide the broad in two, reducing the area of existing habitat to some 6 ha within the northern valley head and 4 ha within the southern. Due to the relatively rapid steepening of the valley sides there is very limited scope for the landward transgression of habitats. There is likely to be a more stable, if shorter shingle ridge beach fronting the two valleys. Under this **non- intervention (A2a)** scenario the internationally designated features of Benacre Broad would not be maintained.

At present, under the adopted **retreat option (A2b)**, the shingle bank across the Broad may be repaired and remain in a relatively natural condition. The bank does not have to provide a significant flood defence function and does not have to be maintained at a stringent level, apart from to reduce regular overtopping into the broad. As the coast moves back, with the Hold the Line policy to the north, the sediment supply to the frontage may reduce. This, together with attrition of material and loss due to continuing drift, will reduce the ability to maintain the profile of the shingle bank. Maintaining the integrity of the bank, as a defence structure, is likely to result in over-steepening, to achieve the same level of protection with a diminishing supply. Intervention in the retreat process may well therefore result in an increased vulnerability to cataclysmal failure, and prevent a more gradual transition to a new state to be achieved. The final outcome of this intervention would be the same as non-intervention. The retreat option, as set out in the SMP, merely manages the rate of loss.

The managed realignment option is likely to cause increasing disturbance to the upper shingle ridge with time, resulting in a decrease in the ability of the area to support breeding little tern. As with the non-intervention policy, the lagoon would decrease in size over time and reedbed and wetland habitats surrounding the Broad and in the spur valleys would eventually be largely lost. This policy, therefore, does not maintain the internationally designated features and would require habitat creation to be undertaken to offset losses. The key aspect of any habitat creation measures would be to develop an integrated transition from saline brackish open water to freshwater reedbed.

As neither allowing natural development of the coast nor the adopted policy would maintain the existing suite of designated ecological interests without mitigation, alternative management approaches are considered. Three technically achievable approaches have been assessed in maintaining the habitat *in situ*.

Beach nourishment (A2c) would require regular and ongoing supply to the coast. This is a section of the coast where there is a continuous and relatively high potential drift. At present the cliffs to the south of the Broad acts to retain material to the north. Any feed to the beach in front of this line will be moved by the drift energy. There would be a need for a continuous re-supply to provide material not only to the shingle bank but also to protect the cliffs. Failure to provide this additional protection would result, still, in the coast retreating, with a consequent loss in the area of the Broad. The supply to the coast, therefore, would need to increase the protection standard, rather than merely maintain that in place at present. This is likely to be an increasingly expensive and disruptive task (e.g. with respect to breeding little tern, although recharge could be undertaken outside of the breeding season). As such, though technically viable, this approach is not considered to be sustainable. The option would, however, re-establish a principal material source to the Suffolk coastline.

Unlike much of the Suffolk coastline, and due to the movement north of Benacre Ness, this section of the shoreline has not had the opportunity to settle to a net stable alignment. At present it is working within the two fixed points of Kessingland and Southwold. Over this distance the coast in effect needs to move back some 800m. The alternative of **erosion control (A2d)** looks at the opportunity to restrict this retreat by subdividing the shoreline. A substantial hard point would need to be constructed to the south of the Broad. The effect of this would be to retain material to the north, and the shingle bank in front of the Broad. To the south, the rate of erosion of the cliff would initially increase, but the shore would stabilise further forward than under a non-intervention scenario. This approach would increase the width of the shingle bank enabling it to deform with change in the wave and tide climate. It is considered that this approach would be technically sustainable over the next fifty to one hundred years and could be adapted in the future to both increase and decrease of the control provided. The approach would not build up stress in the evolution of the shore.

There would be a reduction in the long term volume of material drifting south, bringing forward the time when little drift moves beyond Southwold by some thirty to fifty years. This would result in an increase in the rate of erosion and therefore the potential loss of designated habitat between Benacre Broad and Southwold.

The above alternative attempts to modify the evolution of the shoreline. A more direct approach would be to reinforce and finally replace the existing shingle bank with a robust **direct protection (A2e)**. This might take the form of a wall or revetment, probably with the need for groynes to the front face to retain some toe beach. Construction would need to be relatively massive and would have to allow for transitional control against outflanking. This approach would provide protection to the cSAC interests (i.e. the saline lagoon), despite a need to replicate in some manner the percolation and overtopping of salt water, but would fail to support the SPA interest of the shingle shoreline. Mitigation to replace the loss of this interest would therefore be required. This direct approach would result in stress developing to the frontage and, while sustainable for the next century, would run the risk of sudden failure and increased vulnerability to cataclysmal loss of the designated ecological interests behind the engineered structure.

Local Summary for Element A2

Approach		Comment	Local Conclusion
A2a	Do Nothing	Effective loss of saline lagoon, freshwater and brackish water reedbed. Allows natural processes and maintains sediment supply south.	Viable, but mitigation to offset habitat loss may be required
A2b	Retreat	Effective loss of saline lagoon, freshwater and brackish water reedbed. Allows natural processes and maintains sediment supply south.	Viable solely as a means of buying time for mitigation to offset habitat loss
A2c	Re-charge	Maintains cSAC interest and associated SPA reedbed and wetland habitats, potential disturbance to shingle barrier and little tern that this habitat supports. Long term unsustainbility.	Unsustainable in the long term.
A2d	Erosion Control	Maintains interests in situ. Reduces drift south and dynamic nature of the frontage	Viable subject to impact to south.
A2e	Local Protection	Creates artificial and tenuous situation. Reduces dynamic nature of the frontage.	Inappropriate.

Initial Accountancy Table

Feature	*Baseline*	A2a	A2b	A2c	A2d
Saline/ brackish lagoons	*12ha*	-11ha	-11 ha	-3 ha	- 1 ha
Brackish/freshwater reedbed	*44ha*	- 40ha	- 40 ha	- 5 ha	-1 ha
Wet fen grasslands	*na*	-	-	-	-
Shingle beach	*600m*	- 250m	-250m	0	0

Note figures for different approaches are in terms of loss or gain from the base line.

4.2.5 Covehithe Broad (Abstract and Assessment of HBU A. Element 3)

Description of environmental feature

Inventory	• Saline lagoon cSAC interest • Shingle barrier (SPA) • Reedbed (SPA)
Key function	Saline lagoon maintained by percolation through the shingle barrier and occasional overtopping. Lagoon supports a variety of typical saline lagoon species. It also provides shallow water feeding habitat for little tern nesting on adjacent shingle bank. Breeding marsh harrier use the reedbed. The shingle barrier supports one of the larger little tern breeding colonies along the Suffolk coast.
Dependency	The fronting shingle barrier provides protection to the saline lagoon from full tidal inundation.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain ecological integrity of saline lagoon Loss of existing ecological interest due to erosion, landward transgression of the shingle barrier and swamping of the saline lagoon and reedbed habitat. Long term reduction in the length of the shingle barrier. *Opportunity:* Transient increase in shingle area	**- Sustainable** **- Potential regret** **- Mitigation required:**
Retreat (existing policy)	*Integrity:* Fails to maintain ecological integrity As for non intervention. Increased disturbance to shingle barrier due to recycling and re-profiling. Could impact on breeding little tern unless works undertaken outside of the breeding season. *Opportunity:* None identified	**- Sustainable** **- Potential regret** **- Mitigation required:**

Protect in-situ alternatives

Beach Control Fix coast to south of element and retain shingle frontage	*Integrity:* Maintains ecological integrity of saline lagoon and fronting shingle barrier Position of shingle barrier held and therefore landward transgression and loss of saline lagoon area effectively reduced. Maintains integrity of designated features. Reduces dynamic nature of the frontage. *Opportunity:* Potential increase in the area of shingle and lagoon habitat.	- **Sustainable**

4.2.6 Discussion

Over the last 150 years there has been erosion of some 300m of coastline at Covehithe Broad with a reduction in the size of the Broad from some 2ha to less than 0.5ha. Under a **non-intervention (A3a)** policy this process of reduction would continue. Increasing roll back of the shingle ridge together with a general transgression up valley would tend to further reduce the size of the lagoon. As the adjacent coastline moves back, the valley initially widens giving scope for an increased area of shingle habitat. Further erosion would lead to the shoreline translating into a narrower valley profile, reducing both the area of saline lagoon and extent of the shingle bank. This policy would therefore not maintain the existing designated nature conservation interests, although dynamic natural processes and associated ecological function would prevail. As such, and in order to achieve no net loss, habitat creation to offset the loss of the saline lagoon habitat and reduction in available area for breeding little tern would need be required.

Managed Retreat (A3b), is the adopted SMP policy for the area. Implementation of this policy would result in little change compared to the non-intervention scenario. Any attempt to reform the shingle ridge could damage the function of the ridge with respect to its role in protecting the saline lagoon and acting as a conduit for the passage of saline water. As with non-intervention this policy would not maintain existing designated features and habitat creation to offset loss would be required.

As neither allowing natural development of the coast nor the adopted policy would maintain the existing suite of designated ecological interests without mitigation, alternative management approaches are considered.

There is no scope for recharge or direct defence of the frontage as neither option would materially achieve anything. The recharge would merely provide additional sediment to the shoreline pathway southwards while ensuring adequate supply for the bank to move back with the shoreline. Direct protection would damage the shingle interest, reduce dynamic processes along the frontage and would fail to limit erosion on either side.

The only technically appropriate action to protect *in situ* would be via **erosion control (A3c)**. Typically this could involve construction of a hard point to the south of the area allowing a build up of material to the north. This action would, however, result in more rapid erosion to the south, in comparison with non-intervention. This approach would create or maintain a dynamically stable shingle bank, while maintaining the position and extent of the lagoon. The works would have a fundamental effect on the evolution of the shoreline and would result in a reduction of shingle to the south.

Local Summary for Element A3

Approach		Comment	Local Conclusion
A3a	Do Nothing	Effective loss of designated interest features. Allows natural processes and maintains sediment supply south.	Viable. Habitat creation would be required to maintain habitat extent.
A3b	Realignment	Effective loss of designated interest features. Allows natural processes and maintains sediment supply south.	Viable, but would require habitat creation
A3c	Erosion Control	Maintains interests *in situ*. Reduces drift south. Introduces possibility for enhancement.	Viable subject to impact on processes and designated features to the south.

Initial Accountancy Table

Feature	*Baseline*	A3a	A3b	A3c
Saline lagoons	*0.5ha*	<0.5ha	<0.5ha	+0.5ha
Shingle beach	*400m*	- 250m	-250m	0
Reedbed	*10ha*	<2ha	<2ha	0

Note figures for different approaches are in terms of loss or gain from the base line.

4.2.7 Easton Broad (Abstract and Assessment of HBU A. Element 4)

Description of environmental feature

Inventory

- Saline lagoon (Easton Broad), cSAC/Ramsar interest
- Reedbed and wetland habitats landward of Easton Broad, SPA and Ramsar interest

Key function

Easton Broad is a saline lagoon which supports species typical of this habitat. The lagoon has significantly reduced in size due to landward movement of the shingle barrier over the past few decades.

The reedbeds and associated wetland habitats upstream of the lagoon represent one of the finest reedbed complexes in England. From a SPA perspective these wetland habitats support breeding and wintering marsh harrier and bittern as well as a diverse assemblage of breeding birds including bearded tit. The diversity of wetland habitats support an interesting range of invertebrate and plant communities including several nationally scarce species.

Dependency

The shingle barrier fronting Easton Broad provides protection to the lagoon and the extensive reedbed habitats to landward. Overtopping and breaching of the ridge leads to dieback of the reedbed due to saline inundation.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain ecological integrity of existing interests The shingle ridge would be vulnerable to increased breaching and overtopping leading to further dieback of reedbed habitat to landward. Landward transgression of the shingle barrier may result in further reduction in the extent of the saline lagoon. *Opportunity:* Temporary creation of new saline lagoons	**- Sustainable** **- Potential regret** **- Mitigation required:**
Realignment (existing policy)	*Integrity:* Fails to maintain ecological integrity of existing interests Overall reduction in the extent of designated habitat (particularly reedbed) as landward transgression of shingle bank is managed. Potential increased vulnerability of the bank due to re-profiling following breach. Saline lagoon may reduce in extent. *Opportunity:* Creation of transitional saline lagoons	**- Not sustainable** **- Potential regret** **- Mitigation required:**

Protect *in-situ* alternatives

Beach recharge Import material to maintain ridges and protect cliffs	*Integrity:*	Fails to maintain integrity of existing saline lagoon habitat Regular and major disruption to the shingle ridge fronting the Broad, potentially reducing natural percolation of saline water. Maintenance of the ridge could, however, enable the extensive reedbed habitats to landward to be maintained or saline inundation to be reduced. This would maintain existing SPA designated populations within the site. Interference with existing dynamic processes. *Opportunity:* Increases mobile shingle. Maintains sediment supply to south	**- Not sustainable** **- Mitigation required:**
Beach Control Fix coast to south or offshore of element and retain shingle frontage	*Integrity:*	Maintains integrity of existing ecological interests Extent of saline lagoon and reedbed/wetland habitat to landward maintained largely intact, although a small reduction in total area of habitat could result. *Opportunity:* Increases area and stability of shingle fronting the Broad.	**- Sustainable** **- Some mitigation may be required**
Hard defence Replace shingle with artificial defence (revetment or wall)	*Integrity:*	Partially maintains integrity of existing ecological interests Loss of shingle habitat, artificial percolation to maintain saline flow of water into lagoon would be required. *Opportunity:* Creation of stable habitat features landward of the defence, enabling management measures and future planning to be undertaken. Interference to dynamic processes operating along the frontage.	**- Sustainable** **- Potential regret** **- Mitigation required**

4.2.8 Discussion

Easton Broad, until quite recently (1945), was the largest of the three broads between Southwold and Benacre; being some 25ha in extent. The Broad has reduced in size to some 4ha of open broad, which is backed by approximately 120ha of brackish/ freshwater reed bed and associated wet fen and grasslands up into Easton Valley. A distinction in habitat is made upstream of the sluice at Potter's Bridge, where freshwater conditions predominate. This is the only Broad where there is a significant flood risk due to the proximity of the minor road crossing Potter's Bridge, requiring the maintenance of the level of the seaward shingle ridge. The SMP policy for the frontage is one of managed retreat. This is being actively pursued, but the limits on available beach material coupled with the need to maintain a high level bank has resulted in a very steep, narrow and artificial profile to the bank.

Under a **non-intervention (A4a)** policy there would be a broadening and lowering of the shingle ridge, with more regular overtopping and increased potential for breaching. With continued erosion, particularly of the Easton cliffs, the ridge will tend to move landward, rapidly closing down the remnants of the existing broad and transgress up valley. Under this scenario there would be no action to stop flooding of the road, nor of the area immediately upstream of Potters Bridge. Due to increased tidal inundation of the valley landward of the shingle ridge it would be expected that there would be significant dieback of reedbed habitat up to Potter's Bridge, and possibly further upstream. This would result in the loss of habitat available to breeding and wintering marsh harrier and bittern. The loss of the habitat would also represent an adverse impact with respect to on the Ramsar designated features of the area. Due to the landward transgression of the shingle bank and reedbed dieback, this scenario would provide no significant area of habitat creation in the longer term. Over the period of erosion and transgression, there would be the opportunity for saline lagoons to develop. Any lagoons would probably be more open to direct saline influence and be ephemeral in nature. In the longer term, a stable habitat transition would develop between the open sea and the upper parts of the valley. This would have its own intrinsic ecological value, but would represent an overall reduction in the extent of designated habitat.

The present policy of **realignment (A4b)** is considered to be unsustainable in the long term as it would maintain an increasingly unnatural situation, whereby the shingle ridge becomes increasingly vulnerable to cataclysmic failure which would not allow a more gradual transition to a new state to be achieved. The retreat option, as set out in the SMP, would achieve some delay in the loss of the designated features (reedbed and wetland habitats to landward) in the short term. It would be expected under this option to maintain a flood defence line at Potter's Bridge. This would prevent saline inundation of the extensive reedbed and wetland habitats to landward and safeguard these areas from potential deterioration. However, this approach would, ultimately, result in the loss of a large area of reedbed and saline and brackish habitats to the east of Potter's Bridge, an area which is used by SPA designated populations (bittern and marsh harrier).

Potentially, it may be possible to manage a realignment process whereby the shingle ridge fronting the Broad is modified to provide a more stable structure (e.g. a crescentic shape). This would make the ridge less susceptible to breaching but would increase the frequency of overtopping events. As a consequence, the lagoonal area behind the ridge would be likely to increase in size, or excavation could be undertaken to increase its size as part of the overall managed realignment process. As with any realignment of the shingle ridge there would be a resulting loss of reedbed (SPA) habitat and the replacement of this habitat would need to be considered. In order to safeguard freshwater habitats further up the Easton Valley it would also be necessary to combine this option with the construction of improved flood defences at Potter's Bridge (i.e. a sluice at the bridge).

As neither allowing natural development of the coast nor the adopted policy would maintain the existing level of ecological interest, without mitigation (i.e. habitat creation), alternative measures should be considered. To offset the loss of wetland habitats, the key feature would be to provide some form of transition from saline brackish open water to freshwater reedbed and wet fen.

Three technically achievable approaches have been assessed in maintaining the habitat *in situ*.

Beach nourishment (A2c) would require regular and ongoing supply to the coast. This is a section of the coast where there is a continuous and relatively high potential drift. At present the cliffs to the south of the Broad act to retain material to the north. Any feed to the beach in front of this line would be moved by the drift energy. There would be a need for a continuous re-supply to provide material not only to the shingle bank but also to protect the cliffs. There is an indication that the orientation of the coast is changing and that the apex of change has progressed down the shore, in a manner similar to the movement of Benacre Ness to the north. At present the apex is at Easton Broad. The significance of this change is that drift rates may increase. Recharge could therefore be an increasingly expensive and ecologically disruptive task. As such, though technically viable, this approach is not believed to be sustainable in the long term. The option would, however, re-establish a principal material source to the Suffolk coastline.

At present, this specific location appears to be moving through a period of transition from one coastal orientation to another. It is uncertain whether simple beach connected shoreline control would be effective. To achieve a situation where material and the position of the shore is held, it may be necessary to develop some form of nearshore structure; potentially by reinforcing and drawing out the shingle bank in front of the broad. This alternative of **erosion control (A4d)** would create a substantial hard point about which the shore to the north and south would develop. The approach would still allow movement of the ridge to the Broad, increasing its width and maintaining its ability to deform with change in the wave and tide climate. Potentially there could be development of dune habitat in front of the ridge under this option. The approach is sustainable over the next fifty to one hundred years and would be adaptable in the future, enabling both increase and decrease in the level of control to be achieved. The approach would not build up stress in the evolution of the shoreline.

There would be a reduction in the long term volume of material drifting south, bringing forward the time when little drift moves beyond Southwold by some thirty to fifty years.

The above alternative attempts to modify the evolution of the shoreline. A more direct approach would be to reinforce and finally replace the existing bank with a robust **direct protection (A4e)**. This might take the form of a wall or revetment, probably with the need for groynes to the front face to retain some toe beach. Construction would need to be relatively massive and would have to allow for transitional control against outflanking. This approach would provide protection to the cSAC interest (i.e. the saline lagoon), despite a need to replicate in some manner the percolation and overtopping of salt water, and would provide protection to the extensive reedbed and wetland habitats to landward. Construction would also have to take into account the need to provide an outfall for the stream to prevent flooding and significant ecological change to the area to landward of the shingle ridge.

This direct approach would result in stress developing to the frontage and, while sustainable for the next century, would run the risk of sudden failure and increased vulnerability to cataclysmic loss/change to the existing ecological interests of the area.

Local Summary for Element A4

Approach		Comment	Local Conclusion
A4a	Do Nothing	Effective loss of part of ecological interest (reedbed dieback and impact on SPA designated interests). Saline lagoon habitat present, but extent may not be maintained. Allows natural processes and maintains sediment supply south. Development of natural ecological transitions within the valley system.	Viable. Habitat creation may be required to maintain the extent of designated features.
A4b	Retreat	Reedbed dieback and impact on SPA designated interests as far upstream as Potter's Bridge. Freshwater habitat maintained upstream of bridge. Saline lagoon habitat present, but extent may not be maintained Allows natural processes and maintains sediment supply south.	Viable, but habitat creation required to offset loss of saline lagoon and reedbed habitats.
A4c	Re-charge	Maintains cSAC interest of saline lagoon and provides protection to wetland habitats to landward (SPA/Ramsar interests).	Not sustainable in the long term.
A4d	Erosion Control	Maintains ecological interests *in situ* and potentially increases extent of habitat (shingle). Reduces drift south and does not promote dynamic evolution of the area.	Viable subject to impact to south.
A4e	Local Protection	Maintains ecological interests *in situ* although under a managed and artificial situation. Reduces drift south and does not promote dynamic evolution of the area.	Inappropriate.

Initial Accountancy Table

Feature	*Baseline*	A4a	A4b	A4c	A4d	A4e
Saline/ brackish lagoons	*4ha*	-3ha	-4ha	-1ha	0	0
Brackish reedbeds	*40ha*	-20ha	-30ha	-10ha	0	0
freshwater reedbeds	*80ha*	-70ha	0	0	0	0
Wet fen grasslands	*20ha*	0	0	0	0	0
Shingle beach	*800m*	- 500m	-500m	0	0	-500m

Note figures for different approaches are in terms of loss or gain from the base line.

4.2.9 Overall Assessment for HBU A

In examining HBU A, an initial collation is provided of the non-intervention and current policy or practice for the unit compared with existing habitat extent. This is presented in the accountancy tables below. Although it is recognised that the ecological integrity of the unit cannot be assessed solely from the perspective of extent of habitat, this is felt to provide a useful indication of the key aspects involved.

Assessment of Non-Intervention Policy

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Shingle
A1			-1ha			
A2	+10ha		-11ha	-40ha		-250m
A3			-0.5ha	-8ha		-250m
A4	+30ha	+10ha	-3ha	-90ha	-10ha	-500m
Total Change	+40ha	+10ha	-15.5ha -88%	-138ha -81%	-10ha -50%	-1000m -55%
Baseline	*0ha*	*0ha*	*18ha*	*170ha*	*20ha*	*1,800m*

Assessment of Current Policy

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Shingle
A1			-1ha			
A2			-11ha	-40ha		-250m
A3			-0.5ha			-250m
A4			-3ha	-20ha	0	-500m
Total Change			-15.5ha -88%	-60ha -35%	0ha 0%	-1000m -55%
Baseline	*0ha*	*0ha*	*18ha*	*170ha*	*20ha*	*1,800m*

Under the overall approach of realignment, the continued effort to maintain the shingle ridges is likely, eventually, to result in cataclysmal failure with little opportunity for habitat to adjust appropriately. Additionally, if undertaken inappropriately, managed realignment could disrupt the use of the shingle ridge at Benacre and Covehithe by breeding little tern.

Clearly, it would be possible to defend Potters Bridge while still allowing the shingle ridge to migrate back naturally (or possibly through a managed realignment process). This would result in a more gradual transition while still maintaining the main fresh water habitat of Easton Bavents. Under either option the main requirement for mitigation is brackish/fresh reed beds, saline lagoon conditions and appropriate shingle frontage.

Neither policy, in effect, would safeguard the existing designated features of the cSAC/SPA and, in particular, the saline lagoons that make this area of specific interest. Under the current policy, this feature of the unit suffers more significantly due to the squeeze introduced as a result of defending upstream of Potters Bridge. As previously discussed (see Section 4.2.1) the loss of saline lagoons to erosion under a policy of non-intervention or retreat may be deemed to represent natural change. Erosion along the frontage and the combined impacts of shingle rollback and inundation of the small valleys/re-entrants of Benacre, Covehithe and Easton would lead to the loss of the existing saline lagoons and also significantly limit the potential for the further formation of these features. As a consequence the natural evolution of this section of the coast would result in the virtual elimination of saline lagoons from the area. If this process is viewed as a ‘natural’ process then under current interpretation of the Habitats Directive, and as highlighted in the Favourable Condition Table for the saline lagoon features of the cSAC, then there would not be a requirement to replace the designated habitat lost. This factor also applies to the loss of reedbed habitat and the SPA species that this supports. The predicted loss of designated habitat under ‘natural change’ raises a number of questions/issues, which, while pertinent to this frontage, are not exclusive to it:

- Is the predicted change ‘natural’ or partly due to human activity (e.g. continued management of coastal shingle at Easton Broad) ?
- Should natural change be viewed as a combination of the impact of natural processes and a continuation of the human activity/management that was occurring within the area when the European site was originally designated ?
- If the dynamic process of shoreline retreat is accepted as ‘natural change’ is there a consequent acceptance of the loss of ecological interest and semi-natural habitat along this section of coastline and therefore an overall diminution in the natural resource ?
- If the loss of habitat is not considered acceptable, despite no requirement under the Habitats Directive for replacement, what are the possibilities for the replacement of the habitat lost ?.

This issue cannot be adequately addressed through the CHaMP process, as it effectively requires policy decisions to be made with respect to the Habitats Directive and the Conservation Regulations. However, it is considered feasible to place the potential loss of habitat through natural change within the context of the CHaMP and to identify suitable areas for the replacement of habitat if it is decided that the predicted loss would not be acceptable.

Mitigation Habitat

Two areas of potential habitat creation are considered to be suitable within the HBU: Benacre Ness and Kessingland Levels. The former provides an extensive area of shingle habitat in which new saline lagoons could be excavated. It is considered unlikely that saline lagoons would form naturally along this frontage due to the relative lack of dynamic shingle movement. There are a number of factors that would need to be fully considered in advancing such a proposal:

- The longevity of any newly created lagoons. This aspect would need to be linked to proposed flood defence policy;
- Existing ecological interest of the shingle habitat
- Existing human use and activity on the site
- Technical aspects of ensuring saline intrusion into the newly created lagoons
- Public perception of undertaking such works in an area of existing interest and activity

Although it may be technically feasible to create new lagoons within the ness, given the well established human interest of the area and its existing ecological interest (although not internationally designated) it is suggested that such action would be inappropriate.

Kessingland levels (see Figure 4.1) could provide a significant opportunity for recreation of freshwater reedbed and associated habitats and potentially saline lagoons. Saline input to the levels would have to be managed, and as such it may not be possible to recreate the specific value of the existing saline lagoons along this frontage. In order to advance this measure, it would be necessary to implement and maintain a policy of Hold the Line for this frontage. This policy is currently in place in order to provide protection to the pumping station at Kessingland and prevent inundation of the levels. Although northward movement of the ness could make the Kessingland section more prone to potential breach and inundation in the future, it is considered that the potential opportunity for habitat creation offered by the site coupled with protection of development to the north would justify a HTL policy.

Fig. 4.1. Map of Kessingland Levels area showing extent of the existing floodplain and proximity to Benacre Broad, part of the Benacre-Easton Bavents SPA.

With respect to the areas, or features of habitat which would potentially be lost under the scenarios above, *in-situ* protection provides the opportunity of reducing this loss through retention of more extensive shingle ridges. The various alternatives provide a range from virtual complete retention (by works to all elements) to just considering works to one or two elements (as indicated above for Benacre Denes in providing protection to Kessingland Levels). The table below provides a summary of the potential consequences of the *in-situ* protection option on the designated habitats.

Assessment of Habitat remaining through *in situ* protection

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Shingle
A1			1ha			
A2			11ha	45ha		600m
A3			1ha			400m
A4			4ha	105ha	20ha	800m
Total retained			17ha 94%	150ha 94%	20ha 100%	1800m 100%
Baseline			*18ha*	*170ha*	*20ha*	*1,800m*

4.2.10 Conclusion for Habitat Behavioural Unit A

The internationally important features of this unit cannot be retained without intervention. There is the potential for loss to both the cSAC and SPA features both in terms of saline and freshwater habitats. Kessingland Levels offers the opportunity to offset predicted freshwater and terrestrial habitat loss from within the HBU. Appropriate development of this habitat would take a number of years. The site is unlikely, without heavy modification, to provide replacement for loss of the saline lagoons and shingle banks. Mitigation for this aspect may need to be considered in the assessment of other HBUs. Alternatively, if a policy on non-intervention is taken, then potentially there may be no requirement to offset habitat losses resulting from this decision. This particularly applies to the saline lagoon habitat present along this frontage.

The current policy of managed realignment is only of value in the short term while the mitigation for future losses is addressed. In the longer term, the policy of re-profiling the shingle ridges would be likely to result in increasing damage to this habitat.

4.3 HBU B: Blyth Estuary and Southwold to Dunwich Village

Elements:

1. Blyth Estuary	*Designation*	Part of Minsmere/ Walberswick SPA, Ramsar
	Key Features	Mudflats, Freshwater/brackish reed beds.
2. Southwold Town Marsh	*Designation:*	Part of Minsmere/Walberswick SPA, Ramsar
	Key Features:	Wet grassland habitat
3. Tinkers Marsh	*Designation:*	Part of Minsmere/Walberswick SPA. Ramsar site
	Key Features:	Wet grassland habitat and diverse brackish water habitat (Ramsar)
4. Dunwich to Walberswick Marshes and shingle banks	*Designation*	Part of Minsmere/ Walberswick cSAC, SPA, Ramsar
	Key Features	Freshwater/brackish reedbed with associated wet grassland. Brackish/saline reedbed (SPA) and associated lagoons (not designated as cSAC). Shingle banks (SPA) and drift line vegetation (cSAC).

Management

Trends	*Constraints:*	The open coast comprises a relatively stable, though still dynamic shingle to sand shoreline. Southwold and Dunwich cliffs provide the main natural structure to both coast and estuary; the harbour training walls at Southwold are imposed upon this. There is believed to be little supply of sediment down the coast. The estuary is under considerable stress with an artificially narrow entrance and large intertidal area upstream. The shape of the estuary is controlled naturally by high ground and artificially by the A12 road bridge, the footbridge and the harbour channel and training walls.
	Evolution:	The coastal frontage has moved back relatively slowly over the last 100 years and is likely to continue to retreat. Through both extension and attrition, the shingle ridge between Walberswick and Dunwich is likely to become increasingly vulnerable to fragmentation. The evolution of the Blyth estuary will be dictated significantly by management decisions. The failure of flood defences would have the potential to result in increased pressure, through an increase in tidal volume, and further failure of defences and loss of designated habitat could result.
Current Practice	*Description*	Breaches in the open coast shingle ridge are repaired by reforming and re-profiling the bank. Flood defences are maintained within the estuary.
	Implications	Maintaining the shingle ridge is resulting in an increasingly vulnerable defence. A severe breach may not be repairable and the full extent of Westwood Marshes (Walberswick) could be liable to saline flooding. Within the Blyth estuary there is a recognised need for increased investment in the existing defences. A severe event resulting in failure may lead to the present defence line becoming unsustainable. There would be significant change and/or loss of existing designated areas of habitat adjacent to the estuary, although potentially new areas of intertidal habitat could be created.
Policy	*Description*	Retreat along the shoreline, allowing the shingle ridge to move back as a unit. Hold the shape of the estuary, while abandoning some defences and allowing realignment to occur in selected locations.
	Intent	To allow natural change to occur on the coast while maintaining control within the estuary.

HBU issues: Continued coastal defence management work on the immediate coastline potentially damages cSAC (annual vegetation) and SPA/Ramsar interests. Significant loss of ecological interest could occur over the long term due to failure of the fronting shingle ridge and tidal inundation of freshwater and brackish wetland habitats to landward. Realignment or uncontrolled failure of defences within the Blyth estuary would result in significant change to existing designated ecological interests.

The habitats present in the area form part of a coastal mosaic stretching from north Essex through to the Norfolk Broads.

4.3.1 The Blyth Estuary (Abstract and Assessment of HBU B. Element 1)

Description of environmental features

Inventory	Intertidal mudflats and saltmarsh (SPA/Ramsar)
Key function	The intertidal habitats of the Blyth estuary support nationally and sometimes internationally important populations of wintering waterfowl, in particular avocet.
Dependency	Intertidal areas are dependent on continued tidal influence and maintenance of estuarine processes. The tidal influence of the estuary is also important in influencing the formation of brackish water conditions within areas of adjacent wetland grazing marsh.

Preliminary Assessment of management

Non-intervention	*Integrity:* Maintains integrity of intertidal habitat Increase in area of intertidal mudflat and potentially saltmarsh, providing increased area to support wintering waterfowl. Loss of terrestrial designated habitat to landward of flood defences *Opportunity:* Creation of new areas of intertidal habitat and transitional habitats to higher ground.	**- Sustainable - Potential regret - Mitigation required**
Maintain all defences (existing policy)	*Integrity:* Integrity of intertidal area probably reduced Small-scale loss of saltmarsh vegetation within the estuary due to coastal squeeze. Increasing pressure on defences due to influence of sea-level rise and loss of saltmarsh vegetation (where present). *Opportunity:* None	**- Un-sustainable**

Sustainable alternatives

Selective retreat	*Integrity:* Maintains integrity of intertidal habitat Increases area of mudflat and potentially reed bed. Loss of integrity of other elements. *Opportunity:* Potential to create saltmarsh and transitional habitat	**- Sustainable - Potential regret - Mitigation required**

4.3.2 Discussion

The present morphology of the Blyth estuary has developed, over the last several centuries, largely through reclamation up to the principal low water channel. Subsequent loss of defences, around Bulcamp Marshes, has led to an unbalanced estuary, with considerable stress on sections of remaining defence. The shape and hydraulic performance of the estuary, has limited the potential for fine sediment deposition, with little scope for accretion of the mudflats. Predicted sea level rise would exacerbate the current situation of stress on the existing flood defences.

Under a **non- intervention (B1a)** policy there would be further deterioration of defences and eventual failure, progressively throughout the estuary. Initial failures would most probably occur within the area above the A12 Road Bridge and at Tinkers Marsh. These failures (especially in the upper estuary) would substantially increase the tidal prism, resulting in pressure on and loss of the Reydon Marshes defences and then the marshes to either side of Southwold Harbour. This would result in no significant loss to the designated features of this element (i.e. intertidal habitat), but would result in the loss of grazing marsh habitat and other wetland habitats (e.g. reedbed) adjacent to the estuary (these are considered separately, below).

Although a flood defence strategy for the estuary has been developed, this is currently not adopted and, therefore, no agreed policy is defined for the flood defences within the estuary. A more detailed study of the flood defence issues for the Blyth estuary is being progressed. Current management practise is to **maintain the existing defences (B1b)** throughout the estuary. In order to implement this policy, major investment in the upper estuary and to the defences of Reydon and Tinkers Marshes would be required. There is neither adequate benefit nor environmental requisite, at present, for continuing protection to the upper tidal limits of the estuary (i.e. upstream of the A12 bridge).

The defences at Reydon and Tinkers act to constrain the natural lateral movement of the estuary channel; both defences are under considerable stress and both require extensive capital works to be undertaken in order for the present line of defence to be maintained. In particular, the Tinkers Marsh embankment will require substantial rebuilding if it is to withstand a significant surge event. Such works would only have a minor impact on the existing intertidal habitats within the estuary, with only a small loss of intertidal area due to sea-level rise and coastal squeeze. However, continued defence of this area is going to become increasingly difficult.

Further down stream, the defence to Robinson Marsh is likely to require major investment. There may be some disruption and potential loss of saltmarsh along this edge. However, this does not form part of the designated area (SPA/Ramsar).

This approach would probably maintain designated SPA/Ramsar interests both to landward and to seaward of the defences. While this approach, therefore, enables *in-situ* protection to designated features to landward (see later elements), it constrains future adaptability, in particular, with respect to maintaining the area of intertidal mudflats as sea level rises. In addition, the maintenance of all defences would result in continuing and increasing effort. As such this approach is considered to be technically unsustainable in the medium to long term.

As a result, an alternative approach is considered, whereby, there would be **selective realignment (B1c)** from critical defences, at Tinkers and Robinson's Marshes. The potential for realignment would relieve some of the pressure on the other defences, without increasing the tidal prism such as to damage the harbour fetch of the estuary. This provides a more sustainable approach without damage to the integrity of the intertidal habitats of the estuary, and would in fact result in an increase in the extent of intertidal habitat within the estuary. There would, however, be damage to the integrity of designated grazing marsh/wetland habitat to landward of the defences at Tinker's Marsh and this aspect is considered later.

The approach would create a more sustainable estuary and allow adaptation to future change.

Local Summary for Element B1

Approach		Comment	Local Conclusion
B1a	Non-intervention	No loss of integrity and allows natural processes to continue. Adverse impact on adjacent designated areas (SPA/Ramsar) landward of defences.	Viable, conditional upon assessment of impact on landward designated features (see element 3).
B1b	Maintain	Maintains in the medium term the designated interests of the estuary, but with potential loss in the future due to coastal squeeze. Technically un-sustainable, requiring early commitment to a potentially long term inflexible policy.	Viable in the immediate-term, potential loss of opportunity in the long term.
B1c	Re-alignment	Maintains integrity of element, allowing future adaptability. Adverse impact on adjacent designated areas to landward.	Viable, conditional upon assessment for element 3.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	B1a	B1b	B1c
Intertidal mudflats		*155ha*	0ha	-10ha	0
Saltmarsh		*60ha*	-10ha	-10ha	-5ha
Annual drift-line vegetation		*Na*			
Brackish/freshwater reedbed		*30ha*	-15ha	-5ha	0
Wet grasslands		*12ha*	-	-	-
Shingle beach		*na*	-	-	-

Note figures for different approaches are in terms of loss or gain from the baseline.

There would be an increase in intertidal mudflat and saltmarsh under options B1a and B1b, but this would be outside the designated boundary of the existing SPA/Ramsar site.

4.3.3 Southwold Town Marsh (Abstract and Assessment of HBU B. Element 2)

Description of environmental feature

Inventory	Lowland wet grazing marsh (SPA/Ramsar)
Key function	The grazing marsh of Southwold Town Marshes provides a roosting and feeding area for wintering waterfowl, in particular species such as wigeon. The site also supports a number of breeding waterfowl. The dykes of the area support plant communities characteristic of freshwater through to brackish conditions.
Dependency	The maintenance of brackish conditions in some areas of the site is dependent on links with the estuary (e.g. through percolation of saline water via flood defences and sluices).

Preliminary Assessment of management

Non-intervention	*Integrity:*	Fails to maintain integrity of existing ecological interests	**- Sustainable** **- Potential regret** **- Mitigation required**
	Increases areas of mudflat at the expense of the existing wet grassland		
	Opportunity: Creation of intertidal mudflat, saltmarsh and transitional habitats.		
Maintain defences (existing policy)	*Integrity:*	Maintains integrity of existing ecological interests	**- Sustainable**
	Maintains harbour fetch while protecting existing designated features to landward.		
	Opportunity: None		

Maintain in-situ alternatives

No requirement for alternative approaches to be considered.

Discussion

This element comprises managed wet grassland marsh situated behind the defences along Southwold Harbour. Under a **non- intervention (B2a)** policy the defences would fail and there would be a progressive change to saline conditions over the marshes. The failure of these defences, together with the failure of the harbour control structures would result in a widening of the estuary mouth and could allow a change in tidal pattern within the estuary. This could potentially increase net deposition of fine material throughout the estuary. Under this non- intervention scenario the internationally important features of the element would not be maintained resulting in the loss of the lowland wet grassland and the SPA/Ramsar interests that this supports.

Current management practice is to **maintain the existing defences (B2b).** While requiring continued and possibly increasing investment and effort, the line of the defence is sustainable. This approach would maintain the internationally designated features to landward of the defences without specific damage to other designated ecological interests within the HBU. Maintaining this element would maintain the control the estuary imposes on the immediate coastline.

No alternative approaches are considered.

Local Summary for Element B2

Approach		Comment	Local Conclusion
B1a	Non-intervention	Change of ecological interests from freshwater grazing marsh to intertidal mudflat/saltmarsh. Potential process and habitat change implications for the rest of the estuary.	Viable, but habitat creation to offset loss of grazing marsh could be required. No significant justification for this option.
B1b	Maintain	Maintains the designated interests of the element.	Viable.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	B2a	B2b
Intertidal mudflats		*na*	+75ha	
Annual drift-line vegetation		*na*		
Brackish/freshwater reedbed		*na*		
Wet grasslands		*75ha*	-75ha	0
Shingle beach		*na*		

Note figures for different approaches are in terms of loss or gain from the baseline.

4.3.4 Tinkers Marsh (Abstract and Assessment of HBU B. Element 3)

Description of environmental feature

Inventory	Lowland wet grazing marsh (SPA/Ramsar)
Key function	The former grazing marsh habitat of Tinker's Marsh is heavily influenced by saline water seepage through the flood defences. As a consequence the site supports vegetation characteristic of freshwater through to brackish conditions. Pools of open water within the site provide a feeding area for wintering and breeding waterfowl. Roosting waterfowl use the site at times of high water.
Dependency	Brackish water conditions on the site are maintained via seepage of saline water from the estuary via the flood defences.

Preliminary Assessment of management

Non-intervention	*Integrity:*	Fails to maintain the existing ecological interests of the site	**- Sustainable** **- Potential regret** **- Mitigation required**
	Loss of wet grassland interest, diversity of vegetation communities (Ramsar interest) and habitat supporting breeding and wintering bird populations (SPA).		
	Opportunity: Creation of intertidal habitat with transitional habitats to higher ground.		
Maintain defences (existing policy)	*Integrity:*	Potentially maintains integrity of existing ecological interest	**- Un-sustainable** **- Potential regret**
	Increasing pressure on defences due to sea-level rise. Small-scale loss of intertidal habitat due to coastal squeeze. Defences would need to be engineered to maintain saline seepage.		
	Opportunity: Controlled development of habitat		

Sustainable alternatives

Realignment	*Integrity:*	Fails to maintain the existing ecological interests of the site.	**- Sustainable** **- Potential regret** **- Mitigation required**
Realign channel and manage habitat re-creation	As for non-intervention.		
	Opportunity: Potential to create saltmarsh and sustainable transitional habitat		

4.3.5 Discussion

There is considerable stress on the form of the estuary in maintaining the defences between Reydon and Tinkers Marsh. This is likely to increase with predicted accelerated rise in sea level and if the defences to the estuary above the A12 Bridge are abandoned.

Under a **non- intervention (B3a)** policy there would be further deterioration of defences and eventual failure. Minor breaches already occur and in the event of a major surge event, failure of the Tinkers Marsh frontage could be dramatic, with consequences for other sections of the Blyth estuary. This policy would result in increasing saline intrusion and eventual inundation. There is the potential for saltmarsh creation and development of transitional habitats up to the heathland below Squires Hill. Potentially, overall ecological diversity could be maintained, or possibly increased, however, there would be significant change from the existing range of habitats present on site. The main habitat change, without intervention, would be to increase the area of intertidal mudflat, which would provide additional area for wintering waterfowl thus increasing and supporting this ecological aspect of the SPA. Despite, these changes to valuable habitat areas, the potential to develop a more sustainable estuary form and the creation of habitat within an ecologically sustainable location, the SPA/Ramsar site would lose an existing and important area of habitat, particularly with respect to brackish water terrestrial features. Therefore, under this non-intervention scenario the internationally designated features of Tinker’s Marsh would not be maintained. There maybe a requirement to offset the loss of terrestrial habitat through habitat creation.

Current management practise is to **maintain the existing defences (B3b**), although at present only minimal maintenance is carried out. To maintain the defences, even in the short term, there would have to be significant investment. To justify this, there would have to be long term commitment, potentially leading to an inflexible approach to both management of defences and the natural environment of the estuary. This may result in decisions being made elsewhere, which further reduce future management options. There would be a need with any scheme to artificially maintain the influx of seawater to support brackish habitat conditions. While the approach provides the opportunity for closely controlled habitat development, technically and environmentally it closes down future options. With a recognised need for responsive management, in the face of climate and sea level change, this approach is considered unsustainable. The approach would, however, in all other respects, largely maintain existing ecological interests (although artificially) and therefore meet requirements under the Habitat Regulations.

As a result of concerns over sustainability, an alternative scenario is considered, whereby, there is a **realignment (B3c)** of the estuary channel through the Tinkers Marsh area. This would relieve some of the stress within this section of the estuary providing a more sustainable management structure and estuary form. The opportunity within this approach, distinguishing it from the non-intervention policy, would be in the design of the channel and future habitat development within the area. The intent, however, would be to allow natural change to occur and for transitional habitat from intertidal to higher ground to develop. This approach, while creating the opportunity for development of saltmarsh, mudflat and transitional habitat between mudflat and upland heath, habitats that could significantly contribute to the international interest of the SPA/Ramsar site, would fail to maintain the existing internationally designated features of the site. Habitat change due to this option could directly impact upon breeding avocets (3-8 pairs recorded over the past 3 years), affect the ability of the site to support roosting waterfowl and alter the distribution and extent of Ramsar designated features (i.e. brackish-freshwater grassland) within the Minsmere-Walberswick system. It is therefore likely that there would be a need to provide mitigation for the loss of the Ramsar element of the wet grassland interest and potentially SPA interests directly associated with this ecological element (breeding avocet and waterfowl roosting). This approach would create a more sustainable estuary and allow adaptation to future change.

Local Summary for Element B3

Approach		Comment	Local Conclusion
B3a	Non-intervention	Loss of existing ecological interest, but allows more natural processes to develop. Creation of new ecological interest which would complement existing features (e.g. intertidal). Potentially beneficial impact on adjacent designated sites.	Viable, subject to mitigation for loss of wetland SPA/Ramsar designated features (if required).
B3b	Maintain	Maintains in the long term the designated ecological interests, but with potential loss of opportunity for further habitat creation in the future.	Considered to be unsustainable with respect to long term estuary morphology and wider ecological impacts.
B3c	Re-alignment	Loss of existing ecological interests but allows future adaptability and encourages a more sustainable distribution of habitat within the area.	Viable, subject to mitigation for loss of wetland SPA/Ramsar designated features.

Initial Accountancy Table

Feature *Approach*	*Baseline*	B3a	B3b	B3c
Intertidal mudflats	*Na*	+45ha		+40ha
Annual drift-line vegetation	*Na*			
Brackish/freshwater reedbed	*Na*			
Wet grassland	*50ha*	-50ha	-2ha	-50ha
Shingle beach	*Na*			
Saltmarsh	*Na*	+5ha		+10ha

Note figures for different approaches are in terms of loss or gain from the baseline.

4.3.6 Dunwich to Westwood Marshes and Shingle Banks (Abstract and Assessment of HBU B. Element 4)

Description of environmental feature

Inventory

- Annual vegetation of drift lines (Dunwich shingle bank) – cSAC.
- Brackish-freshwater reedbed and associated wetland habitats - SPA and Ramsar.
- Intertidal saltmarsh and saline lagoons – SPA supporting habitats and Ramsar interest
- Grazing marsh – SPA and Ramsar interest

Key function

Shingle of Dunwich-Walberswick bank supports annual vegetation, mainly along the crest and just to landward.

The freshwater-brackish habitats to landward of the shingle bank (i.e. Westwood Marshes) support SPA designated species such as breeding and wintering marsh harrier, bittern and avocet. The diversity of physical conditions supports a wide range of plant and invertebrate communities including a large number of nationally scarce species. There are important natural transitions from brackish-freshwater and freshwater to terrestrial habitats within the site.

Grazing marsh habitat at Dingle Marshes provides roosting and feeding habitat for a number of bird species, while the dyke systems within the marshes support a range of brackish-freshwater plant and invertebrate communities.

The saline lagoons behind the Dunwich shingle bank, while not designated as cSAC habitat, support a diverse range of characteristic saline lagoon species. They also provide feeding habitat for a number of SPA designated species including avocet.

Dependency

The Dunwich shingle bank provides significant protection to the low-lying wetland habitats to landward from tidal inundation. Percolation through the shingle bank maintains the saline lagoons along the Dunwich frontage.

Preliminary Assessment of management

Non-intervention	*Integrity:*	Fails to maintain existing ecological interests	**- Sustainable** **- Mitigation required**
	Breach of the shingle ridge between Walberswick and Dunwich would result in tidal inundation of the fresh/brackish reedbeds and associated wet grassland habitats to landward with consequent loss/change in existing ecological interest. This would adversely affect cSAC, SPA and Ramsar designated interests.		
	Opportunity: Creation of shingle barrier inlet system with increased intertidal and transitional habitats (e.g. saltmarsh, saline lagoons and brackish reedbed/wetland habitats).		
Retreat by repair (existing policy)	*Integrity:*	Fails to maintain existing ecological interests in the longer term	**- Un-sustainable** **- Potential regret** **- Mitigation required**
	Increases vulnerability of shingle bank to catastrophic failure. Gradual but eventual change/loss of habitats to landward either from erosion or saline inundation. Potential damage to shingle cSAC interest.		
	Opportunity: As for non-intervention. In addition, provides a longer timeframe over which mitigatory habitat could be located and created.		

Sustainable or in situ protection alternatives

Retired defence	*Integrity:*	Maintains freshwater/brackish ecological interests	**- Sustainable** **- Mitigation required**
Allow natural development of front line defence. Provide retired flood defence to landward	Increased saline intrusion along immediate coastal fringe with eventual fragmentation of shingle bank and intermittent or permanent tidal flooding of existing areas of brackish grassland, saltmarsh and saline lagoons. Annual vegetation of drift lines interest could be maintained. A retired defence line would provide protection to brackish/fresh water habitats (e.g. Westwood Marshes) to landward.		
	Opportunity: Potential to create intertidal and transitional habitats (saline-freshwater). Creates isolation of shingle banks. Increases extent of drift line.		
Recharge	*Integrity:*	Maintains existing ecological interests	**- Sustainable** **-**
Shingle recharge to fronting bank Provide retired flood defence	Re-establishes bulk in shingle ridge defence and provides protection to features to landward. Recharge would have to be managed to ensure maintenance of annual vegetation of drift line interest.		
	Opportunity: Potential increase in overall area of shingle habitat		

4.4 Discussion

This division of the coastline comprises three principal, but integral areas; Westwood Marshes, the valley of the Dunwich River (Dingle and Reedland Marshes), separated by the high ground of the Dunwich Forest and the Dingle Great Hill, and Corporation Marshes, forming the confluence between the two other two areas. All three areas are protected on the open coast by a shingle bank that stretches between the harbour structures of the Blyth and Dunwich Village.

The shingle bank has developed as a result of long term erosion of the Blyth/ Dunwich delta, moving back to form the present coastline. Movement of the bank over the last century has been relatively slow, on average approximately 0.5m per year, which emphasises the basic stability of the bay. The frontage is, however, dynamic with movement of material both north and south, and regular overtopping and flattening of the artificially maintained steep shingle ridge. There is a problem with a lack of new material being transported along the frontage, such that continued retreat and continual reworking of material is increasingly creating a fragile and unsustainable defence.

Under a **non- intervention (B4a)** policy it is likely that there would be a relatively rapid dissolution of the shingle bank, with frequent breaching and overtopping. The flooding of the low hinterland, even under normal tides, would result initially in reinforcing the drainage route to the Blyth but would also tend to promote the break-up of the frontline defences, creating a tidal inlet/ barrier frontage. Under more extreme events, flooding would occur through to Westwood Marshes converting this area, most probably, into saltmarsh and intertidal mudflat (see Figure 4.2). While this scenario creates new habitat which would have its own ecological interest, the existing internationally important features of the area would not be maintained and mitigation to offset loss may need to be sought. The annual vegetation of drift line cSAC interest would probably be maintained and could improve due to a lack of human intervention along the frontage.

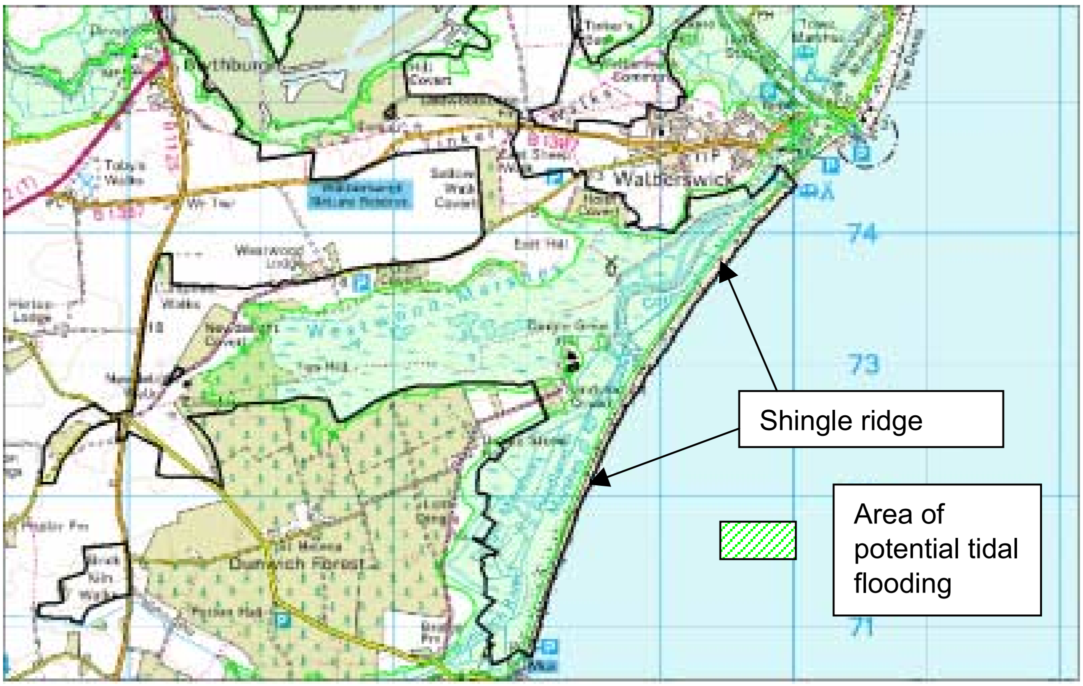

Figure 4.2 Westwood Marshes and extent of tidal flooding that could occur following significant breach and breakdown of the fronting shingle ridge.

Current management practice, supported by the SMP policy, is to allow the existing defences to **retreat (B4b)**. This involves responding to weakening or breach in the shingle bank, reforming the ridge to maintain its height and general integrity. Continuing with this policy is likely to become increasingly difficult, creating an ever steeper and more vulnerable profile. At the same time this action reduces the exposure of habitats to landward to saline influence and thus reduces the system's ability to cope with cataclysmal failure and compromises a gradual transition to a new ecological state. With a lack of new sediment being transported into the area, the loss of material washed inland during overtopping situations and the lengthening of the frontage, this approach is considered unsustainable in the long term. As a major failure becomes inevitable, the effects of the policy would effectively revert to that of non-intervention. The approach does not, in the long term, maintain the internationally designated features of the element. In addition to the approach being unsustainable, mitigation to offset habitat loss would need to be sought.

As neither allowing natural development of the coast nor the adopted policy would maintain the existing and designated ecological interest of the area, without mitigation, alternative approaches to defence are considered.

The first alternative aims to actively manage the natural development of the system, thereby reducing the loss of important habitat areas, while still allowing potential for change. The key element of this would be to manage the disintegration of the front defence line (i.e. the shingle bank), and provide a more substantial **retired defence (B4c)** protecting the fresh and brackish habitats within Westwood Marshes. The intent would be to allow the development of an inlet/barrier frontage, incorporating the development of saline habitats and lagoons as well as increasing the scope for drift line vegetation. This would be allowed to develop throughout the Dingle, Reedland and Corporation Marshes. Defences would be improved between Dingle Great Hill and Walberswick. The approach would not maintain all aspects of the internationally important features but would create potentially, a means of developing a more sustainable approach to the management of the different features. The approach would also tend to heighten the isolation of the open coast shingle habitat reducing human disturbance. However, the potential exists that some habitat creation to offset the loss/change to designated interests between the shingle bank and the retired defence would be required. This is a debatable point as it should be technically possible to retain the majority of the habitat (reedbed) which supports the SPA designated populations and much of the Ramsar interest.

The second alternative approach considers actions necessary to maintain *in situ* the various habitats. The main problem in achieving this is the bulk of the shingle bank defence. Sustaining this would be through **recharge (B4d)**, the bulk of which would be in re-establishing the natural profile of the ridge, with subsequent recharge maintaining the ability of the bank to flex naturally. While this alternative approach would maintain designated features to landward and could be sustainable, there would have to be careful management of the operations to minimise impact on drift line vegetation and on the shingle as a habitat in itself. Care would also have to be taken to ensure that percolation of seawater through the shingle bank was maintained in order to feed the saline lagoons at Dunwich. This approach might result in greater use of the frontage for access between Dunwich and Walberswick, and may require management to prevent damage to shingle vegetation.

Local Summary for Element B4

Approach		Comment	Local Conclusion
B4a	Non-intervention	Loss of/change to existing designated ecological interests. Creates significant opportunity for new habitat development and sustainable ecological function.	Viable, but may require habitat creation to offset loss of designated interest.
B4b	Retreat by repair	Maintains in the short term the designated interests. Increases vulnerability of the shingle bank to breaching. Unsustainable in the longer term.	Viable solely as a means of delay to allow suitable mitigation (habitat creation) to be developed.
B4c	Retire defence	Maintenance of fresh and brackish water wetland habitats to landward. Creates managed opportunity for new intertidal habitat.	Viable, subject to potential habitat creation to offset loss of designated interests.
B4d	Recharge	Protects *in situ* existing habitats	Viable, but does not allow dynamic evolution of the coastline to proceed.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	B4a	B4b	B4c	B4d
Intertidal mudflat		*0*	+175ha	+200	+110ha	0
Annual drift-line vegetation		*4.8km*	+4km	+4km	+2km	0
Brackish/freshwater reedbed		*210ha*	-190ha	-190ha	-80ha	0
Wet grasslands		*105ha*	-100ha	-100ha	-100ha	0
Shingle beach		*10ha*	0	0	0	+10ha
Saltmarsh		*0*	+115ha	+90ha	+70ha	0

Note figures for different approaches are in terms of loss or gain from the baseline.

4.4.1 Overall Assessment for HBU B

In examining HBU B, an initial collation is provided of the non-intervention and current policy or practice for the unit compared with existing habitat extent. This is presented in the accountancy tables below. Even though it is recognised that the integrity of the unit cannot be assessed solely from the perspective of habitat extent alone, this is felt to provide a useful indication of the key issues involved.

Assessment of change for Non-Intervention Policy

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Annual drift line vegetation	Shingle
B1	0	-10ha		-15ha			
B2	+60ha	+15ha			-75ha		
B3	+45ha	+5ha			-50ha		
B4	+175ha	+115ha		-190ha	-100ha	+4km	0
Total Change	+280ha +180%	+125ha +210%	0 0%	-205ha -85%	-225ha -94%	+4km +83%	0ha 0%
Baseline	*155ha*	*60ha*		*240ha*	*240ha*	*4.8km*	*10ha*

Assessment of change for Current Policy

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Annual drift line vegetation	Shingle
B1	-10ha	-10ha		-5ha			
B2							
B3					-2ha		
B4	+200ha	+90ha		-190ha	-100ha	+4km	0
Total Change	+190ha +123%	+80ha +133%		-195ha -81%	-102ha -43%	+4km +83%	0ha 0%
Baseline	*155ha*	*60ha*	*na*	*240ha*	*240ha*	*4.8km*	*10ha*

Either policy would lead to the loss of/change to existing ecological interests and potentially affect the integrity of the designated features within this unit. Under a non-intervention policy the main concern would be for the loss of the large areas of reedbed, associated wetland habitats (e.g. swamp) and grazing marsh at Westwood and Minsmere and the SPA designated populations and plant/invertebrate communities that these areas support. In the case of the current practice there could still be significant loss of reedbed and wetland habitats to landward of the existing line of defence.

The current policy for defence within the Blyth estuary is considered unsustainable without major improvement works to Tinkers marsh. There is concern that such works would rigidly fix the estuary over the next fifty years and in the longer term give rise to further problems of management.

On the open coast the current policy for the Walberswick frontage is retreat. This policy could have a significant impact on the existing balance of habitats within the Unit, with breach and overtopping of the shingle ridge leading to tidal inundation of the freshwater/brackish wetland habitats to landward.

Mitigation Habitat

A major factor in examining this unit is the opportunity for mitigation or adjusting the balance of habitats within the existing designated areas. Tinkers Marsh is clearly viewed as a potential site for realignment, with the opportunity of not just creating additional intertidal area but also providing saline to heathland/terrestrial transitional habitat. Similarly, while failing to maintain the main area of Westwood Marshes incurs a massive and unacceptable loss of reed bed and freshwater fringe habitat, constructive management of the seaward edge of this area could create important new coastal saline features, potentially compensating for the loss of saline lagoons to the north of Southwold (see HBU A).

In addition to these internal areas there are several areas external to the existing designated sites which could be incorporated to provide mitigation for achieving a better physical and ecological balance within the HBU. Two areas considered are Robinson Marsh, close to the mouth of the Blyth estuary and the various marshes upstream of the A12 bridge in the valley of the Blyth River (see Figure 4.3). These latter areas comprise river valley floodplain semi-improved to improved grassland habitat with some areas of marshland. This is of existing ecological interest (County Wildlife Site). Management of this floodplain could provide additional wet grassland and wetland habitats (e.g.

reedbed, open water) which over time could potentially become of greater ecological interest and importance.

Enhancement or conversion to wet grassland habitat would require that flood defences are improved in order to prevent tidal inundation upstream of A12. This would have the added benefit of maintaining a reduced tidal volume within the estuary potentially relieving pressure on defences lower downstream within the estuary. There is potential for loss of this opportunity due to the poor condition of the existing defences above the A12. Failure of these defences, outwith an agreed strategy to maintain them as fresh water habitat, could result in their loss to intertidal habitat with transitions to brackish water and terrestrial habitat.

Robinson's Marsh, opposite Southwold Harbour could provide an opportunity for the creation of intertidal habitat through realignment of the existing defence line.

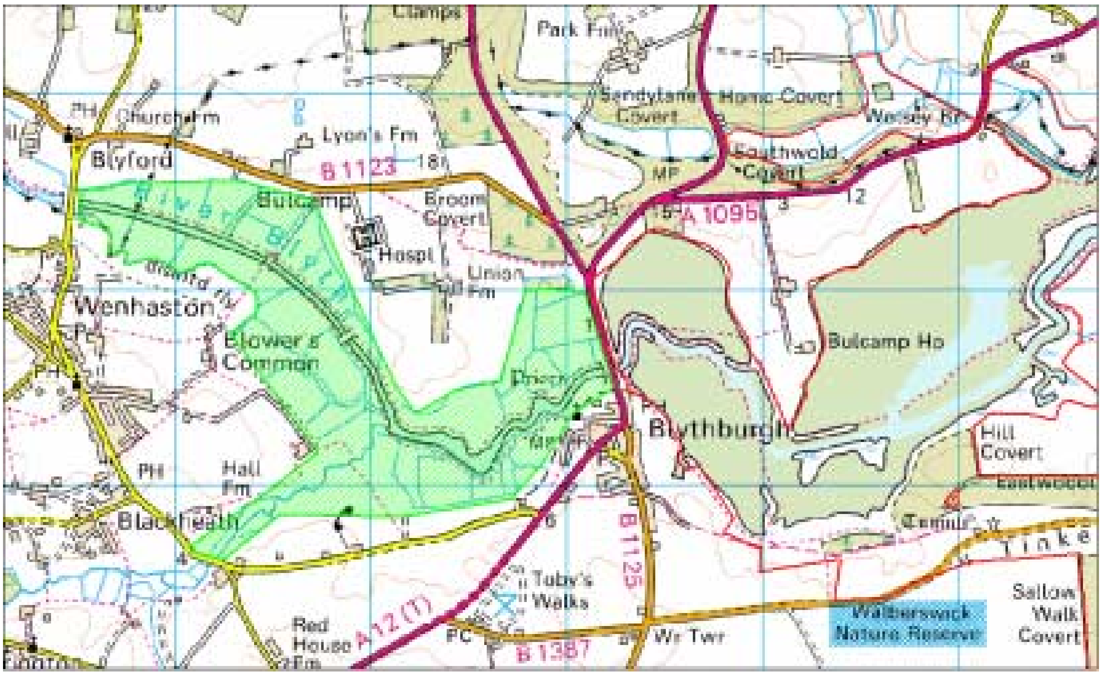

Figure 4.3. Map showing location of River Blyth valley floodplain (highlighted in green) where management could enhance the existing suite of habitats to provide more extensive and improved wetland habitat.

Alternative Scenarios

Two alternative scenarios are collated from the assessment of individual elements. The first considers the policy of maintaining the open coast but allowing adjustment within the estuary by realignment over Tinker's Marsh; this is considered as scenario 1 in the table below.

Assessment of Habitat change (Scenario 1)

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed freshwater	Wet grasslands	Annual drift line vegetation	Shingle
B1	155ha	55ha		30ha	12ha		
B2					75ha		
B3	40ha	10ha			0		
B4				210ha	105ha	4.8km	20ha
Total retained	195ha 126%	65ha 108%		240ha 100%	192ha 80%	4.8km 100%	20ha 200%
Baseline	*155ha*	*60ha*	*na*	*240ha*	*240ha*	*4.8km*	*10ha*

This scenario maintains certain important features of the HBU, increasing the overall area of intertidal and saltmarsh habitat. The scenario reduces the loss of freshwater habitat but ensures that the area retained is sustainable and retains its ecological interest. There would be a need for mitigation for the loss of freshwater/brackish habitat at Tinker's Marsh. This could be provided by management of the valley floodplain areas above the A12 Bridge, providing a sound basis for continued habitat management of this area.

Scenario 2 looks to impose less management on the open coast. In this scenario, the shingle bank in front of Westwood marshes would be allowed to develop freely, enabling not only retreat but also breach. There would be a need to reinforce defences along the Dunwich River and to Westwood Marshes. As with Scenario 1, there would be a need to mitigate for the loss of SPA/Ramsar designated features as a result of the loss of land at Tinker's Marsh. The table below sets out the implications for the various habitats present within the area.

Assessment of habitat change (Scenario 2)

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed freshwater	Wet grasslands	Annual drift line vegetation	Shingle
B1	155ha	55ha		30ha	12		
B2					75ha		
B3	40ha	10ha			0		
B4	110ha	70ha		130ha	5ha	6.8km	20ha
Total retained	305ha 197%	135ha 225%		160ha 67%	92ha 38%	6.8km 142%	20ha 200%
Baseline	*155ha*	*60ha*	*na*	*240ha*	*240ha*	*4.8km*	*10ha*

The potential quality of the isolated shingle banks together with the opportunity to create saline/brackish lagoons within a stable coastal environment provides potential mitigation for loss of saline lagoon habitat from within HBU A.

Mitigation would still be required, primarily for the loss of brackish and freshwater habitat at Westwood Marshes. As with the previous scenario, this mitigation could be potentially provided by management of the river floodplain area above the A12 bridge in terms of wet grassland and freshwater habitats and possibly Kessingland levels for brackish/freshwater reed bed.

4.4.2 Conclusion for Habitat Behavioural Unit B

The internationally important features of this unit cannot be retained fully, either by intervention or by allowing the natural evolution of the coast and estuary to prevail. The main threat within this unit is the loss of freshwater habitat rather than, as the case of HBU A, the loss of maritime habitat. There are concerns also as to the ultimate sustainability of an approach to maintain defences throughout the Blyth Estuary. It is considered that within this HBU there is significant potential within the system to create a more sustainable maritime environment, while looking either to place defence of freshwater habitat on a more sustainable footing or move it to mitigation areas further inland. The scenarios considered would all make use of the area above the A12 Bridge as mitigation. In addition mitigation would be required outside the HBU, but within the CHaMP area.

As a corollary to this, the unit would provide scope for mitigatory habitat for loss in other areas, while still providing, potentially, overall important additional intertidal areas.

It is important that an appropriate strategy for the Blyth is agreed in the near future as this is fundamental to allowing interchange of habitat to be taken forward with confidence.

4.5 HBU C. Minsmere: Dunwich Village to Thorpeness

Elements:		
1. Dunwich Heath	*Designation*	Part of Minsmere/ Walberswick cSAC, SPA/Ramsar
	Key Features	Cliff top heathland (cSAC/SPA).
2. Minsmere	*Designation:*	Part of Minsmere/Walberswick cSAC, SPA/Ramsar
	Key Features:	Freshwater/brackish reedbed, grazing marsh, open water, shingle frontage (all SPA) and annual drift line vegetation (cSAC).

Management		
Trends	*Constraints:*	The apparent straight section of the coast between Dunwich cliffs and Thorpeness is gently distorted by the forward position of the shore at Minsmere Sluice. The frontage is controlled by the relatively resistant cliffs at Dunwich and the bulk of Thorpeness to the south. There has been very little change at Minsmere Sluice over the last century and it seems likely that this point in the coast is semi-fixed by differential drift patterns dictated by the influence of the offshore banks, possibly reinforced by the Sluice structure itself.
	Evolution:	The main area of retreat over the last century has been to the cliffs, this is likely to continue at least in the short term and more so in the event of change in sea level. The rest of the coast has remained very stable with only minor erosion at Thorpeness. The soft frontage across the Minsmere reserve is always vulnerable to change, as seen in the recent erosion to the south of the Sluice. It is however difficult to predict the evolution of this section given the variability of factors influencing change.
Current Practice	*Description*	Little action is taken in terms of defence management. It is assumed, however, that action would be taken in event of threat of breach at Minsmere or erosion at Sizewell.
	Implications	As the Dunwich cliffs continue to erode, it is intended to reinforce the weak spot between the cliffs and the Minsmere bank. Similar action may be required between Sizewell and Minsmere Sluice.
Policy	*Description*	The policy for the unit of coast is managed retreat over the northern length, holding the line at Sizewell and Do Nothing down to Thorpeness, but Holding the Line at Thorpeness.
	Intent	To minimise intervention and the impact on sediment movement, relying on and supporting, where necessary, the line of the coast.

HBU issues: The cliffs at Dunwich will continue to erode with loss of cliff top heathland vegetation (designated cSAC/SPA). Any failure of the natural shoreline defence and secondary embankment to landward at Minsmere would cause saline inundation and potentially result in significant change to existing designated habitats and features depending on the scale and duration of inundation.

4.5.1 Dunwich Heath (Abstract and Assessment of HBU C. Element 1)

Description of environmental feature

Inventory	• Heathland vegetation along the cliff top (cSAC/SPA)
Key function	Lowland heathland vegetation which supports specialised plant and invertebrate communities. SPA designated populations such as nightjar breed in the area, although their use of the cliff top as a breeding site is likely to be extremely limited. Dartford warbler may make more use of the area during both the winter and spring/summer (breeding).
Dependency	Cliff top heath is contiguous with the extensive heathland to the west.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain the extent of existing ecological interest Loss of heathland area and loss of location specific cliff top habitat (cSAC) due to cliff recession. This is, however, a natural process and mitigation for the loss of habitat would not be required. *Opportunity:* Continues to provide sediment to system	**- Sustainable -Mitigation required ? -**
Retreat (existing policy)	*Integrity:* Fails to maintain the extent of existing ecological interest As for non-intervention, except that mitigation to offset habitat loss may be required in this case. *Opportunity:* Continues to provide sediment to system	**- Sustainable - Mitigation required ?**

Maintain in-situ alternatives

Protection to cliffs Revetment or similar	*Integrity:* Maintains area of element Hard defence to retain cliff line, reduces sediment source and introduces strong management restraining natural development of the shore. *Opportunity:* None	**- Sustainable - Potential regret**

4.5.2 Discussion

There is likely to be continued erosion of the cliffs. Over the last century this has resulted in annual retreat in the order of 1m to 2m. It has been estimated that this has provided some 40,000m^3 of sediment to the nearshore system per year, although this supply varies on an annual basis and in the type of material (sand or coarser pebbles from the Westleton Beds). This material is distributed both north and south along the shore; and indeed may also act to feed, indirectly, the offshore banks. Certainly the feed is likely to be important to the Minsmere frontage.

Under a **non- intervention (C1a)** policy there would be further erosion of somewhere in the region of 100 and 150m over the next 100years. This would result in the loss of heathland vegetation along the cliff top, reducing the extent of this feature within the cSAC/SPA. The maritime nature of this section of heathland and any intrinsic ecological interest that this holds would not be affected as this interest would move landward with retreat of the cliff line. As the loss of this area would occur under conditions of natural erosion it is considered that there may not be a requirement for direct mitigation of the loss of heathland. However, as the overall resource would diminish, recognition should be given in future plans for heathland creation to offset this loss if an overall policy of no net loss towards internationally designated habitats is adopted.

The current policy is for **retreat (C1b)**. The consequence of this policy is largely the same as the non-intervention policy above. One specific difference to this is the strengthening of the southern end of the element, ensuring closure to the potential flood threat to Minsmere. This is considered in element C2. This defence would have little influence on element 1 (cliff top heath), although might result in a realignment of the frontage as a whole, influencing differential sediment drift rates. As intervention would be undertaken under this approach potentially, there may be a requirement to undertake habitat creation to offset any loss that could be associated with the approach. The influence on Dunwich cliffs and heathland interest is likely to very limited and in fact could slightly reduce the rate of erosion (i.e. would be of benefit with respect to this feature).

Neither of the above approaches would prevent the loss of heathland vegetation, although as stated this loss would occur under natural erosion of the cliff frontage. The only means of protecting *in situ* the designated feature would be the full **protection of the cliffs (C1c).** This would introduce a management approach to the whole frontage which would be likely to have a detrimental impact on the development of the shore and is not considered appropriate.

Local Summary for Element C1

Approach		Comment	Local Conclusion
C1a	Non-intervention	Loss of heathland vegetation, but allows natural processes to continue.	Viable and sustainable.
C1b	Retreat	Loss of heathland vegetation, but allows natural processes to continue.	Viable and sustainable.
C1c	Protection	Maintains integrity of element, restricts future adjustment of the shore and may have an adverse impact on adjacent designated interests.	Inappropriate

Initial Accountancy Table

Feature	*Baseline*	C1a	C1b	C1c
Intertidal mudflats	*na*	0	0	0
Annual drift-line vegetation	*na*	0	0	0
Brackish/freshwater reedbed	*na*	0	0	0
Wet grasslands	*na*	0	0	0
Shingle beach	*na*	0	0	0
Saltmarsh	*na*	0	0	0
Heath	*290ha*	-20ha	-20ha	0ha

Note figures for different approaches are in terms of loss or gain from the baseline.

4.5.3 Minsmere (Abstract and Assessment of HBU C. Element 2)

Description of environmental feature

Inventory	• Brackish-fresh water reedbed (SPA/Ramsar) • Lowland wet grazing marsh (SPA/Ramsar) • Open water (SPA/Ramsar) • Wet woodland and swamp (SPA/Ramsar) • Shingle/sand dune frontage (cSAC)
Key function	The complex mosaic of wetland habitats at Minsmere support a diverse assemblage of animal and plant communities including a large number of nationally scarce species. The extensive reedbed supports breeding and wintering marsh harrier and bittern, while the man made scrapes support breeding avocet and a wide range of wintering waterfowl species. Grazing marsh in the Minsmere river valley and at the southern end of the site supports breeding waterfowl populations and provides a feeding area for waterfowl during the winter months. The fronting strip of shingle and sand provides habitat for breeding little tern and supports a narrow band of specialist vegetation (annual drift-line, cSAC interest).
Dependency	Many of the wetland areas are interconnected and represent either different successional stages in wetland development or are managed to support specific species populations. The shingle and sand of the coastal strip provides a natural defence to the low-lying land to landward from tidal inundation.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain integrity of existing ecological interests Potentially large-scale loss of freshwater and brackish features should breach of the fronting defences and significant saline inundation occur. *Opportunity:* Potential to open a major new estuary system	**- Sustainable** **- Potential regret** **- Mitigation required**
Retreat (existing policy)	*Integrity:* Maintains the range and diversity of existing ecological interests Managed retreat of the coastal defences through repair and intervention should a breach occur would largely control the potential for significant habitat loss/change. *Opportunity:* None	**- Sustainable**

Maintain in-situ alternatives

The current policy of retreat would maintain the internationally important features and is seen as being sustainable. No further alternatives are therefore considered.

4.5.4 Discussion

The frontage has been relatively stable over the last century and is envisaged to remain so. There is continued erosion of the cliffs to the north and some intermittent periods of erosion to the south of Minsmere. At present it is uncertain whether this latter erosion is part of an ongoing trend or merely a transient feature of the high gross drift rates and local differential pressure on the frontage due to variation in wave climate. There is likely to be some on-going change in the line of natural defence as a result of sea level change.

Under a **non- intervention (C2a)** policy the erosion of the Dunwich cliffs may well result in a weak area developing in the defence line between the intersection of the cliffs and the Minsmere bank. Should there be a breach at this point there is likely to be major inundation of the Minsmere reserve, resulting in the conversion of the current freshwater/ brackish reedbed and freshwater marsh area to saline conditions if the breach remained open. As these conditions develop, with the disruption of drift along the frontage, the position of the breach may well relocate to the old course of the river, resulting in a permanent inlet to a new estuary. There would be likely to be significant development of saltmarsh and mud flats, with the possible further loss of freshwater grassland towards the back of the site. The establishment of a new estuary system (long term) would eventually lead to the creation of an ebb delta, which would build out from the coastline. As a result, new areas of shingle and sand dune habitats could develop at the mouth of the estuary. This could increase the extent of suitable conditions for the establishment of annual vegetation and potential breeding area for species such a little tern.

Despite the possible creation of important new coastal and estuarine habitat, this approach would fail to maintain existing designated features particularly the terrestrial wetland habitats and mitigation for the loss of these may need to be sought.

A similar scenario may be put forward for a breach to the south of Minsmere Sluice. Such a breach could be contained through construction of new defences to the south of the New Cut. Curtailing the extent of inundation is likely to result in a healing of the breach but may still influence the strength of the natural defences to the north.

The current policy is for **retreat (C2b)**. Under this approach, works would be undertaken to strengthen any potential breach areas and, as necessary, in the future to maintain the main defence should change result in this rolling back. The action would protect *in situ* the varied features and habitat within the Minsmere area although with roll back of the coastal fringe there could be some loss of shingle and dune habitat. This would be unlikely to affect the annual vegetation of drift line interest, although an overall reduction in suitable habitat area could have an adverse affect on breeding little tern populations at the site. In many respects, human disturbance is probably more of an issue with respect to the continued ability of this species to breed at the site.

Local Summary for Element C2

Approach		**Comment**	**Local Conclusion**
C2a	Non-intervention	Loss of features but allows development of a new and more natural habitat.	Viable, significant mitigation to offset habitat change may be required.
C2b	Retreat	Maintains features and integrity	Viable.

Initial Accountancy Table

Feature	*Baseline*	C2a	C2b
Intertidal mudflats	*na*	+200ha	0
Saltmarsh	*na*	+60ha	0
Sand dune	*40ha*	-30ha	-20ha
Annual drift-line vegetation	*3.5km*	>3.5km	0
Brackish/freshwater reedbed	*155ha*	-120ha	0
Wet grasslands	*205ha*	-140ha	0
Shingle beach	*3.5km*	>3.5km	0
Heath	*na*	0	0

Note figures for different approaches are in terms of loss or gain from the baseline.

4.5.5 Overall Assessment for HBU C

In examining HBU C, an initial collation is provided of the non-intervention and current policy or practice for the unit compared with existing habitat extent. This is presented as the accountancy tables below. Even though it is recognised that the integrity of the unit cannot be assessed solely from the perspective of the extent of potential habitat change, this is felt to provide a useful indication of the key issues involved.

Assessment of change for non-intervention policy

Element	Mudflats	Saltmarsh	Saline lagoons	Fresh reed bed	Wet grasslands	Annual drift line vegetation	Sand dune	Heath
C1	0	0	0	0	0	0	0	-20ha
C2	+200ha	+60ha		-120ha	-140ha	+?km	-30ha	0
Total Change	+200ha	+60ha	0	-120ha	-140ha	+?km	-30ha	-20ha
Baseline	*0*	*0*	*0*	*155ha*	*205ha*	*3.5km*	*40ha*	*290ha*

Assessment of change for current policy

Element	Mudflats	Saltmarsh	Saline lagoons	Fresh reed bed	Wet grasslands	Annual drift line vegetation	Sand dune	Heath
C1	0	0	0	0	0	0	0	-20ha
C2	0	0	0	0	0	0	0	-20ha
Total Change	0	0	0	0	0	0	-20ha	-20ha
Baseline	*0*	*0*	*0*	*155ha*	*205ha*	*3.5km*	*40ha*	*290ha*

Either policy incurs loss of area of heathland habitat. Significant protection to reduce this loss is unlikely to be justified or desirable.

While potentially allowing breach of the Minsmere system opens up the opportunity for significant habitat change and a return to dynamic coastal conditions, at this time the impact on the coast and, indeed the impact on habitat of the area remains uncertain. This approach would not maintain the integrity of the designated areas and would certainly not satisfy the presumption to maintain habitat to landward of existing defences *in situ*.

Mitigation Habitat

There is scope for mitigation habitat within the HBU area for heath and potentially wet grassland; these being areas behind and to the north of the designated sites.

Alternative Scenarios

There is no requirement for alternative approaches to be considered and none that obviously assist in the management of designated features within the HBU.

4.5.6 Conclusion for Habitat Behavioural Unit C

The internationally important features of this unit cannot be retained fully either by intervention or by allowing the natural systems of the coast to continue.

The principal loss is in relation to cliff top heathland, although there may be a potential need due both to human interaction and the localised landward transgression of the shoreline for the recreation of coastal fringe habitats. Allowing landward movement of the shore would, however, then infringe on terrestrial features within the main bulk of the Minsmere-Walberswick site.

There is believed to be adequate area adjacent to the designated sites to allow for the creation of heathland habitat to offset loss from within the HBU (e.g. through reversion of suitable agricultural land on sandy substrates).

4.6 HBU D. Alde/Ore and Orford Ness Slaughden to East Lane

Elements:

1. Alde/Ore Estuary	*Designation*	Alde/Ore SPA, Ramsar and cSAC
	Key Features	Mudflats and sand flats (cSAC & SPA), Saltmarsh (cSAC & SPA), Estuary (cSAC), Saline lagoons and waterbodies (SPA *Havergate*).
2. Butley	*Designation:*	Part of Alde/Ore SPA, Ramsar and cSAC
	Key Features:	Intertidal mudflat and saltmarsh, estuary (cSAC), Reedbeds (SPA/Ramsar)
3. Hazelwood	*Designation:*	Part of Alde/Ore SPA and Ramsar
	Key Features:	Wet grassland habitat (SPA).
4. Orford Ness and Marshes	*Designation*	Part Alde/Ore SPA, Ramsar and cSAC
	Key Features	Intertidal mudflat & saltmarsh (cSAC/SPA). Shingle habitat (SPA), annual and perennial vegetation (cSAC). Wet and maritime grasslands (SPA). Saline lagoons (cSAC)
5. Shingle Street	*Designation*	Part Alde/Ore Ramsar and cSAC
	Key Features	Shingle habitat annual and perennial vegetation (cSAC). Saline lagoons (cSAC)

Management

Trends	*Constraints:*	There is a weak supply of material moving south past Aldeburgh. Beyond Aldeburgh net drift tends to increase to Orford Ness. Once beyond the Ness material moves south to Shingle Street. The key control points are Aldeburgh and East Lane, with the entrance to the Alde/Ore estuary retaining and controlling material moving south. The Ness is a relic shingle accumulation, now slowly eroding. Within the estuaries, reclamation and subsequent failure of defences upstream of Aldeburgh have had a major impact on the estuary. The shape of the main channel is influence by the topography and by the coastal processes. The balance between flows in the estuary and the energy and sediment of the open coast dictate the length and vulnerability of Orford Spit.
	Evolution:	The coastal frontage is attempting, in effect, to straighten between Aldeburgh and Shingle Street. The neck at Slaughden would breach, if not artificially managed. The estuary itself, assuming no breach at Slaughden, is changing with relative sea level rise both increasing pressure on defences and with respect to its interaction with the coast at Shingle Street
Current Practice	*Description*	Maintain the defence at Slaughden and generally maintain the overall shape and performance of the estuary.
	Implications	Maintaining the neck at Slaughden requires beach management from the Ness. Maintaining the principal defences of the Estuary and ensuring that there is no major impact on the coastal regime requires balancing any realignment with the subsequent increase in tidal volume.
Policy	*Description*	Hold the Line at Slaughden and at Shingle Street but Do Nothing elsewhere. Maintain all defences within the estuary.
	Intent	To allow natural change to occur on the coast but continue to restrain estuary development.

HBU issues: Natural long-term change could cause major change to the existing designated features.

4.6.1 Alde/Ore (Abstract and Assessment of HBU D. Element 1)

Description of environmental feature

Inventory	Saltmarsh (cSAC/SPA/Ramsar) Intertidal mudflats and sandflats (cSAC/SPA/Ramsar) Estuaries (cSAC)
Key function	The intertidal and subtidal habitats of the Alde-Ore support a diverse range of benthic communities that reflect the range of habitat conditions present within the estuary. The intertidal mudflats provide a feeding resource for a number of estuarine bird species including those of international importance (e.g. wintering avocet).
Dependency	The estuary interest of the cSAC effectively represents all of the various habitat elements present within the site. The function and ecological interest of the estuary is dependent on the distribution and balance between these elements.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain the existing designated ecological interests Major change throughout the estuary including loss of saltmarsh, intertidal mudflats and lagoons (Havergate Island). Adverse impact on designations to landward (e.g. grazing marsh at Hazelwood, shingle vegetation and saline lagoons at Orfordness). *Opportunity:* Large-scale increase in intertidal habitat (largely mudflat), significant morphological change to the estuary system with potential for breach at Slaughden.	**- Sustainable - Potential regret - Mitigation required ?**
Response maintenance (existing practice)	*Integrity:* Fails to maintain the existing designated ecological interests Inflexible approach to change due to sea level rise, increasing pressure and loss of intertidal habitats (saltmarsh). *Opportunity:* None	**- Un-sustainable - Mitigation required**

Sustainable alternatives

Strategic Management Re-alignment and managed creation of habitat	*Integrity:* Maintains existing ecological interests Increases areas of mudflat and potentially saltmarsh. Potential to relieve erosive pressure. Possible loss of designated habitats to landward of defences. *Opportunity:* Potential to create saltmarsh and transitory habitat.	**- Sustainable - Potential regret - Mitigation required**

4.6.2 Discussion

The Estuary has developed in a constrained manner through reclamation of large areas of intertidal land (some 2500ha within the system). The abandonment of some areas during the 1950s/60s, together with low rates of relative sea level rise over the last century has resulted in increased flows and pressure on the edge habitats (3% loss of saltmarsh over the last thirty years, University of Newcastle 2000) and on the defences. Further change due to sea-level rise would increase this pressure. There is recognition in the designation of the Alde/Ore and Butley as a cSAC, that the estuary as a whole, with its varied habitats, is an important functioning system. This same interaction is reflected in the physical performance of the estuary, not least in the balance achieved over the lower reaches between estuary flow and coastal dynamics.

Some of the important estuary saltmarsh habitat is retained within the wrinkles of the existing defence line, highlighting the fact that deposition within the estuary is not uniform and that there is certainly no trend for general accretion. This also indicates the need to create quiescent areas for saltmarsh generation, the potential impact of increased energy within the estuary and the interaction between defences and the intertidal habitat.

Under a **non- intervention (D1a)** policy the defences around the estuary would be allowed to deteriorate and in time would fail. It is estimated that this would result in an increase in tidal volume of some 250% and, with possible sea level rise, by some 450%. Due to the relatively low level of many of the surrounding reclaimed areas and, therefore, the high energy inundation of these areas, existing fringe saltmarsh is likely to be lost with creation of mudflat within the areas of flooding. This problem would be exacerbated as flood areas add to the volume of the estuary, increasing flow along the remaining defences. The increase of tidal volume would be likely to result in a weakening of Orford Spit, with consequential breaches and potential shortening of this feature. Much of the lower reaches of the estuary are likely to be returned to a coastal environment.

Despite the possible creation of important new mud flat habitat, this would tend to reduce the variety over the estuary, and certainly within the existing designated boundaries. This scenario would fail to maintain *in situ* the existing internationally important features to landward, and would result in much of the ecological interest being present outside the existing designated boundaries. The potential impact on the designated habitat features of Orfordness could be significant with an overall reduction in the area of shingle habitat. Such habitat could not be replaced within the site and it is unlikely that replacement could be technically achieved. However, this scenario would lead to the development of a fully functioning estuary system which would have ecological value and be sustainable. Compensatory habitat to replace losses to landward (grazing marsh, reedbed) may need to be sought (see other elements below).

The current management practice, in the absence as yet of adopting an estuary strategy for defence, is for ad hoc **response maintenance** and repair of existing defences **(D1b)**, (the EA no longer have responsibility for Lantern and Kings Marshes defences and the northern Lantern Marsh and defences at Havergate Island are abandoned). Under realistic sea level change scenarios, maintenance of all defences would become increasingly difficult and increased flow pressure would increase the loss of fringe habitat. Furthermore, with the almost inevitable loss of Lantern and Kings Marsh and the consequential increase in intertidal area of some 350ha and increase in tidal volume of some 20%, there would be substantial increased pressure over the lower reaches of the estuary. Almost certainly, an increase in tidal volume of this nature would restrict the ability for realignment elsewhere within the estuary.

This approach restricts balanced responsive management of the estuary, while resulting in a loss of internationally designated intertidal habitats. This approach would require habitat mitigation and is considered to be unsustainable in the longer term.

As neither allowing natural development of the estuary nor continuing current practice would maintain the existing extent and value of the ecological interests present within the estuary, an alternative approach has been developed and examined.

The key to management of the varied environmental interests of the estuary element is not just in maintaining this varied habitat in the face of natural change but in maintaining control of the physical development of the estuary in such a way as to allow future response and development. This requires **strategic management** of the coastal and flood defences **(D1c).**

It has already been identified above that realignment over Lantern and Kings Marsh area fails to address this problem, potentially increasing the problem of sustainability, while not dealing with the primary stress points of the estuary. In the report on the estuary strategy (Posford Duvivier 1999), Hazlewood Marsh or Boyton Marsh were considered for realignment, primarily due to a lack of economic justification for continuation of their defence. Neither of these areas is critical to the management of the estuary element and, therefore, neither is considered in the assessment of this element of the HBU, although both are considered later, as elements in their own right and as potential mitigation areas respectively.

The most critical area of stress within the estuary is around the Aldeburgh bends. Due to increased flows through this area, there is a significant loss of saltmarsh fringe and potential for further loss in the area of Cob Island and along the High Street (East Iken Marsh) frontage. Realignment, within certain limits, of Aldeburgh Marshes together with a re-alignment of the tip of the Sudbourne Marsh, could potentially relieve pressure on the fringe habitats as well as the defences in this area. Realignment of this form would provide opportunity for habitat creation (within the aligned area) but is also likely to result in some habitat loss (where breaches are created) of the saltmarsh fringe. Overall intertidal habitat loss would occur within the estuary element, but this would be significantly compensated for by realignment over into areas outside of the SPA/cSAC (e.g. Aldeburgh Marshes).

Local Summary for Element D1

Approach		Comment	Local Conclusion
D1a	Non-intervention	Loss of features but allows development of extensive areas of new intertidal habitat. Potential loss of habitat diversity throughout the system and loss of specific designated habitat.	Sustainable, but significant change to the estuary system would occur.
D1b	Response Maintenance	Fails to maintain a sustainable system resulting in loss of specific habitat.	Inappropriate in the long term.
D1c	Strategic management	Loss of specific areas of habitat but maintaining sustainable control over estuary development.	Viable.

Initial Accountancy Table

Feature *Approach*	*Baseline*	D1a	D1b	D1c
Intertidal mudflats	*500ha*	+40ha	+20ha	+100ha
Annual drift-line vegetation	*Na*	0	0	
Brackish/freshwater reedbed	*20ha*	-15ha	-15ha	-15ha
Wet grasslands	*Na*	0	0	
Shingle beach	*Na*	0	0	
Saltmarsh	*160*	-100	-75	-50a

Note figures for different approaches are in terms of loss or gain from the baseline.

4.6.3 Butley (Abstract and Assessment of HBU D. Element 2)

Description of environmental feature

Inventory
Saltmarsh (cSAC/SPA/Ramsar)
Intertidal mudflats and sandflats (cSAC/SPA/Ramsar)
Estuaries (cSAC)
Reedbed and swamp (SPA/Ramsar)

Key function
The intertidal and subtidal habitats of the Alde-Ore support a diverse range of benthic communities that reflect the range of habitat conditions present within the estuary. The intertidal mudflats provide a feeding resource for a number of estuarine bird species including those of international importance (e.g. wintering avocet).

The reedbeds at the head of the Butley support breeding and wintering birds (e.g. marsh harrier) and diverse plant and invertebrate communities.

Dependency
The estuaries interest of the cSAC effectively represents all of the various habitat elements present within the site. The function and ecological interest of the estuary is dependent on the distribution and balance between these elements.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain existing ecological interests of the element Loss of reedbed in upper regions of the estuary. *Opportunity:* Increase in area of mudflat, saltmarsh and potentially reed beds all outside of the existing designated area.	**- Sustainable** **- Potential regret** **- Mitigation required ?**
Maintain defences (existing practice)	*Integrity:* Fails to maintain existing ecological interests of the element Loss of saltmarsh and reedbed due to coastal squeeze. Increase in intertidal mudflat *Opportunity:* None	**- Sustainable** **- Mitigation required**

Sustainable alternatives

No realistic alternatives available.

4.6.4 Discussion

The Estuary is a relatively stable offshoot to the main Alde/Ore, with reedbed and saltings both along the fringes of the channel and more significantly at the head of the estuary.

Under a **non- intervention (D2a)** policy the defences around the estuary would be allowed to deteriorate and in time fail. It is estimated that this would result in an increase in tidal volume of some 25% in relation to the main estuary. Failure of the defences would result in loss of key features within the existing designated area as flooding occurs to low-lying land behind the defences. There would also be loss of reedbed habitat further upstream under accelerated sea level rise.

The abandonment of defences would substantially increase the potential for intertidal habitat creation (outside the current designated area) but would also result in critical increases in the tidal volume of the main estuary, limiting possible future response in Element 1.

This scenario would therefore fail to maintain existing internationally designated features although a natural and ecologically functional estuary tributary would result and the area of intertidal habitat would increase. Depending on likely ecological succession there could be a requirement to offset, through habitat creation, the loss of reedbed habitat from within the site.

The current management practice, in line with the as yet un-adopted strategy for flood defence, is for **maintenance** and repair of existing defences **(D2b).** Under realistic sea level change scenarios, maintenance of defences is sustainable, although there would be loss of fringing saltmarsh habitat and brackish water reedbed and saltmarsh at the head of the estuary.

Despite these losses, it is considered that there is no viable alternative to the management of the Butley system.

Local Summary for Element D2

Approach		Comment	Local Conclusion
D2a	Non-intervention	Loss of designated habitats within the estuary (saltmarsh, reedbed). Allows development of extensive areas of new intertidal habitat.	Sustainable, but would have significant implications for the rest of the estuary system.
D2b	Maintain	Optimum maintenance of features of the element but still resulting in loss of intertidal habitat.	Viable, subject to appropriate mitigation.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	D2a	D2b
Intertidal mudflats		*70ha*	+40ha	+30ha
Annual drift-line vegetation		*na*	0	0
Brackish/freshwater reedbed		*20ha*	-10ha	-10ha
Wet grasslands		*na*	0	0
Shingle beach		*na*	0	0
Saltmarsh		*80ha*	-50ha	-40ha
Heath		*na*	0	0

Note figures for different approaches are in terms of loss or gain from the baseline.

4.6.5 Hazelwood (Abstract and Assessment of HBU D. Element 3)

Description of environmental feature

Inventory Brackish/freshwater grazing marsh (SPA/Ramsar)

Key function Provides a breeding and roosting site for estuarine bird populations. Supports diverse plant and invertebrate communities.

Dependency Defences prevent tidal inundation from the estuary.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain the existing ecological interests of the element Loss of wet grassland habitat *Opportunity:* Increase in intertidal habitat.	**- Sustainable** **- Potential regret** **- Mitigation required ?**
Response maintenance (existing practice)	*Integrity:* Maintains the integrity of element Maintains protection in-situ to designated feature *Opportunity:* None	**- Sustainable**

Sustainable alternatives

No alternatives considered.

4.6.6 Discussion

The defences of Hazelwood marshes are in generally poor condition. Even so, there is little stress in relation to estuary behaviour and there is no technical reason for not maintaining these defences.

Under a **non- intervention (D3a)** policy the defences would be allowed to deteriorate and in time would fail. The individual increase in estuary volume would not be significant in terms of stress elsewhere in the estuary, although its cumulative impact, should other defences be abandoned, would need to be examined. This approach would provide opportunity for the development of new intertidal areas, with, because of its position, a realistic chance for the area to warp up to provide saltmarsh. This area offers a significant opportunity for mitigation habitat in line with the ecological function of the estuary. The scenario, however, fails to maintain the existing internationally designated feature (wet grazing marsh) and as such mitigation for the wet grassland may have to be sought.

The current management practice is for basic **maintenance** and repair of existing defences **(D3b).** The defence would need to be upgraded. This approach would safeguard the element's contribution to the existing internationally designations of the HBU in a technically sustainable manner.

Local Summary for Element D3

Approach		**Comment**	**Local Conclusion**
D3a	Non-intervention	Loss of terrestrial features but allows development of area of intertidal habitat within the designated area.	Viable as mitigation habitat but change to intertidal may require mitigation.
D3b	Maintain	Existing designated interests maintained.	Viable.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	D3a	D3b
Intertidal mudflats		*na*	+50ha	0
Annual drift-line vegetation		*Na*	0	0
Brackish/freshwater reedbed		*na*	0	0
Wet grasslands		*70ha*	-70	0
Shingle beach		*na*	0	0
Saltmarsh		*na*	+20ha	0
Heath		*na*	0	0

Note figures for different approaches are in terms of loss or gain from the baseline.

4.6.7 Orford Ness and Marshes (Abstract and Assessment of HBU D. Element 4)

Description of environmental feature

Inventory

- Perennial shingle (cSAC/Ramsar)
- Annual vegetation of drift lines (cSAC)
- Saline lagoons (cSAC)
- Saltmarsh (cSAC/SPA)
- Grazing marsh (SPA/Ramsar)
- SPA designated bird populations (lesser-black backed gulls, avocet, little tern)

Key function

Orfordness represents the second largest vegetated shingle structure in the UK and comprises a mosaic of coastal habitat types which have evolved over centuries. The shingle of the main ness supports a specialist flora and fauna as well as providing habitat for the UK's largest breeding colonies of lesser black-backed and herring gulls. Old clay and gravel pits on site support characteristic saline lagoon species.

Dependency

The mosaic of habitats has been formed through natural coastal evolution and human intervention. The shingle of the system effectively provides the fabric to the habitat diversity and structure of the feature itself.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain existing designated ecological interests Loss of wet and maritime grasslands (SPA interest). Gradual loss of extent of shingle and possible attachment of spit to shore. Potential loss of some saline lagoons. Significant impact on HBU *Opportunity:* Opportunity for mudflat and saltmarsh creation and natural development of the system.	**- Sustainable** **- Potential regret** **- Mitigation required ?**
Maintain Slaughden neck, abandon river defences (Existing Practice and Policy)	*Integrity:* Fails to maintain existing designated ecological interests Loss of SPA grassland and cSAC lagoons. Gradual loss of extent of shingle and possible significant loss of length of spit (cSAC shingle habitat and breeding area for little tern). *Opportunity:* Opportunity for mudflat and saltmarsh creation	**- Sustainable** **- Potential regret** **- Mitigation required**

Protection in-situ and sustainable alternatives

Full protection Maintain walls and raise with sea level rise.	*Integrity:*	Maintains existing designated ecological interests Slight and gradual loss of shingle. *Opportunity:* None.	**- Un-sustainable** **- Potential regret**
Effective lowering of riverside defences. Maintain condition and level of flood walls	*Integrity:*	Fails to maintain the existing designated ecological interests. Progressive loss of wet and maritime grassland. Gradual loss of shingle. Proportion of saline lagoon habitat lost. *Opportunity:* Potential to create developing intertidal, brackish habitat.	**- Sustainable** **- Potential regret** **- Mitigation required**

4.6.8 Discussion

There is a reducing supply of sediment from the north onto the Orford Ness frontage. Along the frontage there is a weak net southerly movement of material and an increasing loss of material along the face of the Spit (south of the Ness). The result of this is, in effect, a gradual straightening of the shoreline between Aldeburgh and Shingle Street. Such change would be over a very long time scale (500 to 2000years) but provides the context over which the change should be viewed.

The present day impact of this process is the vulnerability of the neck of land between the river and the sea at Slaughden. This has been variously protected by hard defences and more recently by beach management, bringing material from the designated areas of beach seaward of the Lantern Marshes. In the absence of some form of management it is likely that the neck of land would breach and probably in the longer term remain as a new opening to the Alde Estuary. Although this operation is outside the designated area of the element under consideration, the implications both in terms of the disturbance of the element as a source of recharge material, if operations continue, and the major impact of the breach, if works were abandoned, need to be considered within this element.

Under a **non- intervention (D4a)** approach no further beach management would be undertaken to Slaughden Beach. Furthermore, maintenance of defence of the river face to the Kings and Lantern Marshes would cease.

The following scenario is necessarily a best estimate based on various previous assessments. As a breach or entrance develops to the estuary, the complex interaction of tide through both entrances is likely to result in increased water levels in the vicinity of King Marsh, although flows are likely to be reduced. This increase in water level would make the Kings and Lanterns Marshes more vulnerable to flooding and, due to their lack of maintenance, fail. It remains uncertain how flows would distribute between the two entrances but there is a distinct possibility that the northern entrance may come to dominate. Certainly there is likely to be a reduction in flows within the Ore entrance and, as a consequence, there is likely to be an increased rollover of Orford Spit towards the marshes of Boyton and Orford Haven. Whether the reduced flow within the river Ore would be sufficient to maintain its entrance is again uncertain. There is a possibility that Orford Spit may attach itself to the shoreline.

At the northern end of the feature, the development of the entrance is likely to further reduce the supply of drift material to the south. There is likely to be increased erosion of the beach in front of Lantern Marsh.

Failure of the Kings and Lantern Marshes would result in substantial loss of designated freshwater and maritime grassland as well as some saline lagoons. Although there would be significant development of intertidal and transitional habitat, mitigation may need to be considered to offset the loss of some ecological elements (e.g. saline lagoons). As such this scenario would fail to maintain the existing internationally important features. There is also considerable uncertainty as to how the breach and the estuary would respond. From a precautionary approach this scenario is considered inappropriate at this time.

The current management practice is for beach management to **maintain the neck (D4b)** of land between sea and river at Slaughden. This has involved movement of limited quantities of material from within the cSAC/SPA boundary. These operations have recently been reviewed in detail and the conclusion is that some damage to the annual vegetation of drift line interests is occurring. In the absence, as yet, of adopting an estuary strategy for defence, current management of the estuary defences is on an ad hoc **response maintenance (D4b)**. The defence to Kings and Lantern Marsh are not being maintained by the Environment Agency. It is probable that these defences would fail in the short to medium term. The impact of this on the estuary as a whole has already been considered under element 1. In terms of the Orford Ness element, loss of these defences would result in salt water inundation of the fresh and maritime grasslands of the marshes and in the regular inundation of the saline lagoons on the western side of the Ness. As already discussed for element 1, this approach restricts balanced responsive management of the estuary, while resulting in the loss of important internationally designated habitats within the element. From the perspective of the estuary this is felt to lead to pressure on management of the estuary and is considered unsustainable. From the perspective of the Orford Ness element in isolation, however, the creation of extensive areas of saltmarsh and mudflat fronted by the massive shingle banks of the open coast would be sustainable. The option would require mitigation for the loss of the terrestrial interests of Kings and Lantern Marsh. The beach management is considered sustainable for some time but may require mitigation for current management if not mitigation for the loss of shingle habitat.

As neither allowing natural development of the estuary nor continuing current practice would maintain the existing ecological interests of this element, alternative approaches need to be examined.

To protect the interests of the marshes **full defence (D4c)** could be continued. While feasible, such an approach would be onerous and would increasingly maintain an artificial and vulnerable situation with respect to ecological interests. The approach would assume continued high level protection on the seaward side of the Ness and this, in the longer term, may similarly become onerous, requiring artificial strengthening of the shingle face or retired flood defences. Either way, over time such operations may become more frequent and may result in extensive damage to the shingle ecology (both perennial and annual vegetation) of the coastline. This approach may eventually require extensive mitigation measures and is not considered to be sustainable in the long term.

There is felt almost to be an inevitability of change to the Orford Ness Feature and its marshes. In this final approach, this change is managed to allow a more natural transition to a new ecological state/equilibrium. The line and integrity of the estuary defences would be maintained but no attempt would be made to raise their level, in effecting **lowering the defence level (D4d)** as sea level rise occurs. This would allow, gradually, more frequent tidal inundation from extreme events over the next 50 years. A similar attitude would be taken to the seaward defence in not attempting to maintain the current defence standards in the face of sea level change. The management of this in relation to the use of the marshes to act as control to mitigate extreme increases in tidal volume would need to be examined in more detail. The longer term intent of this approach would be to allow movement to a saline dominated environment, over the next 50 to 100 years, which minimised the need for future intervention.

This approach could minimise the impact on the estuary and on the function of the Ness. The ecological interest of the Ness would therefore largely be left to evolve, albeit through a more controlled and gradual process. The main impact would be a change from existing terrestrial grassland habitats at Kings and Lantern marshes into saline features, probably intertidal mudflat and saltmarsh. This would provide benefits with respect to SPA estuarine bird populations. It is likely that there would be a loss of saline lagoon interest due to the overall development of intertidal habitat. The approach is sustainable but would require a long term programme of mitigation for the loss of terrestrial SPA/Ramsar designated features and the cSAC saline lagoons.

Local Summary for Element D4

Approach		**Comment**	**Local Conclusion**
D4a	Non-intervention	Uncertainty over the development of the estuary under a Slaughden Breach scenario. Major increase in tidal prism and loss of designated habitat.	Inappropriate
D4b	Maintain the neck and abandon the river defences	Fails to maintain the form of the existing estuary system and results in loss of specific designated habitat.	Inappropriate
D4c	Full defence	Unsustainable in the long term	Inappropriate
D4d	Effective lowering of river defences	Allows gradual and regulated change in habitat, but requires a long term programme for mitigation.	Viable.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	D4a	D4b	D4c	D4d
Intertidal mudflats		*30*	+250ha	+200ha	0ha	+100ha
Annual drift-line vegetation		*15km*	-500m	0	0	0
Brackish/freshwater reedbed		*10ha*	-10ha	-10ha	0	-10ha
Wet grasslands		*350ha*	-350ha	-350ha	0	-350ha
Shingle beach		*450ha*	-100ha	-50ha	-200ha	-20ha
Saltmarsh		*90ha*	+100ha	+150ha	0	+250ha

Note figures for different approaches are in terms of loss or gain from the baseline.

4.6.9 Shingle Street (Abstract and Assessment of HBU D. Element 5)

Description of environmental feature

Inventory

- Perennial vegetation of shingle banks (cSAC)
- Annual vegetation of drift lines (cSAC)
- Saline lagoons (cSAC)

Key function Shingle substrate supports a diverse and characteristic plant and invertebrate community. The saline lagoons at this location have been well studied and support a classic saline lagoon community.

Dependency Saline lagoons are ephemeral features created through the movement of shingle from the tip of Orfordness onto the shoreline at Shingle Street.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain the existing designated ecological interests of the element Intermittent loss and gain of saline lagoons. Potential loss of shingle habitat. *Opportunity:* Increase in intertidal habitat outside existing designated boundary of SPA and cSAC.	**- Sustainable** **- Potential regret** **- Mitigation required ?**
Hold the Line (existing practice)	*Integrity:* Maintains existing designated ecological interests of the element Intermittent loss and gain of saline lagoons. *Opportunity:* None	**- Sustainable** **- Mitigation required ?**

Sustainable alternatives

No alternatives considered.

4.6.10 Discussion

Material moves down the coast from Orford Spit and is transferred onto the Shingle Street frontage. This transfer can occur as a gradual feed through the series of banks at Orford Haven or as a process by which the banks detach from the northern side of the Estuary mouth and attach themselves to the Shingle Street frontage. On a longer term cycle the spit to the north extends over the Shingle Street frontage, eventually breaching further north, with a large quantity of material being attached to the southern shore. It is as a result of the latter two mechanisms that lagoons can form on the shingle street side of the estuary.

The shoreline to the south of Shingle Street is maintained at its southern end by the promontory of East Lane. The bay between Shingle Street and East lane is relatively stable in alignment, although material feeding from the north tends to make its way along the frontage and is lost to the coast further south. In considering this element it is necessary to consider the implications of defence down to East Lane.

Under the **non-intervention (D5a)** approach there would be little change in the processes to the north of the element. Material would still move south feeding the frontage. However, under this approach East Lane would not be defended and as it fails it would increasingly allow a greater quantity of material to move southwards. This would deplete the bay of shingle and would, eventually result in loss generally from Shingle Street. As the shingle ridge around the bay weakens, there would be an increased likelihood of breach to the low lying land behind. Opening of this area would tend to act as a sink for material initially resulting in further loss to the open coast frontage. There would be potential gain in terms of intertidal area and shingle banks within the bay but this would be at the detriment of the existing habitats and features around Shingle Street. Although this approach could result in an increase in habitat area there would be a requirement to ensure that the extent and interest of existing designated interests were adequately covered.

Developing from the SMP policy of **Hold the Line (D5b)**, the strategy for the frontage is to maintain the existing line by actions to defend East Lane. This would again allow the existing processes at Shingle Street to continue, bringing intermittently a supply of shingle to the frontage. This would sustain the shingle habitat of the area. The condition of the saline lagoons would depend on the particular state of the coastal cycle. When part of the Spit, or substantial banks attach to the southern coast, they have the potential to entrap lagoons of seawater (this has recently occurred). Subsequent change in the Spit can result in the erosion of the shingle in front of these lagoons and their eventual loss.

This approach maintains the coastal process allowing the lagoons to form and to be lost periodically. In strict terms the approach fails to protect these important features. However, in practice this process allows a continuing revitalisation of the lagoon system. It is arguable, therefore, that no mitigation is required. The policy for the frontage is therefore considered sustainable.

Local Summary for Element D5

Approach		**Comment**	**Local Conclusion**
D5a	Non-intervention	Natural development of saline lagoons would continue, but overall loss of shingle habitat. Allows development of areas of potential intertidal habitat outside the designated area.	Viable as mitigation but also requiring mitigation.
D5b	Maintain	Maintains a sustainable system despite regular loss and redevelopment of saline lagoons.	Viable.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	D5a	D5b
Intertidal mudflats		*Na*	-	-
Annual drift-line vegetation		*2km*	0	0
Brackish/freshwater reedbed		*na*	-	-
Wet grasslands		*na*	-	-
Saline lagoons		*3No*	?	?
Shingle beach		*50ha*	-25ha	0
Saltmarsh		*na*	-	-
Heath		*na*	-	-

Note figures for different approaches are in terms of loss or gain from the baseline.

4.6.11 Overall Assessment for HBU D

In examining HBU D, an initial collation is provided of the non-intervention and current policy or practice for the unit compared with existing habitat extent. This is presented as the accountancy tables below. Even though it is recognised that the integrity of the unit cannot be assessed solely from the perspective of the extent of habitat area, this is felt to provide a useful indication of the key issues involved.

Assessment of change for non-intervention Policy

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Annual drift line vegetation	Shingle	Heath
D1	+40ha	-100ha		-15ha				
D2	+40ha	-50ha		-10ha				
D3	+50ha	+20ha			-70ha			
D4	+250ha	+100ha	-50 (app.)	-10	-350ha	-0.5km	-100ha	
D5			-3No.			0	-25ha	
Total Change	+380ha +163%	-30ha -10%	-53No. -80%	-35ha -70%	-420ha -98%	-0.5km -3%	-125ha -25%	
Baseline	*600ha*	*310ha*	*Approx 65No.*	*50ha*	*425ha*	*17km*	*500ha*	

Assessment of change for current policy or practice

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Annual drift line vegetation	Shingle	Heath
D1	+20ha	-75ha		-15ha				
D2	+30ha	-40ha		-10ha				
D3	0	0			0			
D4	+200ha	+150ha	-50 Approx .	-10ha	-350ha	0	-50ha	
D5			-3No			0	0	
Total Change	+250ha +141%	+35ha 11%	-53No -80%	-35ha -70%	-350ha -83%		-50ha -10%	
Baseline	*600ha*	*310ha*	*65No.*	*50ha*	*425ha*	*17km*	*500ha*	

Both approaches result in loss, almost, across the full suite of habitats within the estuary; there is some potential gain of intertidal mudflat and saltmarsh. Neither approach would be acceptable without an extensive and a varied approach to mitigation if it is required to maintain the full suite and extent of existing designated features.

In addition, as discussed in the element assessment, neither of the above approaches allows significant latitude in the management of the estuary to enable response or appropriate mitigation habitats to be developed. In the case of a non-intervention policy, the future control of the estuary is lost and there are no significant areas within the general area of the HBU to develop freshwater habitat. Within the current practice scenario the loss of Kings and Lantern Marsh, in effect, closes down options for further retreat without major disruption to the estuary behaviour.

The tables do, however, highlight the balance between the loss of freshwater habitat, the gain or loss of intertidal habitat and the control of the future development of the estuary as a whole.

Mitigation Habitat

Within a controlled situation various areas offer potential mitigation. In some areas where these are already within the SPA or cSAC they are included in the assessment tables. These include:

- Kings and Lantern Marshes (element D4), with the potential to add to the saline dominant or intertidal areas, at the expense of the existing freshwater and maritime grassland already present.
- Hazelwood Marshes (element D3), with the potential for development as saltmarsh and intertidal mudflat at the expense of the existing wet grassland.

Areas outside the designated boundaries which could be used as mitigation include:

- Boyton Marsh as potential intertidal area or freshwater grassland. (143ha)
- Aldeburgh Town Marsh, again as potential intertidal marsh or possibly freshwater grassland (100ha)

Abandoning both these areas would result in significant increase in tidal prism which could result, in turn, in damage to the inner face of the Spit. Any further realignment over significant flood plain areas is likely to result in failure of the spit and a substantial increase in the loss of intertidal mudflat and saltmarsh within the designated boundary of the cSAC/SPA.

Other areas of mitigation habitat could be found in the main block of Sudbourne, Orford and Gedgrave Marshes. Here, mitigation would be through management as wet grasslands and potential reedbed development at the heads of freshwater flows into the area (see Figures 4.4 and 4.5). The total area of these marshes is 920ha although only part of this would be suitable for mitigation. Similarly, areas adjacent to the Butley would provide appropriate mitigation for similar habitat (potential of approximately 460ha).

There is therefore quite extensive scope for a balance of habitat extent and distribution to be achieved, while still maintaining the control of the estuary.

Figure 4.4. Potential locations (highlighted in green) for the development of freshwater wetland habitat around the upper Alde Estuary.

Figure 4.5. Potential locations (highlighted in green) for the development of freshwater wetland habitat around the lower Alde Estuary.

Alternative Scenarios

The table below is based on a scenario where all areas of the estuary are held but the effective defence level of the Kings and Lanterns Marshes is allowed to decrease in respect to anticipated sea level rise Scenario 1. The table is expressed in terms of extent of habitat retained.

Assessment of Habitat retained or increased through scenario 1

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Wet grasslands	Annual drift line vegetation	Shingle	Heath
D1	520ha	65ha		5ha				
D2	100ha	40ha		10ha	5ha			
D3					70ha			
D4	130ha	340ha	10No.		0	15	430ha	
D5			0			2km	50ha	
Total	750ha	445ha	10No.	15ha	75ha	17km	480ha	
Change	125%	143%	15%	30%	17%	100%	96%	
Baseline	*600ha*	*310ha*	*65No.*	*50ha*	*430ha*	*17km*	*500ha*	

It may be seen that under this scenario that overtime an approximate balance is achieved, in terms of intertidal habitat, with some shortfall in intertidal area. Potentially, due the manner in which the habitat would convert there may be some greater shortfall in both saltmarsh and mudflat.

The main area of loss would be brackish/fresh grassland, saline lagoons (Orfordness) and reedbeds. Adequate potential for mitigation exists within the estuary system to accommodate this loss.

To address concerns over the development of intertidal area a second scenario (scenario 2) is considered whereby realignment over Aldeburgh Marsh would occur. This would potentially reduce loss of saltmarsh within element 1 (within the designated area of the estuary) by somewhere in the order of 50ha

In addition the marshes would potentially allow creation of a further 50ha of mudflat and 50ha of possible saltmarsh, or could be engineered to provide saline lagoon habitat, providing a precautionary mitigation over and above that created in the progressive conversion of Kings and Lantern Marsh.

4.6.12 Conclusion for Habitat Behavioural Unit D

The internationally important features of this unit cannot be retained fully either by intervention or by allowing the natural systems of the coast and estuary to continue. The recognised intent of management of this area is to maintain control of the way in which the estuary and Orford Spit behave. Within this there are various constraints on the change that may be accepted within the estuary.

The main concern is to achieve a balance of habitats throughout the estuary. There is a continuing loss of saltmarsh and intertidal mudflat and a threat of loss of reedbeds as a result of anticipated sea level rise.

Within the estuary (but outside the existing designated areas) there are identified several potential areas where mitigation can be sought for loss of wet grassland and even reedbed. There is, therefore, scope to concentrate on re-creation of mudflat and saltmarsh by realignment from defended areas within the designated areas, limited by their suitability and their impact on the response to increased tidal volume. The second scenario discussed above provides an appropriate way forward, subject to more detailed study of the physical processes. Alternative approaches would be realignment of the defences at Boyton and Hazelwood.

In neither case would this relieve existing pressure on a critical part of the estuary. In the case of Boyton, realignment could lead to the loss of saltmarsh fringing the defences. It would also exclude Boyton (which is already in part managed as a wet grassland area) from use as mitigation for loss of this habitat elsewhere. In the case of Hazelwood, this would result in the loss of already established and designated wet grassland and would be contrary to the presumption of defence *in-situ* where possible. In the case of Hazelwood the findings of the CHaMP are that realignment of this area is unnecessary and this may be used to update the findings of the estuary strategy.

4.7 HBU: E. Deben: Bawdsey to the Dip including Estuary

Elements:

1. Deben Estuary	*Designation*	The Deben Estuary SPA/Ramsar
	Key Features	Saltmarsh, Intertidal mudflats (important wet grassland features outside the SPA).

Management		
Trends	*Constraints:*	On the open coast material generally moves down from the north along the shore, being held up at the mouth of the estuary within the Knolls system of banks. There is a continuing feed across the estuary with a more intermittent break up of the Knolls, with banks attaching themselves to the opposite shore. The entrance channel to the estuary is relatively constrained. The upper estuary is principally constrained in its overall movement by high ground but opens out in the lower reach with the wide meanders being held by the flood defence works. Change in tidal volume of the estuary would influence the entrance and the coastal processes.
	Evolution:	There is a growing pressure within the estuary, particularly at the lower end. Sea level rise is likely to result in increasing loss of saltmarsh. Some lateral movement of the meanders within the lower estuary would be expected due to tidal volume increases.
Current Practice	*Description*	In general defences within the estuary are maintained although there has been some minor realignment at the head of the estuary. The mouth of the estuary is being defended, with the line of defence still allowing some change within the hydraulic performance of the estuary.
	Implications	The decision to maintain the general configuration of the estuary mouth limits the degree of tidal volume increase within the estuary.
Policy	*Description*	The general policy for the coast is to maintain the coastal processes, allowing a continuation of sediment feed to the south. Within the estuary, the general policy is to maintain the major defended areas. Consideration has been given to realignment over small areas of grassland adjacent to the estuary and outside of the designated boundary of the SPA/Ramsar.
	Intent	To allow some natural change to occur while maintaining control of the development of the estuary as a whole.

HBU issues: There has been extensive loss of saltmarsh over the last 30 years (71ha). The small wet grassland areas adjacent to the estuary are an important supporting habitat to the SPA, although not designated. Similarly, the extensive areas of agricultural land to the lower estuary are important feeding and roosting areas for some waterfowl species.

4.7.1 The Deben Estuary (Abstract and Assessment of HBU E. Element 1)

Description of environmental feature

Inventory	• Intertidal mudflat (SPA/Ramsar) • Saltmarsh (SPA/Ramsar)
Key function	The intertidal area of the estuary supports the designated SPA populations and diverse plant and invertebrate communities.
Dependency	The balance between the two intertidal habitats is dependent on the physical evolution of the estuary system and internal processes of erosion and accretion.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain existing designated ecological interests Loss of habitat within the SPA. *Opportunity:* Increases areas of mudflat and saltmarsh outside SPA boundary.	**- Sustainable - Potential Regret - Mitigation may be required (but also provided)**
Maintain all defences (existing policy)	*Integrity:* Fails to maintain existing designated ecological interests Continued loss of saltmarsh habitat due to coastal squeeze. *Opportunity:* None	**- Sustainable - Potential Regret - Mitigation required.**

Sustainable alternatives

Selective retreat Re-alignment and managed habitat creation	*Integrity:* Fails to maintain existing designated ecological interests Increases areas of mudflat and saltmarsh outside SPA. Continued loss of saltmarsh within SPA and loss of small areas of wet grassland habitat (outside of SPA) *Opportunity:* Potential to create saltmarsh and transitional habitat	**- Sustainable - Potential regret - Mitigation required**

4.7.2 Discussion

The Deben Estuary has developed, over the last several centuries, with reclamation, principally within the lower estuary, up to the principal low water channel. In the upper part of the estuary there has not been a similar restraint, reclamation being confined to offshoot valleys. There has been considerable development of saltmarsh within the natural width of the upper estuary. This is now suffering from erosion.

Under a **non- intervention (E1a)** policy there would be further deterioration of defences and eventual failure, progressively throughout the estuary. The main impact of this would be in the lower estuary and at the entrance. The increase in tidal volume would be in the order of 80% and with anticipated sea level rise some 200% increase. The existing entrance to the estuary would not be able to sustain such an increase in tidal volume and there would be a significant impact to the coastal regime. In addition, the increase in flow and water levels would result in extensive damage to existing SPA/Ramsar designated saltmarsh.

The approach would, however, massively increase the opportunity for intertidal and saltmarsh development outside the SPA boundary, thereby mitigating for loss from within the designated site. There would be loss of areas of wet grassland adjacent to the SPA, which may have a detrimental ecological impact, although potentially transitional saline-freshwater habitat in some of the small tributary valleys would compensate for this loss.

The non-intervention policy is both sustainable, and while failing to protect existing SPA interests, would provide substantial compensatory habitat. It does have other major implications outwith the scope of the CHaMP.

Current management practice is to **maintain the existing defences (E1b)** throughout the estuary. This would require significant investment but is sustainable. The approach would, however, lead to a continuing loss of SPA designated saltmarsh habitat which would require mitigation in order to offset loss. This policy would also maintain the potential for freshwater grassland habitat creation within areas of low-lying land on either side of the estuary. These areas represent the former estuarine floodplain of the Deben and are now almost solely under agricultural production.

An alternative approach is considered, whereby, there is a **selective realignment (E1c)** from critical defences. The intent of this would be to provide appropriate mitigation habitat while maintaining control of the development of the estuary. This provides a more sustainable approach without extensive disruption to the coastal processes. Particular areas identified for realignment within the estuary strategy are at Melton, Martlesham Creek, White Hall, Waldringfield, Ramsholt Lodge and Ramsholt and at Nursery Wood.

Local Summary for Element B1

Approach		Comment	Local Conclusion
E1a	Non-intervention	Loss of Designated features but massive opportunity for mitigation. Major disruption and contrary to open coast policy.	Viable
E1b	Maintain	Continued loss of saltmarsh. Technically sustainable.	In-appropriate
E1c	Re-alignment	Loss of designated features (saltmarsh) but provides mitigation.	Viable

Initial Accountancy Table

Feature	*Baseline*	E1a	E1b	E1c
Intertidal mudflats	*360ha*	+120	+90	+100
Annual drift-line vegetation	*na*	0	0	0
Brackish/freshwater reedbed	*na*	0	0	0
Wet grasslands	*na*	0	0	0
Shingle beach	*na*	0	0	0
Saltmarsh	*250ha*	-150ha	-100ha	-125ha

Note figures for different approaches are in terms of loss or gain from the baseline.

4.7.3 Overall Assessment for HBU D

The Deben has been considered as one element, as such much of the discussion as to its overall assessment has already been undertaken. Maintaining designated features *in-situ* is not an option. As shown in the previous table minimal disruption to both the estuary and the existing habitat is achieved through strategic realignment. This carries with it the necessary mitigation, in that the loss of saltmarsh would be mitigated by the potential for saltmarsh re-creation in the realigned areas.

Mitigation Habitat

Potential mitigation areas include sections of land at:

- Melton;
- Martlesham Creek (south);
- Waldringfield;
- White Hall;
- Ramsholt Lodge;
- Ramsholt;
- Nursery Wood.

Further investigation should be carried out to examine in more detail the scope for re-creation of habitat within each area. Should any area be unsuitable, particularly those of Melton, and Nursery Wood, which offer the greatest opportunity, then mitigation for saltmarsh may need to be sought outwith the HBU. The Alde/Ore HBU D potentially offers scope for this.

4.7.4 Conclusion for Habitat Behavioural Unit E

Due to the continuing loss of saltmarsh within this estuary the internationally important feature would not be maintained. The main problem is that of coastal squeeze, either against natural constraints or man made defences.

Realignment of defences also carries with it potential problems in that: first it may result in damage to existing fringing saltmarsh and secondly that it may result in excessive pressure on defences and, in particular the mouth of the river. There is a need, however, to provide mitigation for the loss of saltmarsh habitat if the maintenance of defences continues. Various areas have been identified within the estuary envelope and these would provide adequate sites for intertidal habitat creation. This needs to be investigated in more detail. Further mitigation may be required and could potentially be found in the Alde/Ore or in the area of Hamford Water (Essex).

4.8 HBU: F. Stour and Orwell Estuaries: Stour and Orwell

Elements:		
1. Orwell Estuary	*Designation*	Part of Stour and Orwell SPA/Ramsar
	Key Features	Mudflats, saltmarsh and wet grassland.
2. Stour Estuary	*Designation:*	Part of Stour and Orwell SPA/Ramsar
	Key Features:	Mudflats and saltmarsh

Management		
Trends	*Constraints:*	The development of both estuaries is strongly influenced by the higher ground abutting the estuaries. In the case of the Orwell, the upper reaches lie predominantly within a narrow steep-sided valley. Only at the southern, lower reach is the potential flood plain wider. Even here the estuary channel is quite strongly controlled by the high ground of Collimer Point and Shotley Point and Sleighton Hill and Fagbury, although at this latter point the development of Felixstowe Port has superseded the natural control. The Stour is a more open estuary within a wider valley, allowing the development of the channel and flats in a more uncontrolled manner between high ground.
	Evolution:	On balance the Orwell is seen as an accreting estuary, although there has been erosion of intertidal area at its southern end. The estuary is not, however, under man made constraint. The Stour, with the exception of its most upper reaches, tends to be an erosive estuary. There is evidence that the erosion within the estuary may be slowing. The dredged entrance to both estuaries acts as a sediment sink tending to reduce the availability of fine material to upper sections of the estuaries. The development of the harbour and associated dredging works have and will continue to have a significant impact on the evolution of the estuaries.
Current Practice	*Description*	The main areas of defence on the Orwell are at Shotley and at Trimley. Defences to both areas are at present maintained although there is no strategy developed for their management. In the Stour defence management has had little impact on the development of the estuary. There is continuing maintenance dredging of the Harbour area.
	Implications	Continued dredging may influence the ability of the estuaries to accrete in line with sea level rise.
Policy	*Description*	There is no formal defence policy for either estuary.
	Intent	To allow natural change to occur.

HBU issues: There is continuing loss of saltmarsh and intertidal area within both estuaries. Trimley provides an important function within the system although this is not recognised within the SPA designation.

4.8.1 The Orwell (Abstract and Assessment of HBU F. Element 1)

Description of environmental feature

Inventory	• Intertidal mudflats (SPA/Ramsar) • Saltmarsh (SPA) • Freshwater/brackish grazing marsh (SPA/Ramsar)
Key function	The intertidal mudflats and saltmarsh provide a feeding resource for internationally important populations of wintering waterfowl. The saltmarsh and adjacent areas of wet grazing marsh at the mouth of the estuary provide a roosting area for waterfowl.
Dependency	The balance between mudflat and saltmarsh is dependent on the overall physical evolution of the estuary and the interplay between erosion and accretion. The wintering waterfowl (i.e. designated SPA interests) depend on both habitats, the loss or significant reduction of one feature, in particular mudflat, would not be countered by gain in the other.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain the existing designated ecological interests Continued loss of saltmarsh and mudflat, with the potential loss of Trimley as a freshwater supporting habitat. *Opportunity:* Creation of saltmarsh and transitional habitat outside the boundary of the SPA	**- Sustainable** **- Potential regret** **- Mitigation required ?**
Maintain all defences (existing policy)	*Integrity:* Fails to maintains the existing designated ecological interests Continued loss of salt marsh habitat and reduction in extent in intertidal mudflat through coastal squeeze. *Opportunity:* None	**- Sustainable** **- Potential regret** **- Mitigation required.**

Sustainable alternatives

There are no alternatives that adequately protect *in-situ* the features of the SPA.

4.8.2 Discussion

Under a **non- intervention (F1a)** policy there would be limited opportunity for saltmarsh growth in the upper estuary as present areas are forced against the natural rising valley slopes. Over the southern section the defences of Trimley and Shotley would fail, opening up the opportunity for intertidal mudflat and salt marsh development outside the main flow area of the channel. Trimley is outside of the designated SPA. Under this scenario, the SPA designated grazing marsh habitat at Shotley would be lost through conversion to intertidal. Trimley is seen as being an important feature of the SPA, in that it provides a feeding and roosting area for SPA designated populations (e.g. dark-bellied brent geese) although it does not lie within the designated area. This function of the Trimley section would be lost, although the additional intertidal area created both here and at Shotley would provide significant new areas of potential feeding habitat for a range of waterfowl species. This approach would fails to maintain the existing distribution and extent of the internationally designated features and mitigation to offset loss/change may have to be sought.

Private effort has been put in to **maintaining the existing defences (F1b)** at Trimley. Such an approach is seen as being sustainable but would require considerably greater investment than at present. Under this approach there would continue to be general squeeze on the saltmarsh habitats along the upper estuary and no opportunity to re establish saltmarsh along the Trimley frontage. Estimated losses are in the region of 1ha/yr of saltmarsh habitat, based on the work of Burd (1992). At this rate all of the saltmarsh within the estuary could potentially be lost within approximately 50 years. While this policy does act to defend an important supporting habitat this is outwith the designation of the SPA. The wet grazing marsh habitat at Shotley would be maintained, although there is the potential that continued maintenance of the floodwalls would reduce the brackish water influence on this site. Due to the continued loss of saltmarsh, this approach would fail to maintain the existing distribution and extent of the internationally designated features and mitigation to offset loss (of intertidal habitat) would have to be sought.

Local Summary for Element F1

Approach		**Comment**	**Local Conclusion**
F1a	Non-intervention	Loss of saltmarsh and reduction in area of intertidal mudflat. Loss of wet grazing marsh at Shotley (SPA/Ramsar) and Trimley (non-SPA). Damages the important supporting Habitat at Trimley.	Viable, but habitat creation to maintain overall resource may be required.
F1b	Maintain	Fails to address the problem of loss of saltmarsh and mudflat through coastal squeeze. Provides no mitigatory habitat.	Inappropriate

Initial Accountancy Table

Feature	*Baseline*	F1a	F1b
Intertidal mudflats	*500ha*	0	-50ha
Annual drift-line vegetation	*Na*	0	0
Brackish/freshwater reedbed	*Na*	0	0
Wet grasslands	*75ha*	-75ha	0
Shingle beach	*Na*	0	0
Saltmarsh	*60ha*	-50ha	-60ha
Heath	*na*	0	0

Note figures for different approaches are in terms of loss or gain from the baseline.

4.8.3 The Stour (Abstract and Assessment of HBU F. Element 2)

Description of environmental feature

Inventory	• Intertidal mudflats (SPA/Ramsar) • Saltmarsh (SPA/Ramsar)
Key function	The intertidal mudflats and saltmarsh provide a feeding resource for internationally important populations of wintering waterfowl. The saltmarsh and adjacent areas of agricultural land (non-designated) provide a roosting area for waterfowl.
Dependency	The balance between mudflat and saltmarsh is dependent on the overall physical evolution of the estuary and the interplay between erosion and accretion. The wintering waterfowl (i.e. designated SPA interests) depend on both habitats, the loss or significant reduction of one feature, in particular mudflat, would not be countered by gain in the other.

Preliminary Assessment of management

Non-intervention	*Integrity:* Fails to maintain existing designated ecological interests Continued loss of saltmarsh and reduction in extent of mudflat. *Opportunity:* Limited increase in intertidal habitat in small valleys on northern side of the estuary	**- Sustainable - Mitigation required ?**
Maintain defences (existing policy)	*Integrity:* Fails to existing designated ecological interests Continued loss of salt marsh and reduction in extent of intertidal mudflat. *Opportunity:* None	**- Sustainable - Mitigation required.**

Sustainable alternatives

There are no alternatives which adequately protect *in-situ* the features of the SPA.

4.8.4 Discussion

Under a **non- intervention (F2a)** policy the current development of the estuary is likely to continue. This would result in the continued loss of salt marsh and mudflat. Small valleys on the northern side of the estuary would eventually become inundated resulting in the creation of small areas of intertidal habitat. Potential inundation of the Stour river valley upstream of the A137 (immediately upstream of the SPA boundary) could significantly increase the tidal volume of the estuary. This would increase erosive power within the system resulting in a greater rate of loss of intertidal habitat. This approach would fail to maintain the existing internationally designated features and mitigation to offset loss may have to be sought.

Maintaining the existing defences (F2b) would have no significant impact on the estuary. The result would be as that discussed above, except that the upstream section of the Stour valley would be maintained and there would be no significant increase in tidal volume due to inundation of this area. Under this approach there would continue to be general squeeze on the saltmarsh habitats along the estuary and no opportunity to re establish saltmarsh. Estimated losses are in the region of 4ha/yr of saltmarsh habitat, based on the work of Burd (1992). At this rate all of the saltmarsh within the estuary could potentially be lost within approximately 30 years. This approach would fail to maintain the existing internationally designated ecological interests of the estuary and mitigation would have to be sought.

A hold the line policy would maintain the existing small tributary valleys along the northern side of the estuary. These valleys have some existing ecological interest (e.g. Holbrook) although none of them are included within the SSSI or SPA/Ramsar site. As such they do offer the potential for some small-scale freshwater grassland habitat creation. In terms of overall area it is unlikely that these valleys would compensate for the potential loss of grassland habitat at Shotley and Trimley if managed re-alignment over these sites were to occur. Additionally, from an ecological perspective, the relatively enclosed nature of the tributary valleys when compared with the floodplain grasslands of the Orwell would be less viable as potential feeding and roosting habitat for estuarine based waterfowl.

Local Summary for Element F2

Approach		Comment	Local Conclusion
F2a	Non-intervention	Loss of saltmarsh and mudflats. Mitigation would be required, although this could potentially be met through inundation of small valleys on northern side of the estuary. Inundation upstream of A137 could significantly increase tidal volume and increase rate of intertidal habitat loss.	Inappropriate given potential significant change due to tidal volume increase.
F2b	Maintain	Fails to address the problem of loss of saltmarsh and mudflat. Provides no compensatory Habitat. Mitigation would be required.	Viable, but habitat creation required to offset intertidal loss.

Initial Accountancy Table

Feature	*Approach*	*Baseline*	F1a	F1b
Intertidal mudflats		*1500ha*	-150ha	-150ha
Annual drift-line vegetation		*Na*	0	0
Brackish/freshwater reedbed		*Na*	0	0
Wet grasslands		*Na*	0	0
Shingle beach		*Na*	0	0
Saltmarsh		*130ha*	-110ha	-120ha
Heath		*na*	0	0

Note figures for different approaches are in terms of loss or gain from the baseline.

4.8.5 Overall Assessment for HBU F

In examining HBU F, an initial collation is provided of the non-intervention and current policy or practice for the unit compared with existing habitat extent. This is presented as the accountancy tables below. Even though it is recognised that the integrity of the unit cannot be assessed solely from the perspective of the extent of predicted habitat change, this is felt to provide a useful indication of the key issues involved.

Assessment of change for Non-Intervention Policy

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Fresh reed bed	Wet grasslands	Annual drift line vegetation	Shingle	Heath
F1	0ha	-50ha				-75ha			
F2	-150ha	-110ha							
Total Change	-150ha -8%	-160ha -84%				-75ha -100%			
Baseline	*2000ha*	*190ha*				*75ha*			

Assessment of change for Current Policy or Practice

Element	Mudflats	Saltmarsh	Saline lagoons	Brackish/fresh reedbed	Fresh reed bed	Wet grasslands	Annual drift line vegetation	Shingle	Heath
D1	-50ha	-60ha							
D2	-150ha	-120ha							
Total Change	-200ha -10%	-180ha -95%				0 0%			
Baseline	*2000ha*	*190ha*				*180ha*			

Both approaches result in significant loss throughout of the important internationally designated intertidal habitats. Neither approach is, therefore, acceptable without significant mitigation.

Mitigation Habitat

There is little scope for the creation of intertidal mitigation habitat within the designated area. In fact the only areas where intertidal habitat creation could be undertaken are Shotley and Trimley on the Orwell and some of the small tributary valleys on the northern side of the Stour. If managed realignment over Shotley were undertaken then compensatory habitat would need to be sought to replace the lowland wet grassland (SPA/Ramsar) lost as a result. Alternative sites outside of the SPA are at Trimley Marshes and the area above the A137 on the Stour (Cattawade Marshes). For both areas realignment could have significant implications with respect to the maintenance of the existing designated features.

At Trimley there would be a significant loss to supporting habitat. Although this is outside of the SPA, to avoid damage to the SPA, there would need to be mitigation for the loss of this wet grazing marsh and open water habitat. Given Trimley's precarious defence, this must be treated as a serious option, with a view potentially to relocate the function of Trimley further back within the valley behind Fagbury and the Port development. This would potentially make greater appropriate environmental use of the area in a more sustainable manner. Consideration would also need to be given as to the development around this area of wet grassland.

The area above the A137 (Cattawade Marshes) would provide scope for either the creation of intertidal habitat or for the maintenance and improvement of lowland grassland habitat. With respect to these habitat types the area would be most suitable for freshwater grassland, particularly as much of the site already supports this habitat. Managed re-alignment over this area would be technically difficult due to the presence of the A137 and the tidal barrage at this location. In addition, even if technically feasible, re-alignment would lead to an increase in the tidal prism which could lead to accelerated intertidal erosion (mudflat and saltmarsh) downstream of the re-alignment area.

Alternative Scenarios

There are no other alternative approaches considered.

4.8.6 Conclusion for Habitat Behavioural Unit F

The internationally important features of this unit cannot be retained fully either by intervention or by allowing natural processes to prevail.

Potentially mitigation for loss of both intertidal and grassland could be achieved within the general area of the estuaries although not within the existing boundaries of the SPA. Options for mitigation would be at Shotley; requiring then mitigation for the loss of SPA designated grassland, and at Trimley; requiring mitigation as supporting habitat. Associated with both these areas would be the need to translate freshwater/terrestrial habitats landward at Trimley.

Additional mitigation may be available above the A137 road bridge (grassland/freshwater habitat).

Mitigation provided by the above areas would require further study of both the detailed potential of the sites and their future management. In the absence of these areas mitigation would have to be sought external to the HBU area. Potential areas would be the Alde/Ore (although this may be limited) or Hamford Water (Essex) area for intertidal habitat.

5 OVERVIEW AND CONCLUSIONS

The previous sections of this CHaMP have provided a consideration of the likely evolution of the Suffolk coastline and its constituent estuaries (namely the Blyth, Alde-Ore, Deben, Orwell and Stour) over the next 30-100 years. Analysis of available information and assessment of change using accepted general coastal process and geomorphological principles suggest the following general scenario (from north to south).

5.1 Kessingland to Southwold

Under the existing policy of non or limited intervention, erosion of the low cliffs between Southwold and Benacre would continue. Roll-back and breach of the shingle bar/beach system fronting the saline lagoons and wetland complexes at Benacre, Covehithe and Easton would be an ongoing process. As a consequence, it is predicted that a significant component of the designated SPA/Ramsar features of this area, notably reedbed, would be lost. The gradual northwards shift of Benacre Ness would also increase the vulnerability of low-lying areas such as Kessingland levels to tidal flooding. Selective measures such as the installation of a tidal barrier as Pottersbridge in the Easton Valley would safeguard freshwater reedbed and other wetland habitats to landward and therefore maintain part of the ecological interest of this site. Other measures could be undertaken to either reduce the rate of erosion and to maintain areas of habitat in their present locations. However, to do so would represent intervention and the emplacement of engineered structures along a section of coastline which is fundamentally dynamic and open to natural processes.

The long-term loss of the saline lagoons and associated wetland habitats represents a 'natural' progression in the evolution of these features. Saline lagoons of the percolation type are ephemeral features and their presence on this stretch of coastline reflects a period of time when conditions (e.g. sediment supply) were suitable for their formation. Trying to maintain the features is technically feasible but would reduce the dynamic nature of the frontage with potentially knock on effects for other ecological and socio-economic interests. While potentially sustainable from a purely technical perspective this is not the recommended way forward and there should be an acceptance that these features will be lost over the next 100 years. A summary of predicted habitat changes within the designated areas (i.e. within the defined boundaries of the cSAC/SPA/Ramsar) is given in Table 5.1. The table relates change to the existing baseline of area of habitat within the site boundaries and provides an indication of the likely habitat creation requirements under the scenarios that have been investigated.

Based on the work undertaken it is apparent that unless intervention occurs, then there would be significant loss of habitat from the designated areas. As such, areas for the creation of new habitat may need to be sought. The overall requirement depends to a certain extent on the view as to whether the change over the CHaMP period is 'natural'. Within the immediate coastal area, Kessingland Levels offers the opportunity to offset predicted freshwater and terrestrial habitat loss. Appropriate development of this habitat would take a number of years. The site is unlikely, without significant modification, to provide replacement for loss of the saline lagoons and shingle banks. In order to advance this measure, it would be necessary to implement and maintain a policy of Hold the Line for this frontage. This policy is currently in place in order to provide protection to the pumping station at Kessingland and prevent inundation of the levels.

A summary of the predicted habitat changes within this unit under non-intervention, existing policy and *in situ* protection is provided in Table 5.1. For *in situ* the total in the Table is for the area retained rather than lost. It should be noted that the inclusion of shingle reflects its importance as a SPA supporting habitat (i.e. for breeding little tern) rather than as a designated habitat of the Benacre-Easton Bavents cSAC.

Table 5.1 – Predicted habitat changes to designated areas (cSAC/SPA/Ramsar) for the Kessingland-Southwold frontage.

BENACRE	Mudflat	Saltmarsh	Saline lagoons	Reedbed	Wet grassland	Shingle
Baseline			*18ha*	*170ha*	*20ha*	*1800m*
Non-intervention.	40ha	10ha	2ha	30ha	10ha	800m
Current policy.			2ha	110ha	20ha	800m
In situ protection measures.			12ha	150ha	20ha	1800m

5.2 Blyth Estuary to Dunwich

Within this area of the CHaMP there are two issues critical to the future development of the internationally designated habitats and the overall extent and distribution of ecological interests.

The first issue concerns the future management of the Blyth Estuary. The present morphology of the estuary has developed, over the last few centuries, largely through reclamation of the former estuarine floodplain up to the principal low water channel. Subsequent loss of defences, around Bulcamp Marshes, has led to an unbalanced estuary, with considerable stress on sections of remaining defence. With sea-level rise, the predicted physical development of the Blyth Estuary will increase the stress placed on the current flood defences. Maintaining the existing line of defence, although technically feasible, would become increasingly costly and unsustainable in the longer term. Continued coastal squeeze would result in the loss of saltmarsh habitat and although this would lead to concomitant increase in intertidal mudflat, this area would decrease over time due to the landward migration of Low Water Mark. Selected re-alignment of the defence line is seen as the most sustainable approach to dealing with this issue. On the basis of analysis of the predicted morphological change to the estuary and an examination of the present defence line configuration it is suggested that re-alignment of the defences to Tinker’s Marsh on the southern side of the Blyth and Robinson Marsh towards the mouth of the estuary should be undertaken. Of these areas, Tinker’s is an area of designated SPA and Ramsar wetland habitat and thus re-alignment would effectively lead to the loss of the existing ecological interest of this area.

Within the Blyth Valley, but outside of the designated SPA/Ramsar, the valley section immediately upstream of the A12 is viewed as a critical area to the overall management of the estuary system. The flood defences to the tidal channel in this area are in poor condition and without significant works to them a large area of the Blyth Valley would be inundated. This would lead to a large increase in the tidal volume of the estuary and result in the erosion of downstream estuarine habitats (notably saltmarsh) and also increase the pressure on flood defences to other sections of the estuary. The continued maintenance of flood defences to this area is therefore a crucial aspect of the overall management of the estuary. If the flood defences within the Valley are maintained then this also opens up the opportunity to improve the management of the valley floor riverine habitats and to create a significant area of freshwater wetland habitat (e.g. grazing marsh, reedbed). This area could mitigate for the potential loss of freshwater wetland habitats within other parts of the CHaMP area.

Overall the opportunity exists to increase the extent of estuarine and wetland habitats within the Blyth Valley to create a more sustainable and ecologically functional suite of habitats. Potentially areas such as Tinker's Marsh offer the opportunity for the creation of estuarine-terrestrial transitional habitats, which are, due to the extensive construction of defences, rare within the Suffolk CHaMP and wider coastal areas. These transitional habitats provide the opportunity for the establishment of species assemblages and communities typical of 'natural' systems which could be viewed as a benefit over the maintenance of similar features within 'artificial' and managed locations.

The other main issue within this frontage is the predicted evolution of the shingle ridge fronting the coastal section between Walberswick and Dunwich and the habitats to landward that this ridge protects from extensive and potentially detrimental tidal inundation. The prediction under sea-level rise and increased storminess is for the shingle ridge to continue its gradual roll-back. If existing management measures are continued (i.e. reforming of the ridge following overtopping and breaching) the potential for catastrophic failure is increased as the morphology of the ridge is effectively artificially maintained in a state which is out of keeping with the prevailing physical conditions. It is considered that the most sustainable option within the timeframe of the CHaMP would be to allow dynamic processes to operate along the open coast, but to provide a retired defence to landward in order to maintain much of the reedbed and wetland complex of Westwood Marshes. However, even under this option there is the possibility that significant tidal inundation could occur and therefore consideration should be given to seeking sites for the creation of new wetland habitats that could eventually replace those present at Walberswick.

Inundation of the area to landward of the shingle barrier would not result in the loss of ecological interest but a change and potentially an interesting complex of brackish-saline coastal habitats (e.g. saltmarsh, saline lagoons etc.) could develop within the site. While this would replace the existing interest it would lead to the creation of a functional and dynamic section of coastline with its integral habitats and ecological interest. The potential for some interesting transitional brackish water habitats (e.g. heathland, freshwater springs/seepages and woodland) could be realised.

A summary of predicted habitat changes within the designated areas (i.e. within the defined boundaries of the cSAC/SPA/Ramsar) is given in Table 5.2 The table relates change to the existing baseline of area of habitat within the site boundaries and provides an indication of the likely habitat creation requirements under the scenarios that have been investigated. The key point to make here is the likely requirement for the creation of freshwater/brackish grassland and reedbed under the continued policy of reprofiling of the shingle bank between Dunwich and Walberswick. Potential sites for the replacement of this habitat include Kessingland Levels and the Blyth Valley upstream of the A12. Between them these sites have the capability to provide in the order of 500ha of suitable land which would more than offset loss from this area and from Benacre to the north.

The section between Walberswick and Dunwich represents an example of the classic issue of trying to deal with dynamic change whilst ensuring protection (i.e. maintenance) to existing designated features. In the time period covered by the CHaMP (i.e. less than 100 years) it may be technically feasible to maintain features to landward of the shingle barrier. However, over the longer term and under accelerated sea-level rise this situation is not considered to be sustainable and therefore consideration should be given to seeking sites for the creation of new wetland habitats which could eventually replace those present at Walberswick.

It would not be possible to replace in entirety the existing diverse ecological interests of the wetland habitats at Walberswick. The site is in effect unique, but then this attribute can be applied to all sites, as the physical, biological and human components that contribute towards the overall ecological interest of an area vary from site to site. Certainly there are ecological elements of the wetland habitats at Walberswick that could be relatively easily replaced. Habitat creation schemes elsewhere in the UK (see Hawke and José 1996; RSPB 1997 and Doody 2003) demonstrate that it is feasible to create extensive areas of reedbed and wetland habitats over relatively short timescales. In this context it should be noted that the reedbed/wetland mosaic at Walberswick has only been in existence since the 1940's when former grazing marsh was flooded as a defence against invasion during World War II. Colonisation by key species typical of habitats such as reedbed can occur relatively rapidly, including all of the bird species associated with freshwater reedbed (bittern, marsh harrier and bearded tit) for which sites such as Walberswick are important. The same applies to many of invertebrate species, although some would appear to be coastal specialists such as the white-mantled wainscot moth, which is only found in coastal reedbeds in Suffolk in the UK, although it has a much wider distribution in mainland Europe.

The invertebrate assemblage at Walberswick-Dunwich reflects the diversity of wetland habitats present at the site. Many of the invertebrate species present are associated with freshwater-brackish transitional habitats. The creation of new freshwater reedbed/wetland habitat away from the coast would not replicate these types of niches and therefore not compensate for the potential loss of some species from the area if inundation were to occur. However, a change to a tidally influenced system at Walberswick would be unlikely to lead to the complete elimination of transitional niche habitats (e.g. brackish-freshwater) and potentially the extent of some of these habitats could be increased. While ecological change would therefore be significant the impact on existing invertebrate communities and populations may not be as drastic as first thought. This aspect also has to be considered against the potential new niches and ecological interest that could be created through breakdown of the shingle barrier and inundation of the existing wetland complex.

Table 5.2 – Predicted habitat changes to designated areas (cSAC/SPA/Ramsar) for the Blyth Estuary and Walberswick-Dunwich frontage.

BLYTH-DUNWICH	Mudflats	Saltmarsh	Saline lagoons	Reedbed	Wet grassland	Drift line vegetation	Shingle
Baseline	*155ha*	*60ha*		*240ha*	*240ha*	*4.8km*	*10ha*
Non Intervention	435ha	185ha		35ha	15ha	8km	10ha
Current policy	335ha	150ha		45ha	138ha	8km	10ha
Maintain open coast + retreat Tinkers	195ha	65ha		240ha	192ha	4.8km	10ha
Retreat open coast + retreat Tinkers	305ha	135ha		160ha	92ha	6.8km	20ha

5.3 Minsmere

The geomorphological predictions for the Minsmere frontage indicate that over the time period under consideration the frontage is likely to be relatively stable.

At Dunwich cliffs, the principal loss of designated habitat would be cliff top heathland (cSAC/SPA). It is recommended that the cliffs remain undefended to ensure that the supply of sediment the cliffs provide is maintained, particularly given that this supply may be important in supplying material to the Minsmere frontage to the south. The loss of heathland, based on current rates of erosion, would amount to approximately 20ha. This loss can be attributed to natural change and therefore the loss may not need to be replaced. However, if it is determined that it is important to maintain the overall resource it is suggested that a new area of heathland could be re-created on existing agricultural land adjacent to heathland in the Minsmere-Walberswick area over the CHaMP period.

The gradual roll back of the shingle beach/barrier fronting the wetland complex at Minsmere would result in the loss of some shingle and sand dune habitat along the immediate coastal fringe. However, features to landward could be maintained *in situ*. This would require some limited intervention in the form of strengthening any potentially weak sections of the flood defence to landward of the barrier.

If no works were taken to strengthen the existing retired defence then potentially non-intervention could potentially result in the formation of a new estuary system/embayment at Minsmere Levels due to breach and breakdown of the shingle barrier. While the formation of a significant area of new coastal and estuarine habitats would be beneficial with respect to the overall extent of these habitat types, and the longer-term functionality of the coastal system, the loss of the features to landward would constitute a major change in the ecological interest of the area.

Again, as with the situation at Walberswick-Dunwich, in the longer term, consideration should be given to undertaking large-scale habitat creation to replace terrestrial-freshwater features away from the immediate coastline. The context of such works with respect to areas such as Minsmere should be borne in mind. Many of the wetland habitats at Minsmere and Walberswick have been in existence for less than 60 years (since the end of World War II). Such decisions should be made as early as possible in order to allow significant time periods (i.e. >50 years) for wetland complexes to become established. This approach would enable decisions on the establishment of dynamic coastal functionality to be more easily made and for future management at sites such as Minsmere to be geared towards alternative habitat suites.

A summary of predicted habitat changes within the designated areas (i.e. within the defined boundaries of the cSAC/SPA/Ramsar) is given in Table 5.3. The table relates change to the existing baseline of area of habitat within the site boundaries and provides an indication of the likely habitat creation requirements under the scenarios that have been investigated. As can be seen there is under existing policy unlikely to be a significant requirement for the replacement of designated habitats. Both the loss of heathland and sand dune could be attributed to natural change and therefore there may be no requirement to directly offset their loss. Potentially, in the longer term, there may be a need to replace the freshwater habitat complex at Minsmere (see discussion above) and if this is the case then an area in the order of 350ha would be required. Potential replacement sites include former estuarine areas around the Alde-Ore and the Deben which between them could provide approximately 1500ha of suitable land. Alternatively, the potential exists for the creation of a new wetland complex away from the immediate coastal area (e.g. the Fens). However, significant consideration would have to be given to the likely ecological differences between an inland and coastal site and whether such differences would be acceptable with respect to the Habitats Directive.

Table 5.3 – Predicted habitat changes to designated areas (cSAC/SPA/Ramsar) for the Minsmere frontage.

MINSMERE	Mudflats	Saltmarsh	Saline lagoons	Reedbed	Wet grassland	Drift line vegetation	Sand dunes	Heath
Baseline				*155ha*	*205ha*	*3.5km*	*40ha*	*290ha*
Non-intervention	200ha	60ha	0	35ha	65ha	+?km	10ha	270ha
Current policy				155ha	205ha	3.5km	20ha	270ha

5.4 Alde-Ore Estuary and Orfordness

There is recognition in the designation of the Alde/Ore and Butley as a cSAC, that the estuary as a whole, with its varied habitats, is an important functioning system. This same interaction is reflected in the physical performance of the estuary, not least in the balance achieved over the lower reaches between estuary flow and coastal dynamics.

The current management practice for the main estuary and the Butley, in the absence as yet of adopting an estuary strategy for defence, is for ad hoc response maintenance and repair of existing defences. The most critical area of stress within the estuary is around the Aldeburgh bends. Due to increased flows through this area, there is a significant loss of saltmarsh fringe and potential for further loss in the area of Cob Island and along the High Street (East Iken Marsh) frontage.

Under realistic sea level change scenarios, maintenance of all defences would become increasingly difficult and increased flow pressure would increase the loss of fringe habitat. Furthermore, with potential short-medium term failure of defences to Lantern and Kings Marsh (the defences to these areas are the responsibility of the National Trust) and the consequential increase in intertidal area of some 350ha and increase in tidal volume of some 20%, there would be substantial increased pressure over the lower reaches of the estuary. Almost certainly, an increase in tidal volume of this nature would restrict the ability for realignment elsewhere within the estuary. This overall approach restricts balanced responsive management of the estuary, while resulting in a loss of internationally designated intertidal habitats. This approach would require habitat mitigation and is considered to be unsustainable in the longer term.

The defences to Hazelwood marshes are in generally poor condition and will require upgrading. Even so, there is little stress in relation to estuary behaviour and there is no technical reason for not maintaining these defences, thereby maintaining the SPA/Ramsar designated grazing marsh to landward.

Along the open coast frontage of Orfordness there is a reducing supply of sediment from the north, resulting in an increasing loss of material along the face of the Spit (south of the Ness). In effect this is leading to a gradual straightening of the shoreline between Aldeburgh and Shingle Street. Such change would be over a very long time scale (500 to 2000years) but provides the context over which the change should be viewed. The present day impact of this process is the vulnerability of the neck of land between the river and the sea at Slaughden.

The potential for a breach at Slaughden and the impact that this could have on the rest of the system represents one of the key topics for the management of the estuary. The neck of land between the river and the sea at Slaughden has been variously protected by hard defences and more recently by beach management, bringing material from the beach seaward of Lantern Marshes. In the absence of some form of management it is likely that the neck of land would breach and probably in the longer term remain as a new opening to the Alde Estuary. Based on a best estimate of likely evolution of the estuary it is considered that as a breach or entrance developed at Slaughden, the complex interaction of tide through both entrances would be likely to result in increased water levels in the vicinity of Kings Marsh, although flows would be reduced. This increase in water level would make the Kings and Lanterns Marshes more vulnerable to flooding and, due to the lack of defence maintenance, failure would result. It remains uncertain how flows would distribute between the two entrances but there is a distinct possibility that the northern entrance may dominate. Certainly there would be a reduction in flow within the Ore entrance and, as a consequence, there is likely to be an increased rollover of Orford Spit towards the marshes of Boyton and Orford Haven. Whether the reduced flow within the river Ore would be sufficient to maintain its entrance is again uncertain. There is a possibility that Orford Spit may, in time, attach itself to the shoreline. Although there is the potential that a breach at Slaughden would lead to the development of a more sustainable estuary form the implications for the designated habitats and species (as well as socio-economic interests) are extremely significant. The potential changes have not been investigated in detail in the CHaMP and it is recommended that this would require a separate and more detailed study.

From Orford Spit, sediment moves down the coast and is transferred onto the Shingle Street frontage. This transfer can occur as a gradual feed through the series of banks at Orford Haven or as a process by which the banks detach from the northern side of the Estuary mouth and attach themselves to the Shingle Street frontage. The shoreline to the south of Shingle Street is maintained at its southern end by the promontory of East Lane. The bay between Shingle Street and East lane is relatively stable in alignment, although material feeding from the north tends to make its way along the frontage and is lost to the coast further south.

The overall prediction for the Alde-Ore system is that the designated internationally important features cannot be retained in their existing extent and distribution either by intervention or by allowing the natural systems of the coast and estuary to continue. Allowing 'natural' change to occur could have significant consequences with respect to the entire morphology of the estuary and its associated habitats and socio-economic interests. While significant gains in coastal intertidal habitats could be gained the overall change is of such a scale that it would be difficult to justify

In order to address potential habitat change within the system a number of alternative defence scenarios and overall approaches to the management of the estuary have been considered. The main objective behind the alternatives is to allow a more controlled and adaptive approach to be taken.

The main scenario considered is one whereby all defences within the estuary are maintained apart from those to Kings and Lantern Marshes on Orfordness. This is because it is considered that it is almost inevitable that there will be change to Orfordness and in order to prevent significant disruption to the rest of the estuary system and allow a more natural transition to a new ecological state/equilibrium this change should be managed. It is proposed that the line and integrity of the estuary defences to Kings and Lantern Marshes should be maintained but no attempt made to raise their level, in effecting lowering the defence level as sea level rise occurs. This would allow, gradually, more frequent tidal inundation from extreme events over the next 50 years. A similar attitude would be taken to the seaward defence in not attempting to maintain the current defence standards in the face of sea level change. The management of this in relation to the use of the marshes to act as control to mitigate extreme increases in tidal volume would need to be examined in more detail. The longer-term intent of this approach would be to allow movement to a saline dominated environment, over the next 50 to 100 years, which would minimise the need for future intervention.

The ecological interest of the Ness would therefore largely be left to evolve, albeit through a more controlled and gradual process. The main impact would be a change from existing terrestrial grassland habitats at Kings and Lantern marshes into saline features, probably intertidal mudflat and saltmarsh. This would provide benefits with respect to SPA estuarine bird populations. It is likely that there would be a loss of saline lagoon interest due to the overall development of intertidal habitat. The approach is sustainable but would require a long-term programme of mitigation for the loss of terrestrial SPA/Ramsar designated features and the cSAC saline lagoons.

A summary of predicted habitat changes within the designated areas (i.e. within the defined boundaries of the cSAC/SPA/Ramsar) is given in Table 5.4. The table relates change to the existing baseline of area of habitat within the site boundaries and provides an indication of the likely habitat creation requirements under the scenarios that have been investigated. The loss of the existing SPA/Ramsar brackish grassland, grazing marsh and reedbed at King's and Lantern Marshes (approximately 350ha) could be offset by the management of land around the estuary in order to re-create these habitat types. Suitable areas include the main block of Sudbourne and Orford Marshes (approximately 500ha) and Gedgrave Marshes (approximately 200ha) where wet grasslands and potential reedbed development could be undertaken at the heads of freshwater flows into the area. Similarly, areas adjacent to the Butley would provide appropriate mitigation for these wetland habitats (e.g. Stone Marshes, 150ha).

Offsetting the long-term loss of shingle habitat from Orfordness and the loss of saline lagoons from Kings and Lantern Marshes is more problematic. It is considered impractical and unsustainable to replace the shingle habitat, as this would require the import and retention of sediment in place. Potentially, saline lagoon habitat could be engineered and incorporated into wetland habitat creation schemes to replace the brackish grassland lost from the estuary (see above).

Two other potential habitat creation areas are Boyton Marsh and Aldeburgh Town Marsh. Both areas offer the potential for the creation of either wet grassland or intertidal habitat. Re-alignment of Aldeburgh Town Marsh may be advanced as a solution to dealing with the stress on the defences in this area rather than solely as a habitat creation measure. There is therefore quite extensive scope for a balance of habitat extent and distribution to be achieved, while still maintaining the control of the estuary.

Table 5.4 – Predicted habitat changes to designated areas (cSAC/SPA/Ramsar) for the Alde-Ore Estuary and Orfordness.

ALDE-ORE	Mudflats	Saltmarsh	Saline lagoons	Reedbed	Wet grassland	Drift line vegetation	Shingle
Baseline	*600ha*	*310ha*	*Approx65*	*50ha*	*430ha*	*17km*	*500ha*
Non-intervention	980ha	280ha	10No.	15ha	5ha	15km	375ha
Current practice	850ha	345ha	10No	15ha	75ha	17km	450ha
Reduce defence to Kings and Lantern	750ha	445ha	10No.	15ha	75ha	17km	480ha

5.5 Deben Estuary

The Deben Estuary has developed, over the last several centuries, with reclamation, principally within the lower estuary, up to the principal low water channel. In the upper part of the estuary there has not been a similar restraint, reclamation being confined to offshoot valleys. There has been considerable development of saltmarsh within the natural width of the upper estuary. This is now suffering from erosion due to coastal squeeze.

Current management practice is to maintain the existing defences throughout the estuary. This would require significant investment but is sustainable. The approach would, however, lead to a continuing loss of SPA designated saltmarsh habitat which would require mitigation in order to offset loss. This policy would also maintain the potential for freshwater grassland habitat creation within areas of low-lying land on either side of the estuary.

Selective realignment from critical defences would provide the opportunity for the creation of intertidal habitat and offset the loss of saltmarsh vegetation while maintaining control of the development of the estuary. This provides a more sustainable approach without extensive disruption to the rest of the estuary system or open coast processes. Particular areas identified for realignment within the estuary strategy are at Melton, Martlesham Creek, White Hall, Waldringfield, Ramsholt Lodge and Ramsholt and at Nursery Wood.

A summary of predicted habitat changes within the designated areas (i.e. within the defined boundaries of the SPA/Ramsar) is given in Table 5.5. The table relates change to the existing baseline of habitat area within the site boundaries and provides an indication of the likely habitat creation requirements under the scenarios that have been investigated. The loss of saltmarsh habitat from within the estuary could not be offset from within the confines of the existing SPA/Ramsar designated area. Re-alignment of areas adjacent to the estuary (as listed above) could provide for the predicted loss of saltmarsh habitat.

Table 5.5 – Predicted habitat changes to designated areas (cSAC/SPA/Ramsar) for the Deben Estuary.

DEBEN	Mudflats	Saltmarsh	Saline lagoons	Reedbed	Wet grassland	Drift line vegetation	Shingle
Baseline	*360ha*	*250ha*					
Non-intervention	580ha	100ha					
Current practice	430ha	150ha					

5.6 Stour and Orwell Estuaries

There is currently no strategy plan for flood defences within the Orwell. The southern side of the Stour Estuary is covered by the Essex SMP which advocates a general policy of Hold the Line apart from small sections of eroding cliff where the policy is Do Nothing. Within the Orwell, private effort has been put in to maintaining the existing defences at Trimley. Such an approach is seen as being sustainable, but would require considerably greater investment than at present. While this policy does act to defend an important supporting habitat, this is outwith the designation of the SPA. Continued maintenance of the flood defences to grazing marsh habitat at Shotley could reduce the brackish water influence on this site. Additionally, the maintenance of both the Trimley and Shotley frontages would significantly limit opportunities within the estuaries to offset the loss of saltmarsh habitat from within the estuary.

In the Stour Estuary, maintaining the existing defences would have no significant impact on the morphology of the estuary. Under this approach there would, however, continue to be general squeeze on the saltmarsh habitats within the estuary (much of this due to the topography of the system) and no opportunity to re establish saltmarsh. A hold the line policy would maintain the existing small tributary valleys along the northern side of the estuary. These valleys have some existing ecological interest (e.g. Holbrook) although none of them are included within the SSSI or SPA/Ramsar site. As such they do offer the potential for some small-scale freshwater grassland or intertidal habitat creation.

There is little scope for the creation of intertidal habitat within the designated area. Within the Orwell the most suitable areas are located towards the mouth of the estuary (Shotley and Trimley) and as such are in morphologically suitable locations. However, from an ecological perspective the loss of either area would have consequences for the maintenance of terrestrial ecological interests. Shotley Marshes are designated SPA and their loss to intertidal habitat would therefore require mitigation. Trimley lies outside of the designated SPA and re-alignment over this area would therefore not directly impact upon the SPA/Ramsar site. However, Trimley Marshes have been developed as a wetland habitat by the Suffolk Wildlife Trust and now support a significant assemblage of wintering and breeding birds which form part of the designated SPA populations. As such, its loss could impact upon the ecological integrity of the SPA. A brief examination of the Trimley site indicates that there is potential scope for the landward translation of wetland habitats. If this were undertaken then there could be an overall gain of habitat within the estuary with an increase in intertidal area resulting from managed realignment. Replacement of the grazing marsh habitat from Shotley could potentially be undertaken in and around the Deben estuary or possibly the Alde-Ore.

On the Stour some of the small tributary valleys on the northern side of the estuary offer some potential for managed realignment. Although these areas are small they could offset some of the predicted loss of saltmarsh habitat from the estuary. Alternatively, the predicted loss of 180ha of saltmarsh (existing practice) could be offset by habitat creation in adjacent areas, notably Hamford Water and/or one or other of the Essex Estuaries. These areas lie within the same overall estuarine complex and would support SPA population assemblages similar to those that use the Stour and Orwell estuaries.

A summary of predicted habitat changes within the designated areas (i.e. within the defined boundaries of the cSAC/SPA/Ramsar) is given in Table 5.6. The table relates change to the existing baseline of area of habitat within the site boundaries and provides an indication of the likely habitat creation requirements under the scenarios that have been investigated.

Table 5.6 – Predicted habitat changes to designated areas (cSAC/SPA/Ramsar) for the Stour and Orwell Estuaries.

STOUR AND ORWELL	**Mudflats**	**Saltmarsh**	**Saline lagoons**	**Reedbed**	**Wet grassland**	**Drift line vegetation**	**Shingle**
Baseline	*2000ha*	*190ha*			*75ha*		
Non intervention	1860ha	25ha			0ha		
Current practice	1800ha	10ha			75ha		
Re-alignment – Shotley	1845ha	40ha			0ha		

5.7 Overview

The Suffolk coast and its estuaries represent one of the most undeveloped and dynamic sections of coastline within eastern and southern England. This is reflected, in part by the significant extent of habitats present within the area. However, despite the presence of these habitats their future existence in their present form cannot be assured.

Rather than taking a position of continued *in situ* maintenance it is considered appropriate that a more flexible and ultimately sustainable philosophy towards the management of the coastal area and its constituent habitats should be taken. This could be achieved through a combination of allowing 'natural' processes to continue limited change to existing flood and coastal defence policies and habitat creation. This combination of actions would result in the development of a more sustainable and ultimately ecologically functional coastal area.

Table 5.7 provides a summary of the overall predicted changes for areas of designated habitat within the Suffolk CHaMP area under a scenario of continuation with current flood and coastal defence policy. As can be seen it is clear that, apart from intertidal mudflat, there are likely to be losses in extent of all other coastal habitats. This loss is built up from a number of factors, but significantly includes:

- Natural erosion of the open coast as a result of sea-level rise and loss of shingle and sand dune habitat;
- Roll back of shingle barriers at Benacre, Easton and Walberswick and loss of reedbed and grazing marsh habitat to landward;
- Tidal inundation of grassland and saline lagoon habitats on Orfordness (Lantern and Kings Marshes);
- Loss of saline lagoons at Benacre, Covehithe and Easton due to ‘natural’ coastal erosion;
- Increase in area of intertidal mudflat as a result of failure of shingle barrier and tidal inundation at Walberswick and overtopping of defences at Kings and Lantern Marshes, Orfordness;
- Loss of saltmarsh due to continued coastal squeeze in the Blyth, Alde-Ore, Deben and Stour and Orwell estuaries. It is predicted that additional growth of saltmarsh in areas such as Walberswick and Orfordness would not compensate for predicted losses due to coastal squeeze.

Table 5.7 – Overall predicted habitat change to designated habitats within the CHaMP area under continued flood and coastal defence policy.

	Mudflats	Saltmarsh	Saline lagoons	Reedbed	Wet grassland	Drift line vegetation	Shingle	Sand dune	Heathland
Baseline	*3115*	*810*	*38*	*615*	*970*	*22*	*500*	*40*	*290*
Benacre			-16ha	-60ha					
Blyth-Dunwich	+180ha	+90ha		-195ha	-102ha	+3km			
Minsmere								-20ha	-20ha
Alde-Ore	+250ha	+35ha	-55(no.)	-35ha	-355ha		-50ha		
Deben	+70ha	-100ha							
Stour and Orwell	-200ha	-180ha							
New baseline	*3415ha*	*655ha*	*8ha*	*290*	*513*	*25+km*	*450*	*20*	*270*
Change	*+300ha*	*-155ha*	*-30ha*	*-325ha*	*-457ha*	*+3km*	*-50ha*	*-20ha*	*-20ha*

Potentially some of these predicted losses could be offset through a change in the current policy (e.g. re-alignment of the defence line in some areas) or through further intervention and management. However, it is suggested that the most sustainable approach is to work with coastal processes and to offset predicted loss through additional habitat creation. The main requirement would be for freshwater and brackish habitats (e.g. reedbed and grazing marsh) and saltmarsh. It is considered that all of the habitat requirement could be met from within the CHaMP area but that some of the intertidal habitat creation requirement (saltmarsh) may have to be undertaken in other areas (e.g. Essex CHaMP area).

It is important to stress here that although significant ecological change within designated sites is predicted in some areas this is not to say that the ecological value of many of the areas would be diminished. Certainly, some species populations would be adversely affected by the predicted changes, notably plant and bird species associated with freshwater/wetland systems such as bittern and marsh harrier. However, some transitional habitats and niche habitats could be increased in extent leading to greater populations of some species or colonisation by others. Predicting ecological outcomes is difficult but it is considered unlikely that areas such as Walberswick and Minsmere would be altered to the extent that they would be considered to be of lesser value in the longer term.

Combining the management of areas where change is predicted with the creation of new areas to offset the loss of some specific interest features would maintain and potentially increase the overall level of ecological interest/resource within Suffolk. Whether such an approach meets requirements with respect to the Habitats Directive at the present time is a debatable question. However, it would promote further dynamic change and associated ecological interest and provide a more sustainable footing for future management.

Over the one hundred year period covered by the CHaMP it will be important to determine the accuracy of the predictions and refine the management response according to the observed direction and magnitude of change. This could be accomplished through the development of a tailored monitoring programme. Some monitoring work is already undertaken, e.g. Environment Agency beach profiles, but to ensure adequate data is obtained it is recommended that a five yearly plan should cover:

- Open coast beach profiles;
- Rates of cliff recession (northern section of CHaMP area);
- Selected shore profiles within the estuaries; and
- Analysis of aerial photographs to record habitat extent and distribution.

The opportunity should be taken during monitoring and future reviews of the CHaMP to include a further forward look so that management measures can be refined and contingency made for the potential loss of areas of habitat at sites such as Minsmere, which although sustainable to maintain within the framework of the existing CHaMP period may come under increasing pressure and may therefore need to be replaced.

6 MONITORING

6.1 Introduction

An essential component of the development of a CHaMP is to monitor the state of the physical and biological systems with which the CHaMP is dealing. Specifically the CHaMP sets out a number of predictions for change and potential management measures that may be required in order to maintain ecological interest. A suitable monitoring strategy therefore needs to document the physical and biological change within the CHaMP area in order to refine predictions and also to determine the results of, and future need for, any management measures.

The monitoring strategy needs to be sufficiently focused to ensure that 'useful' results are derived. Therefore, the selection of the parameters to be monitored should relate, as closely as possible, to the measurement of 'ecological integrity' as defined through the Conservation Objectives and Favourable Condition Tables, provided by English Nature. Ecological integrity (and function) comprises a large number of different variables. However, from a Natura 2000 and CHaMP perspective, it is possible to break these down into two main components, namely the coastal features/processes that maintain and support the habitats/species and the habitats and species themselves.

Monitoring allows predictions to be made about expected rates of change. The ultimate aim of the CHaMPs must be to demonstrate the effects on habitats of geomorphological change. In order to achieve this, monitoring must include those aspects of the geomorphological change of most importance to habitat losses and gains. Also, the monitoring must be targeted towards those habitats, which would demonstrate changes related to geomorphology as clearly as possible. For example, an area of diverse habitats may require monitoring at frequent intervals (spatially and/or temporally) in order to determine the impact on each habitat. A more uniform habitat may be better monitored by more intensive sampling at a lesser frequency. The data and the range of information must be comprehensive and coherent.

The first step in a successful monitoring campaign is a desk study to determine what information exists already. This allows an overview of the regional and local coastal processes and sediment budgets, and provides a baseline survey to establish the situation against which future change will be compared. Sources include literature, historic maps and charts, geological maps, aerial photographs and satellite imagery.

The following sections highlight the main habitat types that should be monitored as part of an ongoing programme to record change and enable refined predictions to be made. Practical options for the monitoring techniques that could be applied are given along with suggested timescales for monitoring frequency. Further detail on the techniques and parameters that could be monitored (if required) are provided in Appendix B.

6.2 Physical monitoring

6.2.1 Saltmarsh and intertidal mudflat systems

The monitoring of saltmarshes and mudflats can range from highly sophisticated electronic instrumentation attached to a frame which is deployed *in situ* on the sediment surface, to manual field measurements using simple pieces of equipment. For small areas a topographic survey can be carried out to assess surface elevation changes using a total station with datalogger.

In view of the costs and practical difficulties of regular monitoring of large areas of mudflat or saltmarsh change by *in situ* methods, there is an increasing role for remote sensing techniques from aircraft or satellite. Remote sensing has the potential for large spatial coverage with high resolution, which would not be practicable with *in situ* methods. For example, experience is being gained with technologies for measuring elevation, such as airborne Laser Induced Direction and Range (LIDAR). Surveys repeated every year would provide digital data to indicate broad-scale changes in elevation through time.

The extent and morphology of intertidal areas can be derived from black and white, 1:5000 scale, stereoscopic aerial photography. It is recommended that, the monitoring be undertaken consistently at periods of low water with five-yearly repeat surveys as a minimum ongoing requirement.

6.2.2 Sand beach and dune systems

Beach morphology can be monitored using cross-shore beach profile data (as already undertaken by the Environment Agency) to assess changes in beach width, slope and volume, and to describe beach behaviour and its variability. These data can be used to identify trends and areas of high net change and high variability. The frequency of beach profiles depends on the specific aim of the monitoring, but for longer term trends bi-annual surveys are considered sufficient. A set of photographs at each of the beach profiling localities allows a comparison to be made between surveys, providing a rapid cheap complimentary system of monitoring more severe events when time may limit opportunity for more formal monitoring.

The position of a dune face can be monitored using marker posts to measure rate and lateral extent of erosion. Marker posts should be located at the toe of the dunes at 50 m intervals or so with a second line set-back 30 m or so landwards, away from direct erosion. The measurements of distance between dune toe and marker should be repeated twice-yearly, and, if possible, before and after major storm events.

Changes in dune morphology are most effectively assessed using aerial photographic surveys on a yearly basis. The photographs can be digitised to provide digital terrain models and compared to provide a record of large-scale morphology changes and variability of upper beach levels. A Total Station may be used at times of high variability (after storms) along cross-shore transects to define catastrophic change along the dune system.

6.2.3 Shingle accumulations

Satellite imagery can provide a comparison of large areas over decadal time scales. Yearly vertical aerial surveys of entire coastline can provides quantitative data on large-scale changes of the coast, such as the retreat of cliffs, changes in channels, movement of the saltmarsh edge. Oblique aerial photography of coastline at yearly intervals can both provide background data on coastal and geomorphological processes and to monitor features such as banks and channels, spits and development of saltmarsh or features within estuaries. This type of monitoring also provides important qualitative data.

6.2.4 Lagoons

Lagoons are areas of shallow, coastal salt water, wholly or partially separated from the sea by sand banks or shingle accumulations. Two main types of lagoon are recognised here. Percolation lagoons generally form in the lee of shingle accumulations and are a feature of a geomorphologically dynamic system. Seawater enters the lagoons by percolation through the barriers and by overtopping them during storms and high spring tides. In lagoonal inlets, seawater enters the lagoon on every tide and the salinity is usually high. Lagoonal habitat types are complex, and a wide range of physical types and origins can be included in the broad definition.

The extent and morphology of lagoon systems is probably best monitored through the use of remote sensing techniques (see Section 6.3). Given the potential for relatively rapid changes in morphology to occur it is recommended that monitoring of this type be undertaken at least annually. Aspects such as salinity should also be monitored and this can be carried out using a standard salinity/conductivity meter. Ideally, salinity should be tested at times of highest and lowest salinity levels (usually late summer and mid-winter/early spring i.e. Jan-March and August each year) as a minimum.

6.2.5 Grazing marsh

The extent of grazing marsh area could be derived from aerial photography as for intertidal mudflat and saltmarsh (i.e. use of 1:5000 black and white or colour photos, with repeat surveys at a minimum of 5 yearly intervals). The same photos could also be used to measure the extent of the internal dyke system within selected areas of grazing marsh, or possibly the entire network depending on the overall requirement.

Measurements of salinity can be taken using a conductivity meter from selected sites where it is known that important brackish water communities are present. It is suggested that measurements should be undertaken on a minimum basis of once every five years and preferably be combined with monitoring of the biological communities at the same time in order to elucidate any potential linked fluctuations/changes.

6.3 Remote sensing applications to stretches of coast

Remote sensing is a generic term describing the measurement of an attribute from a distance. It generally refers to measurement of a land attribute from the air or a sea bed attribute from the sea surface. There is a wide range of techniques available and several questions have to be answered when determining whether remote sensing is required or appropriate.

- What is the objective of the investigation? Can the problem be identified and a hypothesis established?;
- What are the dimensions of the area?;
- What is the smallest unit to identify? Is there a need to map a whole shingle accumulation (broad-scale) or individual pebbles (fine-scale)?;
- What type of product is required? Is it a printed output in the form of maps and/or photographs or an electronic product to integrate with other data? ; and
- Are the available funds sufficient?

Satellite imagery can provide a comparison of large areas over decadal time scales. Yearly vertical aerial surveys of entire coastline can provides quantitative data on large-scale changes of the coast, such as the retreat of cliffs, changes in channels, movement of the saltmarsh edge. Oblique aerial photography of coastline at yearly intervals can both provide background data on coastal and geomorphological processes and to monitor features such as banks and channels, spits and development of saltmarsh or features within estuaries. This type of monitoring also provides important qualitative data. Fixed viewpoint photography involves taking photographs of a monitoring site or fixed area at intervals over time, at exactly the same viewpoint, to show visual changes. Video observations using cameras in the field is recently being promoted to study coastal hydrodynamics and morphology. Image data is collected every daylight hour and fed into a central database covering many years of observations. As such morphodynamics can be studied over a wide range of space and time scales, varying from a storm event (hours-days) to longer term beach development (years-decades).

6.4 Biological Monitoring

As previously stated, predicted changes in morphology are effectively the driving force behind any potential ecological change and therefore the CHaMP should focus on the monitoring of physical components. The measures proposed in Section 11.10 should provide a reasonable assessment of likely changes in the extent of the key habitats within the CHaMP area (saltmarsh, intertidal mudflat, sand dune and grazing marsh). However, in isolation, the monitoring of physical attributes would not provide an indication of any changes in habitat quality or species populations. It is suggested that these components should be monitored through separate programmes developed to inform and ascertain favourable condition for the designated features rather than as a specific element of the CHaMP. Information from the biological monitoring programme would, however, be important in providing an integrated picture of system change and confirming, or not, the predictions outlined in this report.

6.4.1 Monitoring of intertidal habitats

Table 6.1 provides a summary of the biological monitoring that could be undertaken of the intertidal habitats (mudflat and saltmarsh) within the CHaMP area.

Table 6.1 Monitoring of Intertidal Habitat

Focus of Monitoring	Monitoring Technique
Morphology	Irregular monitoring of site and surrounding area to detect change in: size and shape of the habitat, the extent and the condition of fringing habitats. The best approach for monitoring the extent of the saltmarsh would be aerial photography or satellite imagery. This method will detect changes over time much more effectively than field surveys.
Vegetation	Line intercept, point count, quadrats, cover maps, aerial photographs, satellite images and photo stations. CASI.
Aquatic flora	Record species presence/absence along fixed sections (carried out regularly on a monthly – seasonally scale to detect change).
Aquatic Invertebrates	Netting, benthic substrate sampling.
Birds	Regular monitoring of wintering birds, high water counts to tie in with the Wetland Bird Survey count series that is co-ordinated by Wildfowl and Wetlands Trust. Low water monitoring to be undertaken along British Trust for Ornithology guidelines. Monitoring of breeding birds to be undertaken using the standard methodologies for the species concerned.

6.4.2 Monitoring of saline lagoon habitat

Table 6.2 provides a summary of the biological monitoring that could be undertaken for saline lagoon habitat within the CHaMP area.

Table 6.2 Monitoring of Intertidal Habitat

Focus of Monitoring	Monitoring Technique
Morphology	Regular monitoring (once yearly) of site and surrounding area to detect change in size and shape of lagoon; lagoon barrier; extent and condition of fringing habitats and areas of vegetation where appropriate.
Water	Groundwater depth and quality, surface water quality. Long term water level data will be highly advantageous in setting management targets, weekly-monthly recordings are recommended.
Salinity	Test salinity at times of highest and lowest salinity levels (usually late summer and mid-winter/early spring i.e. Jan-March and August each year) as a minimum. The best approach would be monthly measurements
Aquatic flora and drainage channel vegetation	Record species presence/absence along fixed sections or areas of waterbodies (carried out regularly on a monthly – seasonally scale to detect change). Monitoring should focus on any species of nationally scarce plants.
Aquatic Invertebrates	Netting, benthic substrate sampling.
Terrestrial invertebrates	Pitfall traps, sweep netting, water traps, interception traps, transect survey (larger invertebrates)
Birds	Regular monitoring of breeding and wintering birds. Ensure that monitoring of the use of sites and population levels of internationally important wintering birds (identified in site citation) is carried out regularly throughout winter.
Management	Regularly record all management undertaken

6.4.3 Monitoring of grazing marsh habitat

Table 6.3 provides a summary of the biological and physical monitoring that could be undertaken of grazing marsh habitat within the CHaMP area.

Table 11.3 Monitoring of Grazing Marsh Habitat

Focus of Monitoring	Monitoring Technique
Water	Groundwater depth and quality (pH, salinity), surface water quality, inundation depth and frequency.
Vegetation	Line intercept, point count, quadrats, cover maps, aerial photographs, satellite images and photo stations. CASI
Aquatic flora and drainage channel vegetation	Record species presence/absence along fixed sections or areas of waterbodies (carried out regularly on a monthly – seasonal scale to detect change).
Aquatic Invertebrates	Netting, benthic substrate sampling.
Terrestrial invertebrates	Pitfall traps, sweep netting, water traps, interception traps, transect survey (larger invertebrates)
Birds	Regular monitoring of wintering birds, high water counts to tie in with the WeBs count series that is co-ordinated by WWT. Low water monitoring to be undertaken along BTO guidelines. Monitoring of breeding birds to be undertaken using the standard methodologies for the species concerned.
Management	Regularly record all management undertaken i.e. mowing dates, grazing schedules/pressure and water levels.

6.5 Monitoring results

As indicated in Figure 1.1, it is intended that monitoring will be fed back into future revisions of the CHaMP and into the SMP process. The next round of SMPs is required to investigate opportunities for environmental enhancement and management to deliver biodiversity targets both within and outside designated European sites. The monitoring that is proposed to assess the predictions put forward in this CHaMP may be modified or expanded in the light of revisions to the coastal planning process.

7 REFERENCES

Barnes, R.S.K. (2001). The geomorphology and ecology of the shingle-impounded coastal lagoon systems of Britain. In Packham, J.R., Randall, R.E., Barnes, R.S.K. and Neal, A. (eds.) Ecology and Geomorphology of Coastal Shingle. Westbury Publishing, 320-335.

Barnes, R.S.K. and Heath, S.E. (1980). The shingle-foreshore lagoon system of Shingle Street, Suffolk: a preliminary survey. Transactions of the Suffolk Naturalists' Society, 18, 168-181.

Beardall, C.H., Dryden, R.C. and Holzer, T.J. (1991). The Suffolk Estuaries. A report to the Suffolk Wildlife Trust on the Wildlife and Conservation of the Suffolk Estuaries. Segment Publications.

Burd, F.H. (1992). Erosion and vegetation change on the saltmarshes of Essex and north Kent between 1973 and 1988. Report for the Nature Conservancy Council, Peterborough. Research and Survey in Nature Conservation, no 42.

Carr, A.P. (1969). The growth of Orford spit: cartographic and historical evidence from the sixteenth century. Geographical Journal, 135, 28-39.

Carr, A.P. (1986). The estuary of the River Ore, Suffolk: three decades of change in a longer-term context. Field Studies, 6, 439-458.

Fuller, R.M. and Randall, R.E. (1988). The Orford Shingles, Suffolk, UK – classic conflicts in coastline management. Biological Conservation, 46, 95-114.

Green, C.P. and McGregor, D.F.M. (1989). Orfordness: geomorphological conservation perspectives. Transactions of the Institute of British Geographers N.S., 15, 48-59.

Guthrie, J.G.L. (1999a). Environment Agency Anglian Region. Suffolk Estuarine Strategies. River Blyth Strategy Report. Volume 1 Main Report. Posford Duvivier Report, November 1999.

Guthrie, J.G.L. (1999b). Environment Agency Anglian Region. Suffolk Estuarine Strategies. River Alde/Ore Strategy Report. Volume 1 Main Report. Posford Duvivier Report, November 1999.

Guthrie, J.G.L. (1999c). Environment Agency Anglian Region. Suffolk Estuarine Strategies. River Deben Strategy Report. Volume 1 Main Report. Posford Duvivier Report, November 1999.

Halcrow. (1998). Shoreline Management Plan for Sediment Sub-Cell 3C Harwich to Lowestoft.

Halcrow. (2001). Lowestoft to Thorpe Ness Coastal Process and Strategy Study. Volume 2: Coastal Processes (Draft).

Halcrow. (2002). Slaughden Sea Defences Coastal Process Study. Report for the Environment Agency, February 2002.

HR Wallingford (2002). Southern North Sea Sediment Transport Study, Phase 2. Report for Great Yarmouth Borough Council, representing a client Consortia.

IECS. (1993). Stour-Orwell Estuary, Coastal Processes and Conservation. Report to English Nature.

Hawke C.J. and José P.V. (1995). Reedbed management for commercial and wildlife interests. RSPB, Sandy.

Mouchel. (1997). Essex Shoreline Management Plan.

Pethick, J. (1995). Implications of Sea-Level Rise. Sizewell C Recommendations for Coastal Monitoring and Research Programme.

Pethick, J. and Leggett, D. (1995). The morphology of the Anglian coast. In Coastlines of the southern North Sea.

Pettitt, N. (2000). Hollesley to Bawdsey Sea Defences. Coastal Process Report. Posford Duvivier Report, June 2000.

Pye, K. (2001). The nature and geomorphology of coastal shingle. In Packham, J.R., Randall, R.E., Barnes, R.S.K. and Neal, A. (eds.) Ecology and Geomorphology of Coastal Shingle. Westbury Publishing, 2-22.

Randall, R.E. and Fuller, R.M. (2001). The Orford Shingles, Suffolk, UK: Evolving solutions in coastline management. In Packham, J.R., Randall, R.E., Barnes, R.S.K. and Neal, A. (eds.) Ecology and Geomorphology of Coastal Shingle. Westbury Publishing, 242-260.

Royal Society for the Protection of Birds (1997). The Wet Grassland Guide: Managing floodplain and coastal wet grasslands for wildlife. RSPB, EN and ITE.

Suffolk Wildlife Trust (1993) National Vegetation Classification of the Saltmarsh of the Deben, Alde-Ore and Blyth Estuaries, Suffolk. Survey for English Nature.

University of Newcastle. (2000). Erosion of the saltmarshes of Essex between 1988 and 1998. Report for the Environment Agency Anglian Region.

University of Newcastle. (2000). Erosion of the saltmarshes of Essex between 1988 and 1998. Report for the Environment Agency Anglian Region.

Vincent, C.E. (1979). Longshore sand transport rates – a simple model for the East Anglian coastline. Coastal Engineering, 3, 113-136.

APPENDIX A COASTAL GEOMORPHOLOGY OF THE SUFFOLK COAST AND ESTUARIES

1. INTRODUCTION

This Appendix provides a summary of existing geomorphological information for the Suffolk coast and estuaries. The Shoreline Management Plan (SMP) (Halcrow, 1998) divides the Suffolk coast (excluding estuaries) into four process units. These are (from north to south): Lowestoft Ness to Walberswick, Walberswick to The Haven Thorpe Ness, The Haven Thorpe Ness to Shingle Street, and Shingle Street to Port of Felixstowe. For the open coast, this division is maintained, for convenience, in this report, although this should not necessarily imply a rigid division in terms of linkage along the coast. Five estuaries indent the Suffolk coast (from north to south): the Blyth, Alde/Ore, Deben, Orwell and Stour. There is a strong morphological relationship between these estuaries and the open coast, particularly at their mouths.

2. LOWESTOFT NESS TO WALBERSWICK

The geomorphology of the open coast between Lowestoft Ness and Walberswick is influenced by three main factors. These are the behaviour of Benacre Ness, the morphodynamics of nearshore sand banks and the erosion of Pakefield, Kessingland, Covehithe and Easton cliffs. The understanding of the morphodynamics of Benacre Ness is vital to the future management of this stretch of coast.

2.1 Lowestoft Ness to Benacre Ness

South of Lowestoft Ness to Benacre Ness, cliffs ranging from less than 4 m high to a maximum of about 14 m high make up most of the coastline. Pakefield cliffs are composed of Corton Formation sand underlain by silty sand of the Cromer Forest Bed Formation (James and Lewis, 1996). Lowestoft Till overlies the Corton Formation sand in Kessingland cliffs. The cliffs are largely undefended and fronted by a wide mixed sand-shingle beach, with more shingle in the north (over 90%) than in the south (60%) (Vincent, 1979). North of Pakefield, the cliffs are protected by hard sea defences and fronted by the sandy Lowestoft South Beach, which is maintained by groynes. A strip of sand dunes also fronts part of Kessingland cliffs, partially stabilising the cliff face. Historical erosion rates of about 1.8 myr^{-1} have been recorded for Pakefield cliffs, although recent rates are lower as accretion of a wider beach provides more protection from wave attack (Halcrow, 1998). Future Coast (2002a) described a retreat of Lowestoft South Beach between 1889 and 1906, but since 1906 accretion has taken place with a seaward movement of the mean low water along the entire frontage.

Sediment eroded from Pakefield and Kessingland cliffs is introduced to the coastal zone and redistributed by longshore transport processes. In front of Pakefield cliffs, the longshore transport direction appears to experience large directional fluctuations. The potential net longshore transport of mixed sand and shingle is weakly to the south, and very small (500-1600 m^3 yr^{-1}) compared to the gross trends (generally greater than 20,000 m^3yr^{-1} in both north and south directions) (Halcrow, 2001). Halcrow (2001) determined that differential transport of shingle and sand occurs at Pakefield, with shingle moving mainly to the north. They argued that the orientation of the coast at this location allows more exposure to storms from the south-east. During these storms, shingle is moved northward and pushed upward beyond the reach of normal waves. Under normal conditions both northerly and southerly movement of sand and shingle occurs. Vincent (1979) suggested a potential net northerly transport of sand of 41,000 m^3yr^{-1} in front of Pakefield cliffs, converging at Lowestoft Ness, with a potential net southerly transport of sand of about 20,000 m^3 yr^{-1}. The calculations of Vincent (1979) may be unrealistic because the beaches in the area are generally of mixed sand-shingle composition.

Lowestoft Ness is considered to be a point from where sediment is moved offshore and distributed into the bank system by tidal currents (McCave, 1977; Vincent, 1979; Halcrow, 1995). However, the exact mechanism by which this transfer of sediment occurs has not been satisfactorily demonstrated. The ness is now protected and stabilised by sea defences (Halcrow, 1998).

2.2 Benacre Ness

Benacre Ness forms a low promontory which is a maximum 300 m wide and formed of mixed sand-shingle underlain by Holocene intertidal deposits (Halcrow, 1998). It is backed by Kessingland cliffs in the north and low-lying sand dunes and marsh in the south. The modern Hundred River enters the North Sea at Benacre Ness. Sea defences protect the coast at Kessingland, immediately north of Benacre Ness.

Historic maps show that the ness has migrated northwards at an average rate of 22 myr^{-1} over the last 200 years (Birkbeck College and Babtie, 2000). This migration is against the regional transport of sediment, which is to the south (Halcrow, 2001). Benacre Ness is therefore defined as an updrift accretion ness, whereby the longshore transport of sediment south of the ness is less than the sediment supplied to the ness, leading to accretion on the updrift (north) side (Birkbeck College and Babtie, 2000). Halcrow (2001) modelled potential net northerly longshore transport rates for mixed sand and shingle of between 13,800 m^3yr^{-1} and 42,500 m^3yr^{-1} at Kessingland. As the ness moves northwards there is accretion on its north side and thus increased protection of that area, and exposure to wave attack on the south side, causing erosion. Beach profile data between 1992 and 1997 indicate accretion rates of 6.5-7 myr^{-1} on the north side of the ness and erosion rates of 2.5-4 myr^{-1} on the south side (Birkbeck College and Babtie, 2000). This erosion has implications for the survival of The Denes, Benacre Broad, Covehithe Broad and Easton Broad which are a series of estuarine lagoons formed behind the shingle south of the ness. These lagoons have formed by the cutting off of small estuaries that used to flow into the North Sea (Barnes, 2001). They remain lagoons, as seawater is able to overtop the shingle.

About 0.5 km offshore of the ness are two small north-south oriented “en-echelon” bars, collectively called Barnard Shoal. The coastline development at Benacre Ness is dependent on the interaction between the beach and Barnard Shoal. There has been dispute as to whether the ness supplies sediment to the bars or the bars supply sediment to the ness. Robinson (1966, 1980) and Halcrow (1998) suggested that sediment is transferred from the bars, whereas McCave (1978) suggested that the ness is a site where sediment is lost from the coast rather than gained. Based on comparisons of bathymetric charts, Birkbeck College and Babtie (2000) concluded that the ness is a site where sediment is lost from the beach and transferred offshore. Their comparison of charts from 1907 and 1996 showed areas of accretion adjacent to the 1996 position of the ness and offshore below the 12 m contour, and an area of erosion adjacent to the 1907 position of the ness. This spatial pattern of accretion and erosion was postulated to indicate a general transfer of sediment in an offshore direction. Modelling by Halcrow (2001) indicated that, at least for fine sands, there is potential for sediment to be moved offshore under storm conditions.

Wave models show refraction over Barnard Shoal resulting in wave convergence at the ness (Birkbeck College and Babtie, 2000). This focussing of waves might be expected to cause erosion at the ness. This is not the case as the ness is actually accreting. Topographic surveys of the ness indicate an increase in area and volume between November 1995 and March 1997, indicating an overall supply of sediment to the ness. The increase in area was around 24,000 m^2, and the increase in volume 132,000 m^3, equivalent to 66,000 m^3 per year (Birkbeck College and Babtie, 2000). Pye (2001) recognised this accretion and described the ness as a series of relict storm beach ridges (with an active shoreface system), which have built out seawards to form the ness. The models also show that waves tend to break offshore indicating that Barnard Shoal provides some degree of protection to the ness. According to Birkbeck College and Babtie (2000), this offshore break contributes to the accumulation of sediment at the northern end of the ness, while the wave focus helps to explain the form of the ness. However, the models do not fully explain the northerly migration of the ness by wave-driven longshore transport and a more complex interaction of tidal currents and waves may be needed to explain this phenomena; such as that indicated in the results of Southern North Sea Sediment Transport Study (SNS2, HR Wallingford, 2002).

2.3 Benacre Ness to Easton Bavents

The coastline between Benacre Ness and Easton Bavents is dominated by two stretches of undefended cliff less than 6 m high: Covehithe and Easton cliffs. Covehithe cliffs stretch for about 3.5 km and are divided into three sections with the main central section about 2 km long and the other end sections, 600 m and 250 m in length. They consist of a varied sequence of Norwich Crag Formation sediments which, although dominantly sandy in the long central section, do show a notable shingle component (10%) in the southern cliff and significant mud (up to 50%) in the northern cliff (James and Lewis, 1996). Easton cliffs are about 2 km long and contain a varied sequence of Norwich Crag sediments including mixed sand-shingle of the Westleton Beds and clay with sand laminae of the Easton Bavents Clay.

A well developed mixed sand-shingle beach fronts the cliffs, with shingle being the dominant component. Halcrow (1998) argued for a close relationship between the constituents of the beach and cliff although Future Coast (2002a) believed that the shingle is mainly relict. Using historical evidence, they suggested that the feed of sediment from the cliffs is not sufficient to build-up the beaches, but would maintain a state of dynamic equilibrium; the beaches would tend to translate in position rather than flatten or steepen.

The cliffs have receded at rates of 2.2-4 myr^{-1} although Future Coast (2002a) described erosion rates of up to 8 myr^{-1} in places. Clayton (1977) estimated a sand contribution from the cliffs of around 30,000 m^3yr^{-1} (based on a 100 year average). This stretch of coast has a net longshore sediment transport to the south. Halcrow (2001) published a series of potential rates for mixed sand and shingle between Benacre Ness and Easton Broad. Immediately south of the ness, a net southerly rate of 2,500 m^3yr^{-1} was modelled. This value is very low compared to the gross values of 48,800 m^3yr^{-1} to the north and 51,300 m^3yr^{-1} to the south. The net rate increases to just over 18,000 m^3yr^{-1} between Benacre Broad and Covehithe Broad, before reducing again to 3,100 m^3yr^{-1} at Easton Broad.

The stretches of cliff are broken by a series of small brackish lagoons (and marsh) fronted by shingle beach barriers, which are under threat of breaching, by the coastal erosion. Washover deposits are common on the marsh surface. At Benacre Broad the average rate of erosion has been over 4 myr^{-1} (Halcrow, 1998) and is related to the northward migration of Benacre Ness. At Easton Broad the average erosion rate is 2.2

myr^{-1}. These rates keep pace with cliff erosion. Halcrow (1995) described local exposure on the foreshore of intertidal flat and marsh silts and clays caused by erosion of the shingle. The shingle beaches fronting the lagoons are likely to "roll-over" as a response to erosion, but are less likely to withstand future natural pressures, such as sea-level rise. Continued erosion of this stretch of coastline would ultimately lead to the loss of the lagoons and their associated habitats. The Environment Agency is presently maintaining the shingle barriers in front of the lagoons.

2.4 Easton Bavents to Walberswick

South of Easton cliffs to the mouth of the Blyth Estuary, the coast comprises several geomorphological characteristics. Southwold is situated on a 1 km long, 3-8 m high length of defended cliff. The cliff appears to be lithologically variable with both sandy sediments of Norwich Crag and muddy sediments of Lowestoft Till (James and Lewis, 1996). Exposure of sediment at the cliff is poor. To the north and south of Southwold, the land-claimed intertidal areas of the Blyth Estuary and Buss Creek dominate the coast. The low-lying land of the Blyth Estuary is fronted by a narrow and fragile sand dune system (The Denes). The Denes are retained and have grown and stabilised since construction of a training wall along the north side of the Blyth Estuary mouth. The defended Southwold frontage is acting as a hard point, and is developing as a promontory between two eroding bays to the north (Easton-Covehithe) and south (Dunwich-Sizewell).

The processes operating in the Blyth Estuary have only a minor influence on the processes operating along the open coast and offshore. However, the training walls (originally built in the mid-18th century with later extensions) protruding from the coast have a significant effect on coastal shape and impact on longshore sediment movement. The mixed sand-shingle beach at Southwold is maintained by groynes, and by the north training wall of the Blyth Estuary. The net longshore transport direction is weakly to the south (exemplified by accretion of sediment against the north training wall) with an estimated net rate of 3,100 m^3yr^{-1} moving across The Denes frontage (Halcrow, 2001). The north and south gross rates are also low, being 4,700 m^3yr^{-1} and 7,800 m^3yr^{-1}, respectively. The outflow from the Blyth Estuary in combination with the north training wall forces sediment moving in a southerly direction, offshore. Halcrow (1998) suggested that once the sediment is free from the constraint of the walls, longshore currents return it to the coastline. Future Coast (2002a) suggested that sand (and possibly shingle) bypasses the mouth of the Blyth Estuary via a shoal at the mouth. They argued that this is not a continual process but relies upon The Denes beaches first filling up with a sufficient volume of sediment. The Estuary Strategy (Guthrie 1999a) identifies that the increase in estuary tidal prism may result in an increased volume of material held up in the nearshore shoal, with potential, if temporary disruption of sediment drift south.

2.5 Future of the Lowestoft Ness to Walberswick coast

- Future relative sea-level rise and increased storminess are predicted to increase erosion rates along all the cliffed sections between Pakefield and Easton Bavents. Future Coast (2002a) argued that the additional input of sediment from the erosion of these cliffs is unlikely to have a significant impact on the longshore transport rates, as it is predominantly fine sand, which is likely to be transported offshore.

- The predicted evolution of the Lowestoft Ness to Benacre Ness coastline is a reorientation (the embayment between the two nesses is becoming progressively shorter and deeper), with the northern part (Pakefield cliffs) eroding and the southern part (in front of Kessingland cliffs) accreting due to the continued northerly migration of Benacre Ness. The focus of the erosion in the embayment could move northwards as the ness migrates. The rate of northerly migration is anticipated to be similar to the historical rate, unless dominant wave conditions significantly change.

- The continued northerly migration of Benacre Ness in combination with relative sea-level rise and increased storminess will lead to increased erosion south of the modern ness. This may cause breaches in the shingle beach barriers protecting the estuarine lagoons of Benacre Broad, Covehithe Broad and Easton Broad, leading to a new coastal configuration as the coastline is set-back to the landward limit of the Broads. However, Future Coast (2002a) suggested that although a breach could occur during a storm event, it is likely to repair itself fed by the continued supply of sediment from the cliffs, and the anticipated low outflow from the lagoons.

- The sand dunes on either side of the Blyth Estuary mouth are predicted to erode more rapidly with relative sea-level rise.

- Beach levels in front of the defences at Southwold may lower as a result of drawdown (and low longshore sediment transport rates). The rise in relative sea level will cause the low water mark to migrate landward while the high water mark is held stationary by the defence structures. This process is likely to increase the steepness of the beach with a consequent loss of wave attenuation leading to increased erosion.

- As the cliffs at Easton Bavents continue to erode, Southwold will increasingly become a headland, if the current defences are maintained.

3. BLYTH ESTUARY

3.1 Blyth Estuary

The estuary of the River Blyth is microtidal with a mean spring tide range of about 2 m at Southwold. The tidal channel extends about 11 km from the mouth to the tidal limit at Blyford Bridge. The estuary is, for the most part, well mixed, with a small freshwater inflow (annual mean discharge of 0.4 m^3s^{-1} at Holton, near the tidal limit). Freshwater inflow is small in comparison with the tidal inflow (200 m^3s^{-1} on a mean spring tide) and the tidal prism (2.75 x 10^6 m^3 on a mean spring tide, Guthrie, 1999a). The estuary is tidally dominant and salinity variation or a moving turbidity maximum does not complicate estuarine sediment dynamics. Guthrie (1999a) provided best estimate water levels of 1.6 m OD (1 year return period) and 2.26 m OD (100 year return period) for Southwold, and 1.4 m OD (1 year return period) and 2.01 m OD (100 year return period) for Blythburgh.

Since the 16th century, the estuary has undergone considerable land-claim. The most extensive took place during the second half of the 18th century, and a total of 11 km^2 of mudflat and saltmarsh were enclosed by 1840 (Beardall *et al*., 1991). This constrained the estuary into a narrow channel between embankments. From the 1930s the embankments were allowed to deteriorate and progressive abandonment of 2.5 km^2 of this land to the tide has occurred. Bulcamp Marshes were abandoned to the tide during the 1950s and 1960s, when the sea wall was breached. The present estuary is therefore, in places, a rigidly constricted meandering channel, and in other places, has large intertidal areas. The large intertidal to channel volume ratio causes considerable distortion of the tidal current velocities and the estuary is now strongly ebb-dominated. Ebb velocities are up to 40% greater than the flood velocities in some parts of the estuary (ABP, 1996a). In the estuary mouth, peak flood and ebb velocities of 0.8 ms^{-1} and 1.3 ms^{-1}, respectively, have been recorded. This allows flushing of any finer sediment from the estuary to take place along the embanked lower part, thus maintaining its depth. Ebb velocities up to a maximum of 0.2 ms^{-1} are recorded between Blythburgh and Blyford Bridge. The bulk of the tidal prism (80%) is due to the filling and emptying of Bulcamp Marshes intertidal area.

Since abandonment of Bulcamp Marshes, a large expanse of mudflats has developed with only localised saltmarsh re-establishment close to the mean high water mark (French *et al*., 1999, 2000). The poor creation of saltmarsh suggests that the inundated land is at a low level relative to mean high water and that possibly, sediment accumulation is low. At the eastern end of Bulcamp Marshes, French *et al*. (2000) reported inundation of the upper mudflats (*c*. 0.4-0.8 m OD) by 550 (0.7 m OD) and 700 (0.4 m OD) tides per year. Morphological development of the mudflats has been limited, with evolution of creek networks tending to follow the artificial drainage networks excavated during enclosure. Monitoring of the mudflats has shown that wave processes are an important control on sediment resuspension and the rate of elevation change, and hence on saltmarsh creation (French *et al*., 1999, 2000). Mudflats most exposed to waves (fetch *c*. 2 km) suffered erosion at an average rate of 10 mm per year. Sheltered mudflats (fetch <0.4 km) vertically accreted at rates between 7 and 16 mm per year, which is 5 to 10 times higher than the rate of relative sea-level rise (1.6 mm per year measured at Lowestoft between 1956 and 1996). Overall, the surface elevation of Bulcamp Marshes is only on average 0.13 m higher than the existing reclaimed land, even after 55 years of abandonment. While the return of more natural conditions to Bulcamp Marshes has added considerably to the diversity of the natural environment, it also appears to have created a pattern of change to which the estuary regime is still responding.

Between 1972 and 1991 there has been both loss and gain of saltmarsh in different sections of the estuary with an overall net 5% gain (ABP, 1996a). Most of the gains are at the back marsh whereas losses occur near the front edge. In 1972 the saltmarsh area was 0.76 km^2, and in 1991, it was 0.79 km^2.

The particle size of the surface sediments decrease from silt at Blythburgh and on Bulcamp Marshes to shingle at Southwold (ABP, 1996a; French *et al*., 2000). The change occurs near the confluence with Buss Creek and may indicate a change from predominantly depositional conditions upstream to predominantly erosional conditions towards the mouth. In addition, the north and south training walls severely constrain the width of the Blyth Estuary mouth, maintaining a well swept and deep entrance channel.

ABP (1996a) classified the Blyth Estuary into three process units based on morphological and hydrodynamic properties. Process Unit 1 comprises the area of wide intertidal mudflats, including Sandpit Covert Marshes, Angel Marshes and the western half of Bulcamp Marshes. The hydrodynamic-morphological relationships suggest that this unit is behaving as a typical trumpet shaped estuary. The power expenditure on the bed is low and almost uniform across the unit, and hence it is dominated by deposition of silt. Process Unit 2 comprises the eastern half of Bulcamp Marshes. The power expenditure on the bed decreases upstream (initially rapidly) as the estuary widens, and the unit changes from an area of net erosion downstream to an area of net deposition upstream. Both units 1 and 2 have internally generated wind waves that are tidally dependent resulting in maximum stress at the edges of the saltmarsh. Analysis of the saltmarsh extent shows evidence of frontal erosion particularly along the southern shore of Process Unit 2. Process Unit 3 is the narrow embanked section of the estuary from the downstream end of Bulcamp Marshes to the mouth, and is dominantly erosional. The hydrodynamic-morphological relationships suggest this unit is behaving as a simple canal section, the embankments constraining the channel's attempts to meander. Internally generated waves are small but larger sea generated waves are able to enter and propagate along the estuary. Flow velocities are high enough to transport sediment through the unit.

3.2 Future of the Blyth Estuary

There are several factors that will impose constraints on the development of the estuary as relative sea level rises in the future. These are, first, the degree to which at any point in the estuary its width is constricted, and second, the degree to which a change in alignment of the channel is constrained. For example, the estuary at Bulcamp Marshes is wide and the channel is only partially constrained. In contrast, the section at the mouth of the estuary is straight and constrained by defences at the edge of the channel. The unrestricted area may be able to accommodate a rise in sea level without significant change to the regime, whereas in the restricted channel the rise would result in increased pressure on the defences.

Following a postulated rise in sea level of 0.5 m, the following predictions have been made (ABP, 1996a; Guthrie, 1999a).

- The tidal volume would increase from 2.75 x 10^6 m^3 to 4.4 x 10^6 m^3 (159% of present volume) assuming all defences remain intact. The largest overall increase will occur at Angel and Bulcamp Marshes.

- Maximum ebb current velocities would be increased by about 0.1 ms^{-1} in the lower constrained sections of the estuary. This will lead to increased pressure for the estuary to attempt to widen and deepen its channel through erosion, and place the embankments under further stress from scour.

- Maximum ebb current velocities would be reduced by 0.23 ms^{-1} across Bulcamp Marshes leading to an increase in deposition. The saltmarsh areas should remain relatively stable with new growth slowly expanding their area.

- Increased flows along the lower embanked part of the estuary are likely to result in an increase in the amount of sediment deposited immediately offshore from the mouth, possibly leading to formation of an enlarged ebb-tidal delta (or shoal). This increase in delta formation would tend to trap more sediment resulting in disruption of the southerly longshore transport and provide extra shelter to the coast immediately adjacent to the estuary mouth. The main impact will be on the coast to the south, where increased erosion of the shingle beach may make it increasingly difficult to maintain.

- The frequency of return of extreme water levels would increase by a factor of 10 or more. At Southwold, the water level of the 1 year event would increase from 1.6 m OD to 2.1 m OD and the 100 year event from 2.26 m OD to 2.76 m OD.

4. WALBERSWICK TO THORPE NESS

Along this stretch of coast the interaction between cliff erosion, longshore transport and the nearshore sandbank regime is important (Halcrow, 1998). Net longshore transport is dominantly to the south (Halcrow, 2001), and at Thorpe Ness, sediment is transported both offshore and longshore to Aldeburgh. The sediment transported offshore is moved north along the bank system, which shelters the coast, and also feeds sediment to the beaches. Halcrow (2001) argued that under normal, non-storm conditions, the longshore transport predominantly takes place along the intertidal zone (the zone of breaking waves). This changes under storm conditions when a large percentage of the net longshore transport takes place on offshore bars, which according to Future Coast (2002b), are present along most of the coast, at approximately 150-200 m and 350-400 m offshore.

4.1 Walberswick to Dunwich

Between Walberswick and Dunwich the coast comprises a mixed sand-shingle beach. At Walberswick, the first 500 m of beach south of the Blyth Estuary is backed by sand dunes, behind which is a low-lying marsh. Further south, the beach forms a barrier that directly protects low lying marsh areas, which contain the percolation lagoons of the former Dunwich Harbour (Barnes, 2001). Here, seawater percolates through the shingle barrier during high tide and then issues out during low tide. According to Future Coast (2002b) and Halcrow (1998) the crest of the shingle is lowering and the coastline is moving landwards as a consequence of natural processes. Washover deposits of shingle are common on the marsh surface. The coast has generally moved landwards by over 1 myr^{-1} during the past 100 years (Halcrow, 1995). The continued retreat of the shingle would eventually lead to a breach and flooding of the low-lying areas behind. The Dunwich River drains across the marsh into the Blyth Estuary at Walberswick.

Halcrow (2001) modelled a southerly potential net longshore transport rate for mixed sand and shingle of 9,900 m^3yr^{-1} at Corporation Marshes, whereas Vincent (1979) calculated a far higher net value of 148,000 m^3yr^{-1} for sand.

4.2 Dunwich to Minsmere

For 3 km south from Dunwich, the coast comprises unprotected cliffs composed of Norwich Crag Formation (James and Lewis, 1996) fronted by a mixed sand-shingle beach. The cliffs range in height from less than 5 m to over 11 m. Sand dominates the cliff sequence but there are significant areas where shingle can form up to 60% of the sediment (James and Lewis, 1996). The erosion of Dunwich cliffs provides a significant source of sediment to the coastal and nearshore systems. The cliffs have receded around 0.8 myr^{-1} since 1884, although rates as high as 3 myr^{-1} have been recorded (Halcrow, 1995). Clayton (1977) suggested that 40,000 m^3 of sand is liberated from the cliffs every year (based on a 100 year average). However, assuming an average cliff height of 8 m, a length of 3 km, a recession rate of 0.8 myr^{-1}, and 100% sand cliffs, the yield would be around 19,000 m^3yr^{-1}.

According to Future Coast (2002b), erosion of Dunwich cliffs has been intermittent but severe. Erosion takes place during storm events, followed by quieter periods. Between each storm event the beach accretes, fed by sediment from both the north and south. When the beach erodes, the compacted nature of the sand-shingle mix results in the formation of beach cliffs. Lowering of the beach exposes the toe of the cliff to further erosion. Pethick (1995) suggested a link between the erosion of the cliffs at Dunwich and beach changes at Sizewell, further south. He argued that at times of relatively low cliff recession, the beach at Sizewell eroded, and at times of relatively high cliff recession (>3 m), the beach accreted. Halcrow (2001) suggested that under storm conditions sediment is drawn down from the beach onto the offshore bars, along which it is then rapidly transported, then released further offshore.

The sediment supplied from the cliffs is made available for longshore transport. Halcrow (2001) indicated that potential net transport for mixed sand and shingle is south at a rate of 12,100 m^3yr^{-1}. Vincent (1979) provided an alternative view suggesting a net northerly potential transport for sand of 101,000 m^3yr^{-1}. Vincent (1979) suggested that the offshore Dunwich Bank is responsible for the model prediction of a longshore transport convergence around Dunwich. However, he added that little evidence is available from the Dunwich beaches for such a convergence and it must be considered as unsupported by observation. He further suggested that the refraction effect of the bank appears to be over-estimated by the modelled refraction diagrams input into the model.

4.3 Minsmere to Thorpe Ness

The coastline in front of Minsmere and Sizewell comprises low vegetated dunes behind a barrier beach composed of mixed sand-shingle. In the nearshore zone, Sizewell and Dunwich Banks provide a degree of protection from waves to the coast. According to Halcrow (1998) these banks are maintained by sediment transport in both longshore and cross-shore directions. They argued that the banks are in a state of dynamic equilibrium, in which changes to the pattern of waves and currents result in changes to the banks, which, in turn, induce changes to the waves and currents. The coastline in front of Minsmere and Sizewell has, historically, been stable, moving within a band 55 m wide since 1884 (Halcrow, 1995, 1998). This trend is expected to continue as long as the offshore banks remain at their present elevation. However, the implications of sea-level rise on the hydrodynamic forces, wave heights and erosive responses need to be considered.

According to Halcrow (2001) potential net longshore transport rates for mixed sand and shingle are low and to the south along this stretch of coast. They calculated rates of 3,200 m^3yr^{-1} and 3,700 m^3yr^{-1} at Minsmere and Sizewell, respectively. These rates are low compared to the gross estimates in northerly (24,100-39,900 m^3yr^{-1}) and southerly (27,300-43,600 m^3yr^{-1}) directions. Alternatively, Vincent (1979) suggested a potential net rate for sand of 85,000 m^3yr^{-1} at Sizewell. This rate is probably unrealistic as the beach at Sizewell is 75% shingle (McCave, 1977). These data suggest that variability is far more significant than supply.

Sizewell cliffs extend from Sizewell Power Station in the north to Thorpe Ness along a 3 km stretch of coast. The cliffs are variable in height from less than 2 m to over 9 m high, and are well vegetated. For 2 km to the south of Sizewell the cliffs are characterised by Chillesford Sands with negligible shingle (James and Lewis, 1996). The beach in front of the cliffs is composed of mixed sand and shingle. Recently, and since 1888 there has been little cliff erosion (Future Coast, 2002b), and the supply of sediment to the beaches is dependent on erosion of cliffs further to the north.

4.4 Thorpe Ness

At Thorpe Ness the coast comprises cliffs of sandy glacial till with a large (20%) shingle component. A densely packed mixture of shingle and interstitial sand and silt up to 70 m wide forms the beach. Over the last 100 years a reduction in beach volume has resulted in limited erosion of the cliffs from wave action (Halcrow, 1998). However, the beach itself is prone to cliffing under moderate storm conditions (Pye, 2001). Halcrow (2001) has modelled a very small potential net longshore transport rate for sand and shingle of 300 m^3yr^{-1}.

There is presently debate as to whether the ness supplies sediment to the offshore or offshore sources supply sediment to the ness. Pethick and Leggett (1995) suggested that the ness was the main point at which sediment moving south is taken offshore into the bank system. However, according to Halcrow (1998), the high percentage of flint shingle at Thorpe Ness implies a seaward source, as the cliffs nearby do not provide the required volume of this type of sediment. Future Coast (2002b) argued that shingle-sized sediment is not presently sourced from offshore because, even under storm conditions, the currents are not strong enough to mobilise this size of sediment. Modelling by Halcrow (2001) suggested that Thorpe Ness represents a site where there is potential for a net offshore transport of fine sand. They argued that some of this sand is transported onto Sizewell Bank, although there does not seem to be a direct link to Dunwich Bank. Robinson (1980) studied the relationship between Sizewell Bank and Thorpe Ness, along with the impacts of the banks on the reduced erosion rates experienced at Dunwich over the past 50 years. Changes in the pattern of ebb-flood channel configuration here can alter the availability of sediment to the adjacent coast.

There has been a decrease in the width of the beach at Thorpe Ness over the past decade (Halcrow, 1995). Robinson (1980) argued that this may be a consequence of a lack of continuous sediment supply from offshore, possibly as a result of the extension of Sizewell Bank in a northerly direction, reducing the available sediment volume for the beach. Apart from the reduction in width of Thorpe Ness, the cliffs have experienced only minor retreat since 1884. Immediately south of Thorpe Ness, erosion rates of around 0.4 myr^{-1} have been recorded since 1884 (Halcrow, 1995).

This relative stability of Thorpe Ness is likely to be geologically controlled. Crag is exposed offshore and these relatively resistant outcrops may account for the comparatively small retreat of the coast at Thorpe Ness and the land to the north. Birkbeck College and Babtie (2000) suggested the possibility that Thorpe Ness was a headland fixed by a bedrock reef. Pye (2001) defines the ness as an embayment beach ridge plain consisting of a series of relict storm beach ridges and an active shoreface system, which have built out seawards to form the ness.

4.5 Future of the Walberswick to Thorpe Ness coast

- Future relative sea-level rise and increased storminess are predicted to increase erosion rates along the cliffed section at Dunwich. Future Coast (2002b) suggested that the poor retention capacity for finer sediments of the beaches fronting the cliffs allows much of the sediment released from the cliffs to be lost elsewhere, exacerbating the erosion potential.

- Lowering and widening of the shingle barrier beaches in front of low-lying marshes between Walberswick and Dunwich is expected to continue in the future but at an accelerated rate due to sea-level rise and increased storminess. This may lead to an increased risk of flooding and, ultimately, to breaches in the barriers and inundation of the areas behind.

- Future Coast (2002b) suggested that the low dunes at Minsmere, which are attached to the cliffs to the north, are under threat of future breach with an associated increased risk of flooding of the low-lying areas behind. However, they added that redistribution of sand within the dune system should enable the dunes to be sustained.

- Future Coast (2002b) suggested that under rising sea level the offshore sand banks (Dunwich and Sizewell) may migrate inland maintaining similar levels of protection to the beaches as at present.

- Although the position of Thorpe Ness will continue to be partially controlled by the underlying geology, a future accelerated retreat is predicted due to relative sea-level rise and increased storminess.

5. THORPE NESS TO SHINGLE STREET

5.1 Thorpe Ness to Aldeburgh

Between Thorpe Ness and north Aldeburgh, a shingle beach barrier protects low-lying marsh behind. Aldeburgh is situated on a slight rise composed of Crag (>97% sand, James and Lewis, 1996), with a fronting cliff, over 1 km long and a maximum height of about 10 m. The cliff is defended by a seawall and fronted by a shingle beach. Prior to the late 19th century, the coast at Aldeburgh was eroding. Clayton (1987) refers to the loss of six streets since the 16th century. However, at Aldeburgh at present, a system of groynes is associated with a wide shingle beach, and the long-term erosion has been stopped (since 1886) (Future Coast, 2002c). This stretch of coast, therefore, marks a transition between erosion at Thorpe Ness and accretion at north Aldeburgh.

5.2 Aldeburgh to Shingle Street

The feed of shingle that is transported around Thorpe Ness moves south beyond Aldeburgh to form the beaches of Orford Spit and Ness. The spit diverts the course of the River Alde to join the River Ore, with a mouth at Orford Haven between Shingle Street and North Weir Point. The spit is backed by low-lying marsh through which the River Ore meanders. The shingle of the spit and ness is in the range 4 mm to 75 mm and is composed of a high proportion of highly resistant flint (Carr, 1970, 1972). A series of man-made saline lagoons occur on Lantern and Kings Marshes. They were former borrow pits, excavated to provide sediment for flood embankments. Another set of former gravel pit lagoons occurs within the main bulk of the shingle. Both sets of lagoons are fed by seawater percolation through the shingle, occasional overtopping and by rainfall.

The spit probably started to form after the rate of sea-level rise slowed several thousand years ago. It seems likely that a source of offshore sediment was gradually driven onshore. On reaching the shore, the dominant north-easterly wave climate forced the shingle southwards, whilst at the same time, the shingle was also being rolled back landward as sea level continued to rise. Since then, the growth of the spit is recorded by a series of ancient shorelines, which are preserved as shingle ridges with intervening lows.

Steers (1926, 1964) suggested that the construction of the castle at Orford in 1165 marked what was then the end of the spit, suggesting that ridges adjoining Stony Ditch were 12th to 13th century. Further ridges were added in the 14th century, with the higher, more seaward ridges formed in the period from the 17th century onward (Carr, 1970). Maps produced between the 1600s and 1800s show the spit to have grown beyond

Orford and Havergate Island (Carr, 1969). By the late 1800s the spit had grown almost to its present length. Over the last 180 years the length of Orford Spit has fluctuated over a distance of nearly 3 km, although evidence suggests that its alignment has remained unchanged (Carr, 1969, 1972). The present position of the end of the spit is close to its past known maximum.

Orford Ness is defined as a downdrift accretion ness (Birkbeck College and Babtie, 2000) with downdrift accretion accompanied by erosion on the updrift side. The erosion involves the "roll-over" of shingle on to the backing marsh, and old marsh sediments are exposed in places along the foreshore (Birkbeck College and Babtie, 2000). Between Slaughden and Lantern Marshes, the historical trend (before construction of defences) has been retreat of about 1 myr^{-1} (Clayton, 1987; Halcrow, 1995). Halcrow (2002) compared historic maps between 1886 and 2000 and suggested a lower value of around 0.45 myr^{-1} (an average of 50 m over the 114 year period). The analysis also indicated that the beaches at Slaughden have steepened with a foreshore reduction in width of about 50% over the 114 year period. Using beach profile data, Birkbeck College and Babtie (2000) measured average erosion rates of 3 myr^{-1} between 1991 and 1997. However, a storm event in February 1996 caused up to 15 m of erosion along the northern shore of the ness and reduced the height of the beach ridge by over 1 m. Washovers were pushed inland by up to 40 m. Losses of 5-6 m occurred at Slaughden during a single storm surge in October 1998. Clayton (1987) also suggested an erosion rate of 1.5-2 m yr^{-1} immediately north of the ness and progradation of 0.3 m yr^{-1} immediately south of the ness (Halcrow 2002). The overall result of the erosion-accretion patterns is a gradual migration of the ness in a southerly downdrift direction (about 4 myr^{-1}, Clayton, 1987).

The magnitude of these changes vary depending on the method of calculation. Indeed, beach profile data (1992-2000) suggest that sections of the coast between Aldeburgh and North Weir Point are subject to alternating trends of erosion and accretion with no discernible trends. The analysis also showed that annual variability was in excess of the average rates of change during the 8 year period, indicating that conclusions based on average trends, may not be indicative of longer-term trends, as a single years data may reverse the overall apparent trend.

Vincent (1979) calculated high potential net southerly longshore transport rates for sand of 80,000 m^3yr^{-1} north of the ness and 195,000 m^3yr^{-1} south of the ness. These values are well in excess of the available beach sediment supply. The beaches of Orford Spit are almost entirely shingle supporting these high potential transport rates (Halcrow, 1995). Pettitt (2000) suggested that the potential net longshore transport rate for shingle, immediately south of Orford Ness was 67,200m^3yr^{-1} in a southerly direction. At North Weir Point, this value is calculated to increase to 132,700m^3yr^{-1}. Pettitt (2000) also suggested that bi-directional transport (in equal amounts) takes place north of Orford Ness due to the dominance of two wave directions. This indicates that north of Orford Ness, sediment is free to move in either direction, but once it passes Orford Ness it cannot be transported back. SNS2 (HR Wallingford 2002) suggests that the volume of shingle lost from the system at North Weir Point is greater than the volume entering at Aldeburgh, and so overall the system is losing sediment.

The history of Orford Spit and Ness is important with respect to its ecology. Of particular interest is the age of the ridges, their period without wave disturbance, and the roles of sea level, wave height and shingle supply in determining the profiles of the ridges and hollows (Randall and Fuller, 2001). The spit and ness are characterised by a steep upper beach, with relatively deep water on the upper beachface at high tide. The height of the spit varies along its length with a tendency to increase in elevation where sea level has risen during the time of spit formation. Height variation also occurs due to build up of the beach ridges by storms. These ridges are roughly parallel to the shore, and have resulted in extensive areas of stable shingle, fringed by a more dynamic coastal ridge. Ridge heights vary from 3.1 m OD for the most landward (although old ridge crests lower than 1.5 m OD have been described), to around 4.0 m OD in the middle to up to 4.3 m OD to seaward (Carr, 1970; Randall and Fuller, 2001). The intervening lows are generally around 0.3 m lower than the ridge crests. Randall and Fuller (2001) showed that the established ridges contain fine shingle (<10 mm), while the lows between are coarse shingle, and this has had a major influence on the success or failure of plant colonisation. The fine shingle tends to be colonised whereas the coarse shingle is barren. The mechanism by which ridges and lows acquire different grades of shingle is unclear.

At Slaughden the diverted estuary approaches to within 50 m of the low water mark. This area constitutes the greatest danger of breakthrough of the spit, where the River Alde has cut into the landward side, while the sea has eroded the outer side. If the spit was breached at Slaughden, there is potential for the formation of a new mouth to the river with dramatic effects on the coastal morphodynamics of the area. The fragility of the spit at Slaughden was demonstrated by a breach at this point in 1963. About 250,000 m^3 of shingle was transported to the site from the ness to repair the damage.

To protect the coast at Slaughden a rock revetment was placed at the back of the shingle ridge in 1987 followed by further works in 1989 and 1992. A continuous 15-year programme of recharge followed, whereby shingle was removed from the beach between Lantern Marshes and the point of the ness and placed on the foreshore at Slaughden. The average amount of recycled sediment amounts to 7000 m^3yr^{-1} (up to 10,000 m^3yr^{-1} maximum).

Randall and Fuller (2001) postulated that if a breach occurred, southerly longshore transport would be hindered and the shoreline at Aldeburgh would accrete, with the course of the River Alde to the sea steadily lengthening eastwards. The abandoned spit immediately south of Aldeburgh would “roll-over” Lantern Marshes, with enhanced accretion south of the present Orford Ness. Inside the spit, flows in the estuary would reduce and the channel would eventually silt-up.

The process regime at the mouth of the estuary is complex. Breaches through North Weir Point have occurred quite regularly and large shingle banks in the mouth form a route by which sediment is transferred southwards across to Shingle Street. Here, lower and far more ephemeral ridges (rarely exceeding 3.4 m high) are formed (Cobb, 1957; Carr, 1972, 1986), which are protected from all but southerly waves by North Weir Point, producing counter recurved spits, growing up-river, with remnants as far as Havergate. A series of natural lagoons occur at Shingle Street, which are formed by the build-up of shingle and enclosure of small bodies of seawater (Cobb, 1957). This system is subject to more dynamic conditions than the lagoons of Lantern and Kings Marshes and several have been lost through shingle movement since the 1970s. More recent photographs indicate that northerly drift into the estuary has either significantly reduced, or ceased (Pettitt, 2000). The inward pointing spits now appear to be only the inactive remnants of the original features and are being slowly eroded by wave and current action. This change itself is recognised as transitory. Towards Shingle Street, Pettitt (2000) calculated a potential net northerly longshore transport rate for shingle of 83,300m^3yr^{-1}.

Orford Spit has grown in a “cyclic” fashion (Cobb, 1957; Carr, 1969, 1972, 1986) with periods of elongation intermittent with periods of shortening. According to Carr (1986) the cyclicity may be caused by fluctuations in the protection from waves afforded by nearshore sandbanks: Aldeburgh Ridge and Whiting Bank. The orientation and position of these banks provide protection in places and wave focussing in other areas (Future Coast, 2002c).

Steers (1926, 1964) calculated an average growth of 14 myr^{-1} from 1601 to 1897, although it wasn’t necessarily continuous. During this period, Orford Spit is known to have undergone at least two periods of growth followed by collapse. Cobb (1957) and Carr (1969) stated that the spit reached a maximum length in 1811 and again in 1892. In both cases the most southerly location is reported to have been approximately opposite the Martello tower at the southern end of Shingle Street. This may represent the critical length of the spit, the maximum length that it can develop to before in becomes unstable and breaches (Cobb, 1957). This may suggest that limiting effects are local not nearshore. The 1892 cycle was ended by a severe storm in November 1893 (Cobb, 1957). This caused a breach, followed by progressive retreat in which the isolated portion of the spit formed a series of islands and banks. These were eventually driven onto the Shingle Street frontage by wave action initiating development of the lagoons (Cobb, 1957). By 1921 the spit had retreated to its most northerly location in this period (Carr, 1969, 1986). This 2.7 km retreat was almost twice the distance that occurred at the end of the 1811 cycle.

A number of mechanisms, by which a breach may occur have been suggested, including increased hydraulic gradient and direct wave attack. As the spit gets longer the hydraulic efficiency of the estuary decreases. This results in an increased hydraulic gradient across the spit (between its seaward and river sides), leading to increased seepage through the spit. This may be sufficient to cause a breach, probably by exploiting an existing weakness. A surge associated with a storm event could increase the hydraulic gradient. A storm may also result in changes to the estuary mouth bathymetry, possibly causing a partial blockage, and leading to an increased hydraulic gradient across the spit.

Another measure of spit growth is the variation observed at Shingle Street. Aerial photographs show a “bulge” along the frontage, with an apex that has been moving in a southerly direction around 20 myr^{-1} (Pettitt, 2000). The bulge is the main location where sediment that has crossed the mouth of the estuary is being transported onshore. The location of the bulge is therefore an indicator of the position of the “effective end” of the spit, making allowances for the submerged banks at the tip. By extrapolation it is possible to predict that, assuming a linear growth, the spit will reach it’s critical length by about 2020 (Pettitt, 2000).

From a consideration of the predicted transport rates and observed growth of the spit, Pettitt (2000) was able to calculate how much sediment crosses the estuary mouth. The sediment transport analyses indicated that between about 70,000 and 130,000 m^3 of sediment moves in a southerly direction along the beach, south of the ness, every year. By assuming a typical cross-section for Orford Spit, Pettitt (2000) calculated that approximately 35,000 m^3yr^{-1} of sediment is sufficient to sustain a growth rate of 20 myr^{-1}. This indicates that between 25% and 50% of the sediment transported along the beach contributes to the growth of Orford Spit. Therefore, the remaining sediment must cross the estuary mouth and reach the Shingle Street frontage, between 35,000 and 95,000 m^3yr^{-1}, depending on wave climates.

5.3 Future of the Thorpe Ness to Shingle Street coast

- Groynes at Aldeburgh will continue to maintain the beach along this stretch of coast. This coast will therefore remain stable, continuing to be slightly accretional. However, the groynes are unlikely to solve the long-term problems of a finite shingle supply.

- The diminishing supply of shingle to the north of Orford Spit, the continued steepening of the beach, relative sea-level rise and increased storminess will place increasing pressure on the Slaughden frontage, and increase the threat of breach.

- Future Coast (2002c) suggested that Orford Ness is a key control point and any changes in its form and position could have considerable impact for areas to the north and south. They argued that the entire foreland is undergoing large-scale re-alignment under a diminishing sediment volume regime.

- The accretional trend along the downdrift side of Orford Ness is expected to continue. There will continue to be a net loss of shingle from Orford Ness onto the coastline further south between Shingle Street and Felixstowe.

- Any significant increases in tidal volume and tidal flow, due to relative sea-level rise, are likely to change the pattern of sediment dynamics across Orford Haven, either due to a greater quantity of shingle being trapped in the mouth or due to premature or major rupturing of the shingle spit.

- North Weir Point is dynamic and known to vary by up to 3-4 km in response to breaching the spit. This cyclicity is likely to continue.

- Orford Spit is currently extending southwards parallel to the shore at a rate of approximately 20 myr^{-1}. In this process between 25% and 50% of the sediment is retained by the spit. It is predicted that this will continue well into the 21st century, until the spit becomes unstable. At this time (*c*. 2010 to 2030) the spit will probably breach and deposit a large shingle supply on the shore near Shingle Street, possibly creating another bulge.

6. ALDE/ORE ESTUARY

6.1 Alde/Ore Estuary

The estuary of the River Alde/Ore stretches from the normal tidal limit at Snape to Orford Haven. Between Snape and the cliffs at Iken, the southerly course of the Alde Estuary channel is fixed by a series of abandoned embankments, within which flows are generally slow. From Iken to Barber's Point the intertidal area widens to around 1 km with a narrow, meandering low water channel which is largely unrestricted. At Barber's Point the low water channel reaches its maximum width. Intertidal mudflats bordered by narrow saltmarsh dominate this area. Between Barber's Point and Slaughden the estuary narrows and forms several tight meanders, confined by both defences and natural high ground, before turning sharply south at Slaughden. In this reach, the flow velocities start to increase, particularly on the outer sides of the bends. From Slaughden to Shingle Street the estuary is confined between embankments (restricting any tendency for lateral movement) and flows parallel to the coast confined by Orford Spit. At Orford, the channel splits around Havergate Island. This division of the channel increases the flow area of the river and the general velocities decrease. The River

Butley joins the Alde/Ore Estuary at the south end of Havergate, where the two channels converge again. The tidal limit of the River Butley is at Butley Mills. Downstream of Havergate to its mouth, the estuary is at its widest, behind the spit. There is little scope for increase in width without cutting into the defences to landward or cutting back the shingle ridge on its seaward side.

The tides at Orford have spring and neap ranges of 2.9 m and 1.7 m, respectively (mesotidal). The present volume of water moving into and out of the estuary over a spring tide is around 9.6 x 10^6 m^3 (Guthrie, 1999b), spread fairly evenly throughout the estuary. Guthrie (1999b) provided best estimate water levels of 2.05 m OD (1 year return period) and 2.80 m OD (100 year return period) for Snape, and 2.25 m OD (1 year return period) and 3.02 m OD (100 year return period) for the estuary mouth.

Tidal current flow velocities are generally symmetrical, with velocities varying in accordance with the tidal range and distance from the estuary mouth (ABP, 1996b). Peak surface velocity at Boyton Marsh has been measured as 1.2 ms^{-1}, whereas further upstream at Sudbourne Marsh the value lowers to 0.6 ms^{-1}, and in the wide intertidal section 0.25 ms^{-1}. Modelling in the wider upstream parts of the estuary show that the time for settlement of sediments at high water slack is increased in the wider marsh areas (ABP, 1996b). Any deposition therefore is more likely to add to the upper marsh levels than to the lower intertidal areas. The models also show that the velocities change very slowly in the mid-section of the estuary, but as soon as it widens the velocities drop by over 50% and continue to fall as the tidal limit is approached. Particle size along most of the estuary is dominated by mud (ABP, 1996b). Sand occurs where flow velocities are higher (Slaughden bend) and gravel occurs towards the mouth.

The estuary has a small freshwater inflow, with an average input of 0.62 m^3s^{-1} (ABP, 1996b). There is a distinct seasonal pattern with flows in winter (1.8 m^3s^{-1}) being six times higher than flows in summer (0.3 m^3s^{-1}). On a spring tide, the tidal inflow at the mouth of the estuary is 1500 m^3s^{-1} making the estuary system tidally dominant.

Over the past several thousand years the development of the Alde/Ore Estuary has been intimately linked to the development of Orford Spit and the land-claim of saltmarsh formed in the shelter of the spit. The main enclosure of saltmarsh took place in two phases, between the 11th and 13th centuries and in the 16th and 17th centuries (Beardall *et al*., 1991). Beardall *et al*. (1991) estimated that 14.5 km^2 and 25.2 km^2 of saltmarsh and mudflat, respectively have been reclaimed and protected by embankments, leaving only 3.4 km^2 of saltmarsh and 5.4 km^2 of mudflat in the Alde/Ore/Butley system.

Between 1971 and 1992 there has been both loss and gain of saltmarsh, with an overall net loss (8.5% compared to 1971, ABP, 1996b). Most of the saltmarsh was lost from the middle estuary (75%) with 25% loss from the lower and upper estuary. The total area of saltmarsh in 1971 was 3.7 km^2 and 3.4 km^2 in 1992. The recent total area of pioneer saltmarsh is low (7.5% of total saltmarsh area) suggesting that little accretion is taking place. The loss of saltmarsh is considered to be due to excessive submergence caused by relative sea-level rise.

ABP (1996b) classified the Alde/Ore Estuary into four main process units based on morphological and hydrodynamic properties. Process Unit 1 comprises an area of wide intertidal mudflat and saltmarsh, which exhibits properties characteristic of a classic trumpet shaped estuary where the width and depth reduce exponentially up-estuary. The intertidal area is 0.5-1 km wide and is crossed by a narrow sinuous low-water channel. The power expenditure on the bed is very low, and hence, the unit is marginally depositional in nature with potential for sedimentation on the higher mudflat and saltmarsh. Process Unit 2 is transitional between the banked channel downstream and unit 1, and has the morphological characteristics of an “inverted” estuary with the mouth at the upstream end. The power expenditure on the bed is constant and very low. It is an area of small net deposition. Both units 1 and 2 have internally generated waves, which are tidally dependent resulting in maximum stress at the edges of the saltmarsh and the embankments.

Process Unit 3 is a narrow gently meandering bank-parallel section. This unit has evolved due to the historical development of Orford Spit and anthropogenic influences, being constrained on both sides by embankments. The power expenditure is larger than units 1 and 2 but smaller than unit 4. The channel division around Havergate Island reduces the overall energy expenditure reducing the erosional effects on the bed and embankments compared to those up and down estuary. The unit has a small depositional potential with respect to sand and a net potential for erosion of mud. Internally generated wave heights are generally uniform and small. Process Unit 4 is a straight narrow bank-parallel section, which is characterised more by coastal processes rather than estuarine processes. The unit has a high potential for deposition of sand and a high potential for erosion of mud and therefore has the most potential for overall change. Waves are dominated by those generated at sea into the entrance and there is little evidence for the formation of tidal deltas at the entrance.

6.2 Future of the Alde/Ore Estuary

There are several factors that will impose constraints on the development of the estuary as relative sea level rises in the future. These are, first, the degree to which at any point in the estuary its width is constricted, and second, the degree to which a change in alignment of the channel is constrained. Following a postulated rise in sea level of 0.5 m, the following predictions have been made (ABP, 1996b; Guthrie, 1999b).

- The frequency of return of extreme water levels is predicted to increase by a factor of 10 or more. At Snape, the water level of the 1 year event would increase from 2.05 m OD to 2.55 m OD and the 100 year event from 2.8 m OD to 3.3 m OD. Correspondingly the water levels at the estuary mouth would increase from 2.25 m OD to 2.75 m OD (1 year event) and from 3.02 m OD to 3.5 m OD (100 year event).

- The peak ebb velocities will increase by about 0.1 ms^{-1} from the estuary mouth to the confluence with the Butley river, thus increasing the potential to scour the bed and banks in this section. However, an increased sediment load through the area may cause deposition of coarser sediment at times of lower flows.

- Power dissipation at the channel bed in all areas of the estuary is predicted to increase. The greatest increases will occur in the relatively narrow channels south of Aldeburgh increasing the likelihood of morphological change.

- The tidal volume would increase from 9.6 x 10^6 m^3 to 13.82 x 10^6 m^3 (144% of present volume) assuming all defences remain intact.

- In the wide intertidal area, the increase in tidal prism is likely to lead to only a small increase in velocities, because the area is tolerant of large changes in tidal volume due to the limited constraint of the channel. The velocity increase may be too small to cause any significant increase in erosion in the area.

- The saltmarsh areas of the estuary are gradually being eroded, and this trend will probably continue with relative sea-level rise.

7. SHINGLE STREET TO PORT OF FELIXSTOWE

This stretch of coast differs geologically (dominated by London Clay) and hydrodynamically (lower energy dissipative environment) from the Suffolk coast further north. Longshore transport is dominantly to the south towards Woodbridge Haven, where sediment is temporarily held in The Knolls and spits at the entrance to the Deben Estuary. Offshore banks provide varying degrees of protection to the coast, and during north-east storms, sediment from the banks is redistributed onto the beaches along the Felixstowe frontage.

7.1 Shingle Street to Felixstowe Ferry

The northern part of this stretch of coast is generally low-lying, formed of marsh fronted by mixed sand-shingle beaches. The southern part is dominated by 3 km of generally unprotected eroding cliffs, up to 16 m high, composed of sands and gravels of the Red Crag (up to 13 m thick in places) resting on London Clay (generally less than 3 m thick) (James and Lewis, 1996). The cliffs at Bawdsey are the most northerly exposure of London Clay on the East Anglian coast. The Red Crag has a significant gravel component, varying from 25-30%. The beach is highly mobile and, in places, London Clay outcrops on the foreshore. Halcrow (1998) argued that the onshore movement of sediment is critical to maintaining beach levels.

This whole stretch of coast is presently held in position by a gun emplacement at East Lane which acts as a “strong point” maintaining a coastal configuration which would not naturally occur (Halcrow, 1998; Pettitt, 2000). East Lane acts as an artificial promontory, which has become more pronounced as the “soft” coastline to either side has eroded. This erosion has been markedly more severe on the south of East Lane due to the promontory intercepting the net southerly longshore sediment transport (Pettitt, 2000). Aerial photographs show that there has been little overall change to the frontage south of Shingle Street towards East Lane over the last fifty years. Pettitt (2000) suggested that the promontory acts as a longshore transport regulator; sediment cannot supply the downdrift side until it has built up sufficiently on the updrift side. This is likely to lead to periods of erosion on the downdrift side prior to a sufficient build up on the updrift side. At Bawdsey, the potential net longshore transport rate for shingle is 141,000 m^3yr^{-1} to the south (Pettitt, 2000).

According to Halcrow (1998) the processes at the Deben Estuary mouth are poorly understood. The main complicating factor is the presence of The Knolls, a series of mobile, transient shingle bars to the north and south of the mouth supplied by sediment from the north. Halcrow (1998) suggested that there is a greater potential for sediment movement into the area from the north, than there is for sediment loss to the south, and so The Knolls are accreting. Their configuration is influenced by the interaction of waves, tides and sediment supply, and depending on their configuration, they provide varying degrees of protection to the downdrift coast. The interaction and stability of the bars depend to a large degree on the volume of flow into and out of the estuary. There is evidence that the bars develop within limits beyond which growth is restricted by wave action and the outflow from the estuary. They accrete over a period of time, gradually becoming unstable, before a storm event drives sediment across the channel and onto the Felixstowe Ferry frontage, which is then redistributed by wave action on to the Felixstowe beaches (BMT Ceemaid, 1990). This has led to general stability along the coast south of the estuary. There is no mechanism for transport northwards across the estuary, and so it is a one-way transport boundary. These processes result in steady erosion of the Felixstowe Ferry frontage followed by significant accretion over a very short period of time. Overall, there appears to be a balance between discreet accretion events and the long-term erosion trend along the frontage (Pettitt, 2000).

During storm conditions, The Knolls rapidly change shape, orientation and location, with a resulting change in the tidal flows in the lower estuary. They can be breached and eroded, and no longer act as a wave protection system, enabling waves to propagate into the lower estuary. The ebb channel breaks through The Knolls altering the orientation of the ebb flow, reducing the length of The Knolls and providing further supply of sediment to be transported away.

BMT Ceemaid (1989a, 1989b, 1990) showed that The Knolls have undergone periods of both accretion and depletion over the period 1950 to 1988. ABP (1996c) showed that the shoals were at that their greatest extent in 1913 and again in 1985. The smallest volume was in 1960. BMT Ceemaid (1990) suggested that there may be a 15 year cycle, consisting of growth of The Knolls and steady erosion along the southern shore, followed by collapse and accretion along the southern shore. Aerial photographs from 1953 illustrate the effect that a major storm can have on The Knolls. The event appears to have driven a large quantity of sediment onshore, towards the frontage in front of the Martello tower.

7.2 Felixstowe Ferry to Landguard Common

The Felixstowe coast has historically been protected from erosion by revetments and seawalls, and groynes maintain the beach. From Felixstowe Ferry to Cobbolds Point, the coast consists of low cliffs, composed of Red Crag resting on London Clay (generally less than 3 m in thickness) (James and Lewis, 1996). The cliffs contain over 75% sand. About 4 km of cliff front the coast with a maximum height of about 17 m, although cliff elevation is variable with heights down to 2.5 m. At Felixstowe the cliff turns inland away from the coast to leave a lower lying coast to the south, formed of a variety of morphological types. The beach between Felixstowe Ferry and Landguard Common is typically mixed sand-shingle with outcrops of London Clay in places along the foreshore.

Cobbolds Point forms a protected promontory, which is exposed to high energy wave action. Consequently there is a narrow beach of fluctuating width. The sediment transport regime at Cobbolds Point is presently under debate (Future Coast, 2002d). One argument suggests that the point is an area of net sediment transport divergence with sediment moving north and south from the point. Another argument suggests that net sediment movement is southwards, but that reversals do occur. At Cobbolds Point, Future Coast (2002d) suggested that the sand fraction of the beach is more responsive to reversal in sediment transport and is moved both north and south. However, shingle is moved southwards by high energy waves from the north-east. Pettitt (2000) calculated a potential net longshore transport rate for shingle of 62,700 m^3yr^{-1} to the south.

The volatility of the beaches along this stretch of coast is linked to changes in channel and bar configuration at the Deben Estuary mouth. The cross-channel component of sediment transport from The Knolls is therefore critical to the maintenance of beach levels.

7.3 Landguard Common to Landguard Point

This stretch of coast is low-lying, formed of Landguard Spit and shingle beach, fronting marsh that has been land-claimed from the Orwell Estuary. The end of the spit is held in position by Landguard Point Jetty, which acts as a terminal groyne, and from the point a shore normal shingle bank extends offshore. Until the mid 1980s, sediment was extracted from the beach at Landguard Point (typically 10,000 m^3yr^{-1}) to reduce the need for dredging of the Harwich Harbour approach channel. This practice has now stopped. The jetty limits the amount of sediment moving into Harwich Harbour, and allows the beach to remain relatively stable. Historical evidence suggests that if sediment was not trapped behind the jetty, it would be transported into the mouth of the Orwell Estuary, rather than building out across the estuary (SNS2 HR Wallingford 2002). It was identified that the probable extent of drift along the shoreline was in the order of 20,000m3yr to 30,000m3yr based on the dredging record from immediately within the mouth of the estuary. There is no evidence of material moving from the Felixstowe frontage across the main Harwich channel. This view was supported by Futurecoast (2002)

The onshore-offshore movement of sediment was believed to be important to beach level maintenance along this coast (Halcrow, 1998). From Landguard Point, sediment was thought to move offshore to Cork Sand where it was believed to be stored temporarily. IECS (1993) suggested that Cork Sand marks the ebb tidal delta of the Orwell-Stour-Harwich Harbour system. Easterly or north-easterly storms were thought to move the sediment onshore towards the Naze where a longer term store exists. Mouchel (1997) suggested that around 70,000 m^3yr^{-1} was input to the Naze, most of which coming from Cork Sand, while some (10,000 m^3yr^{-1}) is derived from the cliffs at the Naze. Measurement work undertaken as part of SNS2 (HR Wallingford 2002) demonstrated no substantial link between Cork Sands and the Naze.

7.4 Future of the Shingle Street to Port of Felixstowe coast

- The future evolution of the shoreline between Shingle Street and East Lane depends to a large extent on the behaviour of the East Lane promontory. If it is removed or retreated then the coast would erode and release significant quantities of sediment into the system, probably to feed The Knolls and Felixstowe beaches. The shingle ridge to the north would gradually be stripped of sediment and possibly draw more sediment off Orford Spit.

- Sediment would still be transported intermittently through East Lane and across the mouth of the Deben via The Knolls.

- Under rising sea levels there is likely to be increased rollover of the shingle beaches over the low-lying marshes to the south of Shingle Street.

- Future relative sea-level rise and increased storminess are predicted to increase erosion rates along the cliffed section at Bawdsey, releasing larger quantities of fine sand and mud to the nearshore system. Most of this sediment may be lost offshore.

- With relative sea-level rise the beach on Landguard Spit may retreat, but the continued build-up of sediment behind the jetty will ensure that retreat is limited.

8. DEBEN ESTUARY

8.1 Deben Estuary

The normal tidal limit of the Deben Estuary is at Bromeswell. From Bromeswell to Martlesham Creek the estuary is confined to a narrow channel by embankments and gently meanders through narrow fringing mudflats and saltmarsh. Between Martlesham Creek and Ramsholt the channel meanders within the limits of a relatively wide intertidal area which is bounded by either natural high ground or defended land-claim. At Ramsholt, the estuary narrows and continues to its mouth at Woodbridge Haven confined on both sides by embankments with large areas of low-lying land-claim on either side. The mouth of the estuary is unusual in that it narrows before entering the sea. A ridge of higher land to the east at Bawdsey constricts the estuary mouth between it and a low ridge of shingle at Felixstowe Ferry on the opposite bank.

The tides entering the Deben Estuary at Woodbridge Haven have a mean spring and mean neap range of 3.2 m and 1.9 m, respectively. At Woodbridge, the tidal range is 0.3-0.4 m higher than at Woodbridge Haven. The flow velocities are ebb dominant with peak velocities 40-50% higher than the flood (ABP, 1996c). Peak spring tide velocities reach 0.5 ms^{-1} whereas ebb velocities peak at 0.75 ms^{-1}. In general, neap tide velocities are 0.1 to 0.2 ms^{-1} lower. The daily average freshwater input to the estuary is around 0.6 m^3s^{-1}. On a spring tide, the peak tidal flow at the mouth is around 1700 m^3s^{-1}. The typical river flow is negligible in influencing the overall character of the estuary, which is driven by the influx of tidal saline water. It has been estimated that the supply of sediment to the estuary from offshore is around 16 times greater than that supplied down river (Beardall *et al*., 1991).

The present volume of water moving into and out of the estuary over a spring tide is around 8.95×10^6 m^3 (Guthrie, 1999c). Over half this volume (5.14×10^6 m^3) is due to the filling and emptying of the middle reaches of the estuary. Guthrie (1999c) provided best estimate water levels of 2.55 m OD (1 year return period) and 3.35 m OD (100 year return period) for Woodbridge Haven, and 2.7 m OD (1 year return period) and 3.62 m OD (100 year return period) for Woodbridge.

Interaction between tidal estuary processes and open coast processes has led to the development of a series of shifting shingle bars at the mouth of the estuary known as The Knolls. Here, the topography is in continuous motion due to the processes driven predominantly by waves and modified by tidal currents into and out of the estuary. On the flood, secondary flows exist through swatchways in The Knolls, causing the main current to be deflected onto the western bank of the channel. During the ebb, the main flow is down the eastern bank of the channel, with secondary flows redefining swatchways in The Knolls.

Inside the mouth of the estuary, the flood stream flows to the east of Horse Sand, while on the ebb, a secondary flow passes to the west of Horse Sand. There is therefore a net anticlockwise flow around this bank, which is located in the region where the rapid flow through the mouth on the flood has decelerated sufficiently to deposit its sand fraction. Between 1950 and 1988, Horse Sand maintained a constant position and orientation with a shallow, almost drying channel between Horse Sand and the west bank and a much deeper, steeper-sided channel to the east.

Between the 11^{th} and 17^{th} centuries the Deben Estuary underwent periods of land-claim, most of which took place along the lower part of the estuary. The marshes at Bawdsey, Ramsholt, Falkenham and Felixstowe Ferry were frequently flooded prior to land-claim. Beardall *et al*. (1991) estimated enclosure of 22.4 km^2 of former saltmarsh and mudflats within the estuary. Around 4.5 km^2 of mudflat and 2.3 km^2 of saltmarsh remain. The development of marsh communities in the Deben has been strongly influenced by the control of tidal flooding by embanking adjacent agricultural areas. This large amount of land-claim suggests that the relationships between hydrodynamics and morphology are likely to be far from those of an ideal estuary.

Particle size along the estuary is variable with no consistent pattern. The mouth is dominated by gravel indicating a possible lag with finer sediment being winnowed and transported away. Between Waldringfield and Bawdsey the edge of the low water channel is sandy silt with 50-60% fine to medium sand. The mudflats are composed of mud with little or no sand.

ABP (1996c) classified the Deben Estuary into two process units based on morphological and hydrodynamic properties. Process Unit 1 consists of a narrow low water channel, which reduces in width and depth in an up-estuary direction. Morphologically it exhibits properties characteristic of a classic trumpet shaped estuary, despite land-claim. The power expenditure on the bed is about half that of Process Unit 2. There is little potential for erosion or deposition for fine sediments. Internally generated waves are relatively small, but larger than those down estuary. Process Unit 2 consists of a gently meandering channel of constant width but variable depth, which exhibits morphological relationships similar to those of a canal system. This has resulted from a more extensive historical land-claim of the mudflat and saltmarsh nearer the estuary entrance. The power expenditure at the bed increases downstream with a significant increase at the mouth. Narrow strips of saltmarsh or mudflat exist in front of flood defence embankments. The estuary entrance is very dynamic whilst the sediment dynamics show alternate reaches of potential erosion and deposition of sand and little potential erosion or deposition of silt. The immediate entrance has a high erosional potential. Internally generated waves are generally smaller than in unit 1.

8.2 Future of the Deben Estuary

Following a postulated rise in sea level of 0.5 m, the following predictions have been made (ABP, 1996c; Guthrie, 1999c).

- The tidal volume would increase from 8.95 x 10^6 m^3 to 11.77 x 10^6 m^3 (132% of present volume) assuming all defences remain intact.

- Tidal current velocities towards the mouth will increase, whilst those further upstream will decrease by up to 50%. Assuming a supply of sediment, this should promote deposition in the upper estuary and increase the potential stress to erode on the lower estuary.

- An increase in the tidal volume of the estuary will probably effect the evolution and periodic growth of The Knolls. An increased flow from the estuary may drive the sediment transport mechanism at the mouth of the estuary further offshore. This would result in a shortage of beach sediment both locally, on the Felixstowe Ferry frontage, and further afield towards Felixstowe. This, in turn, could lead to erosion along these frontages. A widening and deepening of the estuary mouth, may increase the possibility of the spit breaching or as a minimum retaining greater quantities of sediment within the ebb tide delta and having a serious impact on the downdrift coast.

- The frequency of return of extreme water levels would increase by a factor of 10 or more. At Woodbridge Haven, the water level of the 1 year event would increase from 2.55 m OD to 3.05 m OD and the 100 year event from 3.35 m OD to 3.85 m OD. Correspondingly the water levels at Woodbridge would increase from 2.7 m OD to 3.2 m OD (1 year event) and from 3.62 m OD to 4.12 m OD (100 year event).

- The stress at the mouth of the estuary due to penetration of waves from offshore, will increase.

- The future morphology of the estuary mouth will continue to respond to storm events, which are not necessarily predictable.

9. ORWELL ESTUARY-STOUR ESTUARY-HARWICH HARBOUR SYSTEM

9.1 Orwell Estuary

The Orwell Estuary extends from its tidal limit at Horseshoe Weir in Ipswich to Harwich, a distance of approximately 15 km, merging with the Stour Estuary in Harwich Harbour. The tidal range in the Orwell increases slowly upstream, with the mean spring tidal range being 3.9 m at Ipswich, compared with 3.6 m at Harwich. The mean neap tidal range at Ipswich is 2.4 m compared with 2.3 m at Harwich. The mean fresh water flow is about 1.4 m^3s^{-1} and although information on salinity distribution is not available, Simpson (2001) argued that the estuary will exhibit similar behaviour to the Stour, being well mixed throughout, except under periods of unusually high and prolonged freshwater flow.

The estuary covers an area of 11.5 km^2, with about 6.0 km^2 of this area is intertidal flats above CD, 0.5 km^2 is saltmarsh and 5.0 km^2 subtidal (Simpson, 2001). The low water channel is about 500 m wide at Shotley decreasing to 80 m at Ipswich. The width of intertidal flat is 200-400 m on the north bank of the estuary and 100-200 m on the south bank. Saltmarsh is confined to four main areas; at Crane's Hill, Levington Creek, Colton Creek and a thin strip at the cliff face east of Pinmill. Recent aerial photography also shows pioneer saltmarsh growth at Bridge Wood and Orwell Park on the northern shore (University of Newcastle, 2000). Seawall protection stretches from Shotley Point at the mouth to just before Colton Creek saltmarsh on the south shore and stretches from Fagbury Point as far as Trimley on the north shore.

On a spring tide, typical peak tidal current speeds at Shotley Point are 0.8 ms^{-1}, with currents generally decreasing with distance up the estuary. Typical peak current speeds at the mouth on neap tides are approximately 0.65 ms^{-1}. For most of the length of the estuary, peak ebb speeds are faster than peak flood speeds. However, this reverses in the uppermost parts of the estuary with a peak ebb speed of about 0.2 ms^{-1}, compared with a peak flood speed of 0.3 ms^{-1} (on mean spring tides).

The reach upstream of Woolverstone Marina is flood dominant and characterised by muddy sediment. Sediment particle size generally becomes sandier with distance downstream. However, mud occurs near the harbour showing the influence of the deepened areas on mud settling.

The most important source of sediment to the Orwell Estuary is from offshore, passing through the harbour on the flood tide. The flux of fluvial sediment is small and therefore suspended sediment concentrations increase with distance downstream in the estuary.

The higher concentrations brought in on the flood tide (promoting import of sediment) are balanced by the ebb-dominant current speeds of the lower estuary (promoting export of sediment). Wave events cause resuspension of the intertidal sediments, which tend to be redistributed within the estuary or to pass out of the estuary on the ebb tide.

Comparison of 1994 and 1999 bathymetric surveys of the Orwell Estuary show that over this period the estuary experienced net accretion upstream of Levington Creek (at an average vertical rate of 13-14 $mmyr^{-1}$) and net erosion downstream of the creek (at an average rate of 20-28 $mmyr^{-1}$). Overall the estuary is accreting at a rate of 20,000-30,000 m^3yr^{-1}. However, not all of the estuary's intertidal area is covered by the survey data and there is still some uncertainty over the behaviour of the remaining saltmarsh and upper profile of the intertidal flats. Based on the available evidence, it would appear that the Orwell is an accreting estuary and should be considered to be flood dominant as a whole. This is despite the fact that peak ebb tide current speeds are higher than those of the flood for most of the estuary length and in spite of the erosion currently experienced in the lower estuary.

Although overall, the intertidal areas of the Orwell are accreting, the saltmarshes are presently experiencing net erosion. Between 1973 and 1988, erosion was responsible for the loss of about 33% of the Orwell saltmarsh area, the majority of which (74%) was from the pioneer zone at the seaward edge of open stretches at Trimley Marshes and Shotley Point. Large areas of pioneer marsh communities were lost at Levington Creek and Woolverstone Park. Between 1988 and 1997 the pace of saltmarsh erosion almost halved compared to the rate for 1973-88 and losses from net erosion were of the same magnitude as losses from land-claim activities. In terms of percentages the rate of loss of intertidal reduced from 2.2% a year to 1.7% a year. The erosion appears to have continued from at least the 19th century (Beardall *et al.*, 1991).

9.2 Stour Estuary

The Stour estuary covers an area of 26.5 km^2, of which 17.5 km^2 is intertidal and the remaining 9 km^2 subtidal. Analysis of aerial photographs from 1997 (University of Newcastle, 2000) shows that of the 17.5 km^2 of intertidal area, saltmarsh accounts for 1.07 km^2. The Stour Estuary is backed by steeply rising land and is therefore characterised by a relatively natural coastline with very few stretches of seawall. The southern shore from Parkeston to Mistley is undeveloped with low cliffs fronting large areas of agricultural land (Mouchel, 1997). The cliffs at Jacques Bay are eroding at rates of 0.5 myr^{-1}.

The low water channel is approximately 120 to 150 m wide as far as Wrabness. Further upstream it decreases in width, becoming less than 30 m wide at Mistley. The area of intertidal flats is extensive and is separated into bays by outcrops. The principal bays are Seafield, Holbrook and Erwarton Bay on the northern shore and Copperas and Bathside Bay on the southern shore. Holbrook Bay is the largest expanse of intertidal flat being some 1.5 km wide. Above high water neaps saltmarsh exists along the entire length of the estuary as far downstream as Parkeston Quay and as far upstream as Manningtree. The width of saltmarsh is largely between 50 and 100 m, but in Seafield Bay, the east part of Copperas Bay and the west part of Erwarton Bay, the saltmarsh is more extensive with widths of up to 200 m, 600 m and 300 m, respectively. On the south shore east of Mistley there is a 1km stretch of saltmarsh backed by cliffs about 18m high.

The tidal range in the Stour is amplified over the length of the estuary. The mean spring and neap ranges at Harwich are 3.6 m and 2.3 m, respectively, while at Mistley they are 3.9 m and 2.4 m. Peak tidal current speeds at Shotley for a mean spring tide are 1 ms^{-1} (ebb) and 0.7 ms^{-1} (flood). Peak currents for a mean neap tide are 0.7 ms^{-1} (ebb) and 0.5 ms^{-1} (flood). For most of the length of the Stour, ebb current speeds are greater than flood current speeds, both decreasing in magnitude with distance upstream. However, this changes near the head of the estuary at Manningtree where peak flood currents become faster than those at peak ebb. This is due to the cumulative effects of friction on the propagating tidal wave which cause the crest of the flooding tidal wave to travel upstream quicker than the trough of the flooding wave, causing an increasingly shortened flood tide and an increase in flood current speed over that of ebb currents.

The mean fresh water flow in the Stour is around 3.0 m^3s^{-1} (Langham) to 3.5 m^3s^{-1} (Stratford St Mary). The Stour, therefore, has a relatively small fluvial discharge compared with the tidal discharge entering the harbour (peak discharge is approximately 10,000 m^3s^{-1} on a flood tide). As a result, salinity levels are not generally influenced by fresh water except near the head of the estuary, and most of the estuary is well-mixed. However, under periods of high and prolonged freshwater flows the estuary may exhibit vertical salinity gradients (Simpson, 2001).

Waves in the Stour are generated locally as a response to wind action with typical wave heights of the order of 0.2-0.3 m, although strong westerly winds can generate waves in excess of 1 m in height throughout much of the estuary (Simpson, 2001). These waves only affect the bed when the water is shallow and so influence the intertidal areas more than the channels.

This ebb-dominance of the Stour Estuary tends to promote the export of sediment. The effect of local wind-induced waves also promotes export of sediment by causing the resuspension of material from the intertidal flats so that the stronger ebb tide currents can carry it downstream. However, landwards of Mistley the estuary is flood-dominant and tends to act as a sink for any fine sediment that progresses this far upstream. This stretch is therefore characterised by muddy sediment. Further downstream the channel bed becomes progressively sandier with patches of gravel. Intertidal areas are mostly muddy but contain high proportions of sand and gravel.

The most important source of sediment to the Stour Estuary is from offshore, passing through the harbour on the flood tide. The flux of fluvial sediment is small and therefore suspended sediment concentrations increase with distance downstream in the estuary. The higher concentrations brought in on the flood tide (promoting import of sediment) are balanced by the ebb-dominant current speeds of the lower estuary (promoting export of sediment). Wave events cause resuspension of the intertidal sediments, which tend to be redistributed within the estuary or to pass out of the estuary on the ebb tide.

The estuary has been experiencing erosion of intertidal areas since the 1920s when much of the prevalent eelgrass population, which had a binding effect on sediment, died off. It has been estimated that between 1925 and 1965 more than 20 x 10^6 m^3 of sediment was eroded from the intertidal areas of the Stour (Simpson, 2001). At a steady rate, this represents erosion of about 500,000 m^3yr^{-1} and is broadly equivalent to an average vertical rate of erosion of around 20 $mmyr^{-1}$ year. Beardall *et al.* (1991) estimated 15 x 10^6 m^3 of net erosion over the entire Stour/Orwell system between 1925 and 1965 which is derived from the same analysis.

The erosion of the intertidal areas of the Stour is still ongoing, but at a lower rate to that estimated for 1925-1965. Based on an analysis of bed changes between 1994 and 1999 the present erosion rate is about 13 $mmyr^{-1}$ for the intertidal mudflat areas (Simpson, 2001). The average volume eroded per year is estimated to be 240,000 m^3yr^{-1} for the period 1994 to 1999. The observations for this period demonstrate that the erosion appears to be greater along the lower part of the intertidal profile.

Almost half of the original area of saltmarsh in the Stour Estuary was lost between 1973 and 1988 (Burd, 1992). Only 5% of the loss was due to land-claim, notably in the Harwich area, where *Spartina* marsh has been covered by dredged material. In 1973, the pioneer zone was dominant, occupying almost three times the area of any other individual zone (Burd, 1992). By 1988, 60% of the pioneer zone had been lost, and 64% of the remainder was still occupied by pioneer communities. Between 1988 and 1997 the pace of saltmarsh erosion had reduced threefold when compared to the rate for 1973-88 and losses from net erosion were of the same magnitude as losses from land-claim activities. In terms of percentages, the rate of loss of intertidal area reduced from 2.6% a year to 1.8% a year. Comparison of 1997 aerial photographs and 1999/2000 CASI surveys is sufficiently different to throw considerable uncertainty on the rates of loss discussed above (Simpson, 2001).

9.3 Harwich Harbour

Harwich Harbour occupies an area of around 6 km^2 and is located at the seaward confluence of the Orwell and Stour Estuaries. It has been extensively developed over the last thirty years, and this development has been accompanied by loss of tidal volume as the Trinity Container Terminal has been extended into intertidal areas. Presently the subtidal volume of the harbour area is about 50 x 10^6 m^3 and the intertidal volume about 22 x 10^6 m^3 (Simpson, 2001). The tides at Harwich have a range of approximately 3.6 m on mean spring tides and 2.3 m on mean neap tides.

The fastest flood tidal current at the harbour mouth on a mean spring tide is approximately 1 ms^{-1} with a peak ebb speed of up to 1.5 ms^{-1} (Simpson, 2001). The flood current speeds are fairly uniform across the entrance, except for an area of slow or reversed currents adjacent to the Landguard Point side. The ebb currents are strongest along the Landguard Point side. The peak tidal discharge through the harbour mouth at mean springs is of the order of 10,000 m^3s^{-1} on the flood tide and 14,000 m^3s^{-1} on the ebb tide. On mean neap tides the peak tidal discharge is around 8,000 m^3s^{-1} on both flood and ebb. On a single spring tide the total volume of water entering the harbour is about 140 x 10^6 m^3 and on a neap tide is about 100 x 10^6 m^3.

Mud entering the harbour area is derived from a number of sources. Sediment from the offshore area is brought south along the nearshore zone by the prevailing tidal and wave-induced currents (which are directed south-west along the nearshore) and enters the harbour on the flood tide. Some of this mud may be trapped within the deepened approach channel and berths due to the slower speeds encountered there. The measured rate of daily accretion in the harbour, between November 2000 and February 2001, varied over the range 1,000-20,000 m^3 but the average rate is currently estimated to be of the order of 8,000m^3/day based on the results of bathymetric analysis in the harbour (Simpson, 2001). Some of the mud passes upstream into the Stour and Orwell estuaries where it may be deposited on intertidal areas. However, this sediment maybe resuspended from within the estuary on the ebb tide and flushed back out of the estuary. The net marine input of suspended sediment to the harbour is around 5.5 x 10^6 tonnes per year or an average of 8,000 tonnes per tide (Simpson, 2001).

To the north of the Harwich approach channel, the open coast beaches are composed mainly of shingle and net longshore transport of sediment is predominantly southward. A significant proportion of shingle reaching Landguard Point is carried round to the beach on the harbour side of the point. Some of this sediment can be carried into the most southerly berth at Felixstowe, where a small amount of dredging of gravel is required. Some of the sediment is probably carried offshore by the strong ebb currents around Landguard Point. There is no evidence of shingle accumulating in the navigation channel. The harbour mouth marks a divide in the littoral transport system, with little or no beach sediment crossing the channel.

9.4 Future of the Orwell Estuary-Stour Estuary-Harwich Harbour System

- Sea-level rise impacts may also take the form of saltmarsh erosion so that a rapid deterioration in these areas must be anticipated.

10. HARWICH TO THE NAZE

10.1 Harwich to Walton Backwaters

Harwich sits on 2 km long London Clay cliffs, which are capped by Red Crag (James and Lewis, 1996). South of Harwich to Hamford Water the coast comprises a shingle beach backed by a flood embankment protecting low-lying land behind. This stretch of coast is strongly influenced by the tidal regimes of Hamford Water and the Stour-Orwell system, as well as the complex sediment transport regime, which exists between Cork Sand and the frontage.

10.2 Walton Backwaters to the Naze

South of Walton Backwaters, the cliffs at the Naze are composed of Red Crag on London Clay with an average height of about 12 m. They are eroding at an average rate of 1.8 myr^{-1} (Mouchel, 1997). The Naze marks a convergence of longshore sediment transport directions, with sediment moving southwards to the north and northwards to the south. This convergence may force sediments offshore where they are carried northwards towards the Suffolk banks and southwards into the Thames Estuary (Mouchel, 1997).

10.3 Walton Backwaters

The Walton Backwaters is a tidal inlet 5 km south of Harwich, covering an area of about 24 km^2 comprising intertidal mudflats, saltmarsh, and numerous islands interspersed with ancient land-claims and embankments. The entrance is about 1.5 km wide with a single channel through Pye Sand, known as Hamford Water, which then divides into two main channels either side of a large central island called Horsey Island. The tidal range at the entrance to the Backwaters is comparable with that at Harwich, and there is negligible moderation of the tide within the inlet.

To the south of Hamford Water between Stone Point and the Naze is a 1.5 km promontory of low-lying marsh and sand dunes, fronted by a muddy foreshore, which protects the southern half of Walton Backwaters from waves generated offshore. The promontory is subject to fully developed offshore waves from the east and north-east. Pye Sand has shown no systematic change over the last 100 years although it does show periodic changes in extent due to the nature of the sediment movement northwards from a temporary storage area at the Naze. Over the last 50 years this stretch of coast has suffered extensive erosion of the foreshore, exposing the sand dunes and saltmarsh behind to greater risk of inundation and wave attack during periods of high water. This was the site of a beach recharge scheme. To the north of Hamford Water is an area of exposed seawall near Foulton Hall, from which extends a long beach of fine sand fronting saltmarsh which extends into the Backwaters. The shoreline in the vicinity of Foulton Hall has experienced erosion over the last 50 years and was also the site of a recharge scheme.

The movement of suspended sediment in Hamford Water is due to tidal movements (Mouchel, 1997). This may mean that the movement of sediment in Hamford Water is restricted to oscillations of the suspended sediment load across the mouth and that significant net movements of bedload into the estuary is unlikely. The distribution of sediment within Walton Backwaters is characterised by intertidal mudflats with saltmarshes in the quieter inner areas, especially those backed by embankments. There is a much higher proportion of saltmarsh in Walton Backwaters than in the Stour or Orwell Estuaries (University of Newcastle, 2000). Bed sediment types in the main channels, including Hamford Water, are not well documented. On either side of Hamford Water, including Pye Sand, are drying banks of mixed fine sand and clay.

Walton Backwaters has large areas of saltmarsh with some degree of fragmentation and highly dissected areas. Over 10 km^2 of saltmarsh has been land-claimed within Walton Backwaters in the past, although many of the enclosing walls have been breached to allow the enclosed areas to revert back to saltmarsh. The saltmarsh regions in Walton Backwaters are in a state of dynamic equilibrium, with some areas accreting whilst others are eroding. Between 1973 and 1988, the Walton Backwaters lost 19.3% of its original 8.76 km^2 of saltmarsh, mainly through erosion (Burd, 1992). Over the period 1988-97 the rate of loss of saltmarsh has apparently quickened in Walton Backwaters rising from 0.8%/yr to 2.6%/yr. However, comparison of 1998 aerial photographs and 1999/2000 CASI surveys is sufficiently different to throw considerable uncertainty on the rates of loss (Simpson, 2001).

10.4 Future of Harwich to the Naze

- Continued erosion of the saltmarshes of the Walton Backwaters is predicted due to sea-level rise.

- If interruption of sediment supply to Pye Sands occurs this may lead to accelerated erosion as it protects the mouth of the inlet.

11. REFERENCES

ABP. 1996a. National Rivers Authority Anglian Region. Blyth Estuary Strategy Phase 1 Estuarine Processes Assessment. ABP Research Report R539, March 1996.

ABP. 1996b. National Rivers Authority Anglian Region. Alde/Ore Estuary Strategy Phase 1 Estuarine Processes Assessment. ABP Research Report R540, March 1996.

ABP. 1996c. National Rivers Authority Anglian Region. Deben Estuary Strategy Phase 1 Estuarine Processes Assessment. ABP Research Report R541, March 1996.

Babtie Dobbie. 1993. Waveney District Council Shoreline Strategy.]

Barnes, R.S.K. 2001. The geomorphology and ecology of the shingle-impounded coastal lagoon systems of Britain. In Packham, J.R., Randall, R.E., Barnes, R.S.K. and

Neal, A. (eds) Ecology and Geomorphology of Coastal Shingle. Westbury Publishing, 320-335.

Barnes, R.S.K. and Heath, S.E. 1980. The shingle-foreshore lagoon system of Shingle Street, Suffolk: a preliminary survey. Transactions of the Suffolk Naturalists' Society, 18, 168-181.

Beardall, C.H., Dryden, R.C. and Holzer, T.J. 1991. The Suffolk Estuaries. A report to the Suffolk Wildlife Trust on the Wildlife and Conservation of the Suffolk Estuaries. Segment Publications.

Birkbeck College and Babtie. 2000. Spits and Nesses. Basic processes and effects on long-term coastal morphodynamics. Final Report.

BMT Ceemaid. 1989a. Felixstowe Ferry Sea Defence Study, Addendum to Working Papers 1 and 2. Historical Events. Further On Site Consultations. Report for the NRA Anglian Region.

BMT Ceemaid. 1989b. Felixstowe Ferry Sea Defence Study, Working Paper 4. Digital Ground Modelling. Report for the NRA Anglian Region.

BMT Ceemaid. 1990. Felixstowe Ferry Sea Defence Study, Final Report. Report for the NRA Anglian Region.

Burd, F.H. 1992. Erosion and vegetation change on the saltmarshes of Essex and north Kent between 1973 and 1988. Report for the Nature Conservancy Council, Peterborough. Research and Survey in Nature Conservation, no 42.

Carr, A.P. 1969. The growth of Orford spit: cartographic and historical evidence from the sixteenth century. Geographical Journal, 135, 28-39.

Carr, A.P. 1970. The evolution of Orford Ness, Suffolk, before 1600 AD: geomorphological evidence. Zeitschrift fur Geomorphologie, N.F., 14, 289-300.

Carr, A.P. 1972. Aspects of spit development and decay: the estuary of the River Ore, Suffolk. Field Studies, 4, 633-653.

Carr, A.P. 1986. The estuary of the River Ore, Suffolk: three decades of change in a longer-term context. Field Studies, 6, 439-458.

Clayton, K.M. 1977. Beach profile and volume changes. East Anglian Coastal Research Programme Report No 5. University of East Anglia, Norwich, UK.

Clayton, K.M. 1987. Orfordness: coastal stability and coastal defences. Report to Nature Conservancy Council, Peterborough.

Cobb, R.T. 1957. Shingle Street: Suffolk. A brief geographical introduction. Annual Report of the Field Studies Council, 3, 31-42.

French, C.E., French, J.R., Clifford, N.J. and Watson, C.J. 1999. Abandoned reclamations as analogues for sea defence re-alignment. In. Kraus, N.C. and McDougal, W.G. eds. Coastal Sediments '99, Vol 3, Proceedings of the Fourth International

Conference on Coastal Engineering and Science of Coastal Sediment Processes. American Society of Civil Engineers, New York.

French, C.E., French, J.R., Clifford, N.J. and Watson, C.J. 2000. Sedimentation-erosion dynamics of abandoned reclamations: the role of waves and tides. Continental Shelf Research, 20, 1711-1733.

Fuller, R.M. and Randall, R.E. 1988. The Orford Shingles, Suffolk, UK – classic conflicts in coastline management. Biological Conservation, 46, 95-114.

Future Coast. 2002a. Draft Shoreline Behaviour Statement: Lowestoft to Blyth Estuary.January, 2002 version.

Future Coast. 2002b. Draft Shoreline Behaviour Statement: Blyth Estuary to Thorpe Ness. January, 2002 version.

Future Coast. 2002c. Draft Shoreline Behaviour Statement: Thorpe Ness to Shingle Street. January, 2002 version.

*Future Coast. 2002d. Draft Shoreline Behaviour Statement: Shingle Street to Landguard Point, Felixstowe. January, 2002 version.

Green, C.P. and McGregor, D.F.M. 1989. Orfordness: geomorphological conservation perspectives. Transactions of the Institute of British Geographers N.S., 15, 48-59.

Guthrie, J.G.L. 1999a. Environment Agency Anglian Region. Suffolk Estuarine Strategies. River Blyth Strategy Report. Volume 1 Main Report. Posford Duvivier Report, November 1999.

Guthrie, J.G.L. 1999b. Environment Agency Anglian Region. Suffolk Estuarine Strategies. River Alde/Ore Strategy Report. Volume 1 Main Report. Posford Duvivier Report, November 1999.

Guthrie, J.G.L. 1999c. Environment Agency Anglian Region. Suffolk Estuarine Strategies. River Deben Strategy Report. Volume 1 Main Report. Posford Duvivier Report, November 1999.

Halcrow. 1995. Shoreline Management Plan for Sediment Sub-Cell 3C Harwich to Lowestoft. Interim Reports. Volume 2 – Compilation of Data, Volume 3 – Figures and Maps.

Halcrow. 1998. Shoreline Management Plan for Sediment Sub-Cell 3C Harwich to Lowestoft.

Halcrow. 2001. Lowestoft to Thorpe Ness Coastal Process and Strategy Study. Volume 2: Coastal Processes (Draft).

Halcrow. 2002. Slaughden Sea Defences Coastal Process Study. Report for the Environment Agency, February 2002.

HR Wallingford 2002. Southern North Sea Sediment Transport Study, Phase 2. Report for Great Yarmouth Borough Council, representing a client Consortia.

IECS. 1993. Stour-Orwell Estuary, Coastal Processes and Conservation. Report to English Nature.

James and Lewis. 1996.

Lees, B.J. 1983. Observation and tidal and residual currents in the Sizewell-Dunwich area. Deutsche Hydrographische Zeitschrift, 36, 1-24.

McCave, I.N. 1977. Sediments of the East Anglian coast. East Anglian Coastal Research Programme Report No 6. University of East Anglia, Norwich, UK.

McCave, I.N. 1978. Grain size trends and transport along beaches: an example from eastern England. Marine Geology, 28, M43-M51.

[McGregor, D.F.M. and Green, C.P. 1990. Composition of the Orfordness shingle. Proceedings of the Geologists' Association, 101, 259-263.]

Mouchel. 1997. Essex Shoreline Management Plan.

Pethick, J. 1995. Implications of Sea-Level Rise. Sizewell C Recommendations for Coastal Monitoring and Research Programme.

Pethick, J. and Leggett, D. 1995. The morphology of the Anglian coast. In Coastlines of the southern North Sea.

Pettitt, N. 2000. Hollesley to Bawdsey Sea Defences. Coastal Process Report. Posford Duvivier Report, June 2000.

Pontee, N.P. 1995. The Morphodynamics and Sedimentary Architecture of Mixed Sand and Gravel Beaches, Suffolk, UK. Unpublished PhD Thesis, University of Reading]

Pye, K. 2001. The nature and geomorphology of coastal shingle. In Packham, J.R., Randall, R.E., Barnes, R.S.K. and Neal, A. (eds.) Ecology and Geomorphology of Coastal Shingle. Westbury Publishing, 2-22.

Randall, R.E. 1973. Shingle Street, Suffolk: an analysis of a geomorphic cycle. Bulletin of the Geological Society of Norfolk, 24, 15-35.]

Randall, R.E. and Fuller, R.M. 2001. The Orford Shingles, Suffolk, UK: Evolving solutions in coastline management. In Packham, J.R., Randall, R.E., Barnes, R.S.K. and Neal, A. (eds.) Ecology and Geomorphology of Coastal Shingle. Westbury Publishing, 242-260.

Robinson, A.H.W. 1966. Residual currents in relation to shoreline evolution of the East Anglian coast. Marine Geology, 4, 57-84.

Robinson, A.H.W. 1980. Erosion and accretion along part of the Suffolk coast of East Anglia, England. Marine Geology, 37, 133-146.

Simpson, M. 2001. Bathside Bay Tidal Works and Approach Channel Deepening Environmental Statement. Posford Haskoning Report, October 2001.

Steers, J.A. 1926. Orford Ness: a study in coastal physiography. Proceedings of the Geologists' Association, 37, 306-325.

Steers, J.A. 1964. The Coastline of England and Wales. Second Edition. Cambridge University Press.

University of Newcastle. 2000. Erosion of the saltmarshes of Essex between 1988 and 1998. Report for the Environment Agency Anglian Region.

Vincent, C.E. 1979. Longshore sand transport rates – a simple model for the East Anglian coastline. Coastal Engineering, 3, 113-136.

APPENDIX B – MONITORING TECHNIQUES

1. SALTMARSH AND INTERTIDAL MUDFLAT SYSTEMS

A prediction of the surface elevation of intertidal areas in muddy estuaries and coasts is required to enable effective habitat management. An intertidal area comprises a system in which water and sediment are transferred between the mudflat and the subtidal nearshore zone and between the mudflat and the adjacent saltmarsh. The rate of sedimentation in the intertidal zone is critically important in view of rising relative sea level. Mudflats can experience rapid morphological changes being both sources and sinks of fine cohesive sediment, and respond to changing environmental factors particularly local wave and tidal action. Sedimentation rates on saltmarshes may be influenced by a range of factors, in particular their elevation and age and their relationship to the duration of tidal flooding.

The monitoring of saltmarshes and mudflats can range from highly sophisticated electronic instrumentation attached to a frame which is deployed *in situ* on the sediment surface, to manual field measurements using simple pieces of equipment. The tendency has been for the more advanced systems to be applied to mudflat environments. In these cases, the medium term (hours to several weeks) morphological behaviour of the mudflat is monitored in detail at one site, and measurements of the main physical processes are simultaneously made over the same period at locations within the site. These types of frame are likely to be inappropriate and beyond the resources of CHaMPs. Less sophisticated techniques can be utilised to monitor both medium and long term (weeks to decades) geomorphological change on saltmarshes and mudflats, which are likely to be more appropriate to CHaMPs. However, the collection of process data still requires more sophisticated equipment. The most cost-effective strategy for monitoring processes may be a one-day intensive deployment over a single over-marsh tide occurrence. An indication of seasonality is important, and so the deployment may have to be carried out over one day during both the March and September spring tidal cycles, with more if possible.

1.1 Elevation changes over small areas

A topographic survey can be carried out to assess surface elevation changes over small areas. Such a survey would involve sampling a number of random points across the saltmarsh or mudflat surface using a total station with data logger. The elevation data should be related to a common datum using a permanent benchmark. The data is input into a computer package to produce contour maps (digital terrain models) and quantitative measurements of volume changes. A t-test may be used to statistically evaluate the differences between two surveyed surfaces. An area should be surveyed at least once a year.

1.2 Elevation changes over large areas

In view of the costs and practical difficulties of regular monitoring of large areas of mudflat or saltmarsh for elevation change by *in situ* methods, there is an increasing role for remote sensing techniques from aircraft or satellite. Remote sensing has the potential for large spatial coverage with high resolution, which would not be practicable with *in situ* methods. For example, experience is being gained with technologies for measuring elevation, such as airborne Laser Induced Direction and Range (LIDAR). Surveys repeated every year would provide digital data to indicate broad-scale changes in elevation through time.

1.3 Accretion rates

Medium term sediment deposition (total accretion over one or more tidal cycles) on a saltmarsh can be measured using pre-weighed pairs of filter papers. Smaller diameter papers placed on top of larger diameter papers ensure a clean surface under the top paper. The double filters can be secured into the saltmarsh surface using three plastic coated paper clips bent at right angles and pinned into the sediment. Replicate filters are laid down in each zone of the saltmarsh at positions chosen at random and left for 2, 4 and 10 tidal inundations during the spring tidal cycle. The deposition of sediment is calculated as grams dry weight deposited per 100 cm^2. The sediment deposited in each zone can be analysed for particle size and organic content.

Long term accretion rates can be measured using perforated aluminium accretion plates (20 cm or so square) buried at random positions along a line perpendicular to the slope, between the highest part of the saltmarsh and low water mark. The plates should be buried to a depth of *c*. 10 cm and left to settle for 4-6 months before the initial baseline measurements are made. The plates can be located generally using cane markers, and exactly using a metal detector. Measurements should be made every 3-6 months, by taking up to 15 readings from the sediment surface to each plate, using a fine metal ruler or graduated metal pin. From these data it is possible to calculate and record an average depth.

An alternative method is to lay-down 1 m^2 patches of medium-grained sand or white feldspar on the surface. The rate of accretion at subsequent intervals is recorded by extraction of annual or bi-annual microcores.

At the saltmarsh-mudflat boundary where there are patches of vegetation surrounded by unvegetated areas at the same elevation, pairs of canes (*c*. 1-2 m long) can be pushed into the surface, a metre or so apart until they are precisely level at a height of 20-35 cm above the sediment. Five pairs of canes should be used for each vegetation type and for the mudflat. From a level placed across the canes, five measurements can be taken to the sediment surface at positions initially selected randomly, but subsequently permanently.

1.4 Saltmarsh-mudflat boundary and drainage changes

Comparison of stereo vertical aerial photographs acquired on a yearly basis can provide a record of the changing position of the saltmarsh-mudflat boundary and development of the drainage system.

1.5 Sediment composition and distribution

Sediment composition and distribution can be evaluated by a campaign of sub-surface and surface sampling followed by laboratory analysis. Particle size (% clay, silt and sand, mean and median particle size, sorting), clay mineralogy, organic content and geotechnical properties may be investigated, which are used to characterise the sediment type. Particle size reflects the physical processes acting across the intertidal area. The geotechnical parameters give an indication of the sediment stability, shear strength and its susceptibility to erosion. Organic content is critical as it influences the infaunal community and can cause de-oxygenation, which can be detrimental to biota. Sub-surface samples may be collected along transects to assess temporal changes and at a number of random points across the intertidal area to determine spatial changes.

Surface sediments should be collected using a random sampling procedure twice a year. The surface and sub-surface samples can be compared.

1.6 Suspended sediment concentrations

Suspended sediment concentrations can be measured using turbidity meters along a transect from the mudflat, along the main creek through to the head of the saltmarsh. A temporal concentration profile for each station along the transect can be constructed and the patterns of sediment concentration in the water recorded throughout the tide. The spatial variability of suspended sediment can be analysed by taking water samples from across the intertidal area. The samples can be analysed to determine sediment concentration, particle size and organic content.

1.7 Currents and waves

Current velocities can be measured using two sets of two current metres arranged vertically on the mudflat and in the main creek to record over one tidal cycle. The current meters should be deployed simultaneously with the turbidity meters. This provides data on bed shear stress and tidal current asymmetry. Flow velocities over the saltmarsh surface can be analysed by release of drogues throughout the duration of the tide. The release and recovery positions are recorded and the vectors of speed and direction plotted to assess water movement. To investigate waves, three wave recorders can be deployed, one on the mudflat, one in the main creek and one on the saltmarsh.

1.8 Advanced monitoring of mudflat processes

Two large-scale UK based projects are chosen here to highlight sophisticated monitoring techniques on intertidal mudflats: LISP-UK and INTRMUD.

The Littoral Investigation of Sediment Properties (LISP-UK) project was concerned with the dynamics of sediment transport to and from the intertidal mudflats within the Humber Estuary. Its main aim was to assess the relative importance of hydrodynamic, sedimentological, biological and atmospheric processes in determining shear strength, erosion rate and critical erosion shear stress of cohesive intertidal sediments *in situ*.

The Morphological Development of Intertidal Mudflats (INTRMUD) investigated mudflat processes to provide a basis of understanding for proper management. The project assessed the morphological characteristics of mudflats in areas with different tidal ranges and the effect of wave exposure, fauna and flora, atmospheric processes and sediment properties on these characteristics.

To measure medium term mudflat processes and dynamics, both projects utilised sophisticated instrumentation on frames located *in situ* on the mudflat. As part of LISP-UK, a benthic rig (POST, Profile of Sediment Transport) was deployed over a week in spring 1995 to assess the relationship between current velocity, bed shear stress and suspended sediment concentration. The rig, specifically developed to measure sediment fluxes in very shallow water (less than 1m), comprises four miniaturised electromagnetic current meters (ECM) and four compact optical backscatter sensors (OBS), with additional input from conventional hydrostatic pressure and CTD instruments. For INTRMUD, data were collected using a rig (PROTEUS) deployed over a 3 week period in winter 1995. The hydrodynamics, cohesive sediment processes and bed levels were monitored using ECM, turbidity sensors, a pressure transducer and an ultrasonic bed level detector.

2.0 SAND BEACH AND DUNE SYSTEMS

Sand beaches and dunes are highly dynamic landforms, susceptible to episodes of erosion and growth, usually brought about by the varying weather. The dunes are normally fronted by the beach, which provides the sand that is driven onshore and formed into dunes by onshore winds. Dunes lose sand by surface erosion by wind action or marine erosion of the toe and seaward beach face mainly by waves. Management of dunes and fronting sand beaches is important as dunes provide a range of important habitats, often with abundant flowers, insects and other wildlife. They also have considerable value from the viewpoint of geomorphology, showing how coastal landforms evolve under the action of natural processes.

2.1 Beach monitoring

2.1.1 Morphology

Beach morphology can be monitored using cross-shore beach profile data to assess changes in beach width, slope and volume, and to describe beach behaviour and its variability. These data can be used to identify trends and areas of high net change and high variability. Key data points collected in the surveys should be located on breaks of slopes and high and low points. All the beach profiles should be referenced to national grid co-ordinates and to ordnance datum using a temporary benchmark. They should also, if possible, be defined by a fixed control point and orientation. The frequency of beach profiles depends on the specific aim of the monitoring.

Several techniques of varying sophistication are available for collecting beach survey data. The least sophisticated method (although not necessarily the least accurate) is survey using a quick set level, staff and chain. Beach morphology changes can also be monitored using erosion pins, surveyed at each low tide over the experiment period. More advanced methods include using a Total Station with electronic distance measurement to a survey reflector prism and computer logging of data points.

In developing a beach profiling strategy it is essential that the limitations of method be recognised at the outset. Thought must be given to how and when the data is collected and over what time period. For example, because of natural variation on the coast, the true pattern of beach change may only become apparent after a long period of time. Possibly time-scales longer than 10 years of monitoring may be required before trends may be distinguished.

A set of photographs at each of the beach profiling localities allows a comparison to be made between surveys, providing a rapid cheap complimentary system of monitoring more severe events when time may limit opportunity for more formal monitoring.

2.1.2 Sediment composition and distribution

Sediment composition and distribution can be evaluated by a campaign of sub-surface and surface sampling followed by laboratory analysis. The campaign should start with a qualitative assessment of the sediments at the surface and at depth. Sample sites can then be selected based on these observations to reflect sediment variability across the beach. Sampling should be repeated at six-monthly intervals. Laboratory analysis will determine particle size and other textural parameters, which can be interpreted in the context of sedimentary processes and temporal change. A qualitative assessment of particle size may be made at each height and position determination during the beach survey.

2.1.3 Waves and currents

To monitor waves and currents, wave recorders and current meters may be deployed in the nearshore zone. However, this may be costly and difficult. Alternatively, it is possible to obtain high quality predicted wave information from the Meteorological Office for offshore points. This offshore data can be transferred inshore using a numerical transformation model for analysis. If cost-effective, a wave rider buoy could be deployed to monitor a year of waves to augment any pre-existing wave climate data.

2.2 Dune monitoring

Three important areas of dune development are considered for monitoring.

2.2.1 Dune face erosion

The position of a dune face can be monitored using marker posts to measure rate and lateral extent of erosion. Marker posts should be located at the toe of the dunes at 50 m intervals or so with a second line set-back 30 m or so landwards, away from direct erosion. The measurements of distance between dune toe and marker should be repeated twice-yearly, and, if possible, before and after major storm events.

2.2.2 Dune morphology changes

Changes in dune morphology are most effectively assessed using aerial photographic surveys on a yearly basis. The photographs can be digitised to provide digital terrain models and compared to provide a record of large-scale morphology changes and variability of upper beach levels. A Total Station may be used at times of high variability (after storms) along cross-shore transects to define catastrophic change along the dune system.

2.2.3 Sediment composition and distribution

Sediment composition and distribution can be evaluated by a campaign of sub-surface and surface sampling followed by laboratory analysis. Laboratory analysis will determine particle size and other textural parameters from which maps of the temporal and spatial variability can be constructed. The sediment characteristics can be used to define sediment pathways across dune complex.

2.2.4 Wind

An anemometer can be set up for local wind conditions and compared to those measured regionally by the Meteorological Office.

3.0 SHINGLE ACCUMULATIONS

Three types of coastal shingle accumulation are recognised. First, fringing beaches are generally backed by cliffs and may comprise multiple ridges in conditions with an abundance of shingle. Second, freestanding linear barriers are swash-aligned and migrate landwards through rollover, whereby beach face sediment is passed over the barrier crest by storm waves. The balance between crest build-up due to wave overtopping and crest breakdown due to overwashing determines the rate of migration. Drift-aligned barriers are large volumes of shingle concentrated into barrier spits by longshore transport. Third, cuspate forelands are sedimentary landforms of a triangular planform projecting as a promontory into the sea. They build out seawards into deeper water and progress slowly down the coast, as sediment is eroded from the updrift side and deposited downdrift.

The long term evolution of shingle accumulations is linked to relative sea level rise, longshore transport rate and sediment supply, hydraulic conditions (tides and waves) and barrier geometry. Changes in any combination of these controlling variables may result in either building or degradation of the barrier. The latter may result in periodic overwashing and landward migration. The evolutionary process of shingle barriers is a significant CHaMPs issue particularly if an increasing frequency of barrier overwashing results in either a breach or migration towards and over important back-barrier habitats and driftline communities or destruction of pioneer species on the shingle itself. Monitoring of shingle accumulations should be carried out during a variety of wave states, particularly high-energy conditions, when large quantities of shingle may be moved.

As an example, the Shingle Beach Transport Project monitored shingle accumulations and is used here as a basis for monitoring geomorphologically similar CHaMPs sites. The project (funded by MAFF and EA) developed improved techniques for the prediction of beach transport and long term morphological development where coarse-grained sediment forms a significant proportion of the beach material. Short-term sediment transport data obtained from a series of field experiments were used to verify and/or develop existing or new transport models for shingle beaches.

The field programmes took place over a couple of 2-month periods in the autumns of 1996 and 1997 at West Beach, Shoreham and Beach Green, Lancing. Several standard monitoring techniques were employed during the campaigns to meet the objectives. Beach surveys were conducted using a GPS or total station at a spatial resolution sufficient for production of digital terrain models to record beach morphology changes and estimate transport volumes. Offshore and beach face waves and beach face wave and tide induced currents were recorded to estimate the cross-shore distributions of wave energy and to validate existing wave transformation models. Electronic and aluminium tracing studies obtained measurements of transport rates, the cross-shore and vertical distribution of transport and particle size dependency. The measurements were made at a variety of temporal resolutions ranging from one or two tides (morphological surveys and tracers) to semi-continuous monitoring of instantaneous events (wave and current recording) over the full duration of the field programme.