North Norfolk Coast
Coastal Habitat Management Plan
Final Report

January 2003




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North Norfolk Coastal Habitat Management Plan (CHaMP)

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English Nature and Environment Agency

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PLEASE READ FIRST

Foreword to the North Norfolk 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 North Norfolk 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.
- A detailed schedule of habitat and feature monitoring could be developed to drive strategic monitoring programmes in the North Norfolk 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

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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

1.1 Background

The coastal environment is an extremely important natural resource. Many sites around the UK coastline, including the North Norfolk coast, support significant assemblages of habitats and species which are recognised for their ecological and nature conservation importance through designation under the European Union Habitats Directive (Council Directive 92/43/EEC) and Birds Directive (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 for 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”. Ramsar sites are designated under an international convention, but under UK Government policy are treated as European sites.

Coastal Habitat Management Plans (CHaMPs) are being produced to provide a way of fulfilling the UK Governments obligations under the Habitats and Birds Directives and the Ramsar Convention, to avoid damage and deterioration to Natura 2000 and Ramsar sites; particularly when developing Shoreline Management Plans (SMPs) and Flood and Coastal Defence Strategies (FCDSs), and planning coastal defence maintenance and capital works. They will apply where the conservation of all of the existing interests *in situ* is not possible due to natural or quasi-natural changes to shorelines (i.e. showing dynamic behaviour). CHaMPs will therefore form an important link in the coastal planning process for managing Natura 2000 European and Ramsar sites. The CHaMP considers various options for the management of the frontage and proposes measures to ensure that future SMPs and FCDSs are compliant with the Habitats and Birds Directives. This process is informed using the best available information, including that set out in the relevant SMP, together with the FCDSs that are currently available.

The primary functions of CHaMPs are:

- 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 informing the strategic direction for the conservation measures that are necessary to offset predicted losses. Suitable locations for new habitats that may need to be created and the flood and coastal defence policy required to maintain protected habitat are also proposed; and
- Provide information to inform the relevant SMPs and strategies 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 and Ramsar designations and outlines the conservation objectives for the management of the designated interest features occurring on the North Norfolk coast. An informed review of coastal process information contained in the relevant SMPs, and other information, including available strategic plans for flood and coastal defences, available data and expert opinion has been undertaken to predict shoreline change likely to occur over the next 30-100 year period. The geomorphological prediction takes into account predicted climate change and sea level rise over the study time period. An analysis 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. 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 option of habitat creation has been considered.

Where predictions of change indicate that an adverse effect on the ecological integrity of a designated feature could occur, then the CHaMP considers 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 will not always be possible to conserve designated interests in the same location. With respect to this, it is considered important to ensure that the functionality of any created habitat is of equal or greater value than that lost. The conservation of coastal habitats such as saltmarsh, shingle and mudflats should therefore be considered in the context of enabling all the components of the coastal system to function coherently.

1.3 The North Norfolk 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 SMP (Subcell 3a: Snettisham to Sheringham) and relevant FCDSs. This process is represented graphically in Figure 1.1. It is intended that this CHaMP will focus on the need for the SMP to re-examine preferred strategic defence options, within the CHaMP area, to ensure that the ecological interests of all designated SAC, SPA and Ramsar features are maintained. This process will apply equally to FCDSs, both retrospectively in the case of those that have been recently completed and to those that may be undertaken in the future.

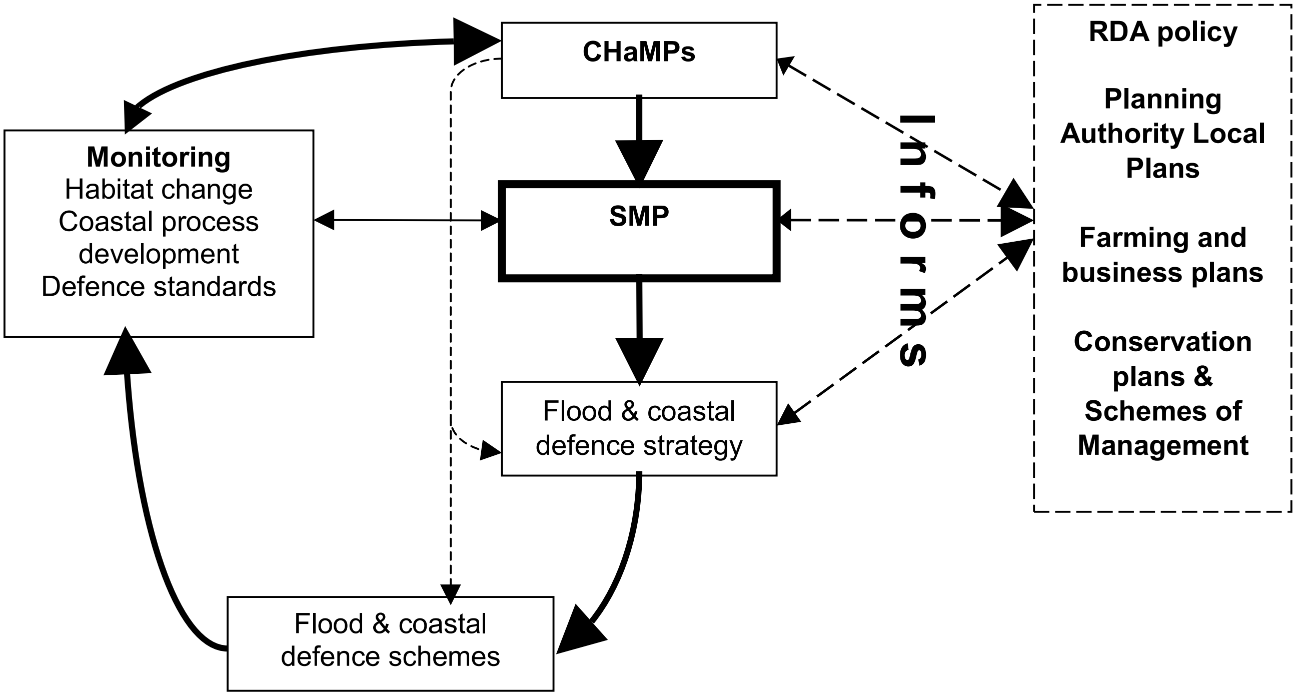


Figure 1.1 The CHaMP planning cycle

1.4 Definition of the CHaMP area

This CHaMP builds upon the preliminary CHaMP produced for North Norfolk (English Nature 1999). The preliminary CHaMP considered the potential impact of adopted SMP coastal defence policies on the designated features of the coastline between Old Hunstanton and Sheringham. This CHaMP effectively reviews the previous work and provides further information and discussion of likely physical change for the same area. Therefore, although the CHaMP includes and covers the European sites listed below it does not include an assessment of habitat change for The Wash:

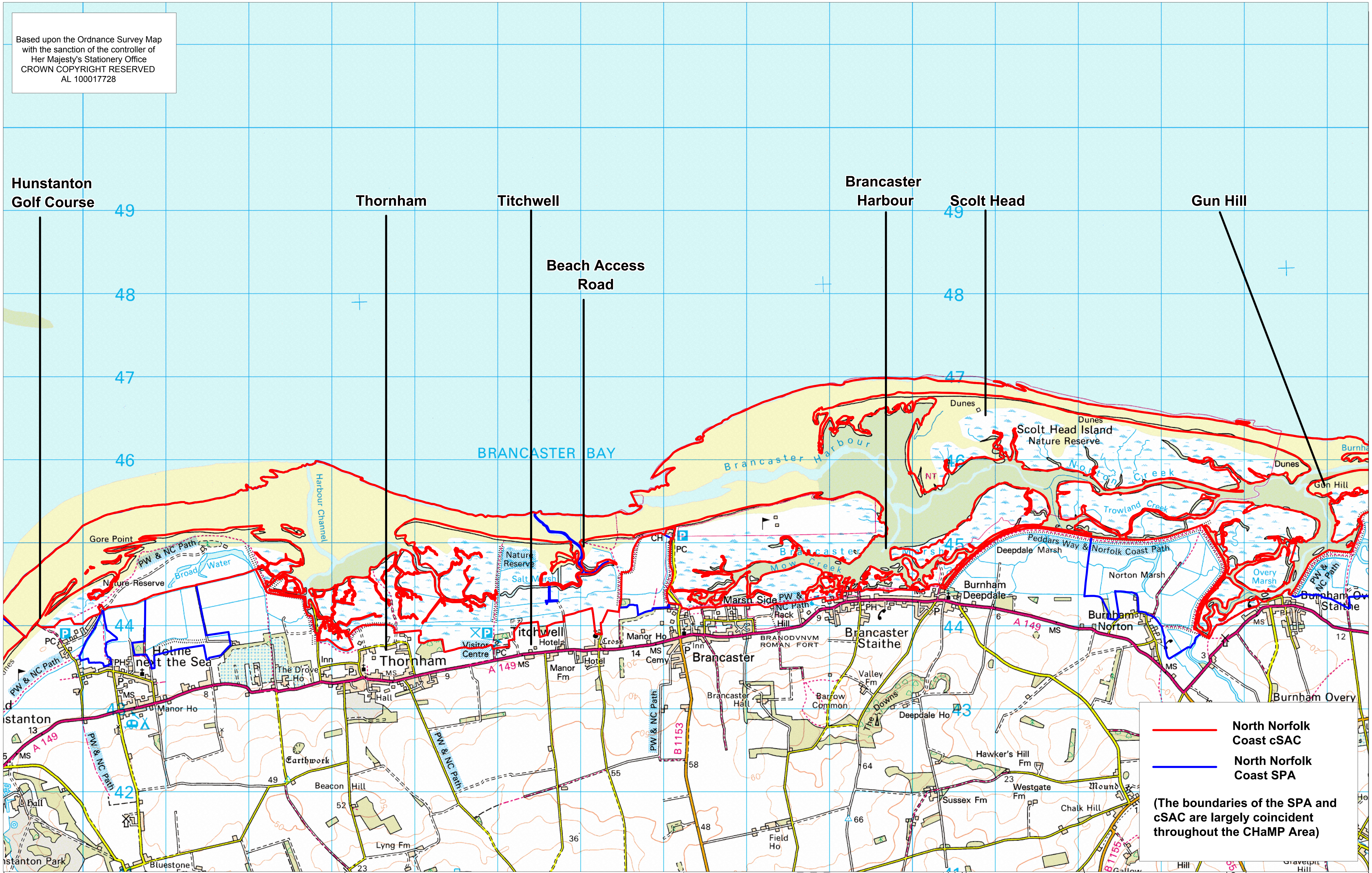
- North Norfolk Coast SAC;
- The Wash and North Norfolk Coast SAC;
- North Norfolk Coast SPA; and
- North Norfolk Coast Ramsar site.

It should be noted that the CHaMP deals only with Natura 2000 and Ramsar designated features and does not consider all of the nature conservation interest within the area covered by the plan.

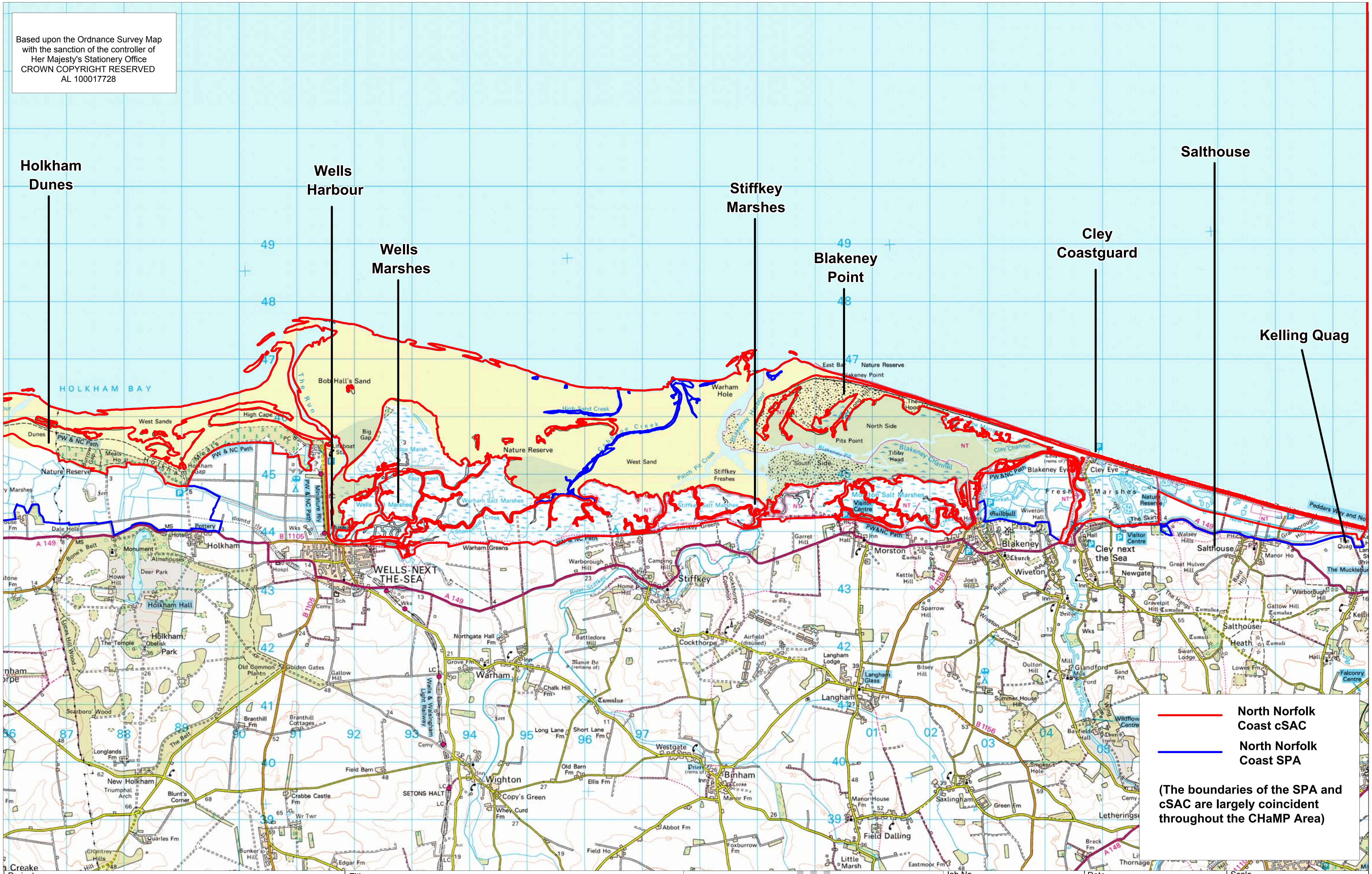
The area covered by the CHaMP extends from Snettisham in the west to Sheringham in the east (see Figure 1.2) and covers all of the European designated interest features within this area (i.e. the overlapping SAC, SPA and Ramsar features). In the interests of developing an integrated approach to the assesment of physical and ecological change the CHaMP also considers, where appropriate, habitats immediately inland or seaward that influence or are influenced by the shoreline e.g. freshwater grazing marshes, coastal woodlands, nearshore reefs, subtidal sediments etc.

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 primary zone within which habitat creation opportunities could be sought in the event that options are not available *in situ*, or immediately adjoining the designated sites. 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.

The coastline of North Norfolk is naturally dynamic. Despite the many modifications to the coast form, these dynamic processes continue and are important in maintaining the existing ecological interests of the coastal area. Enabling the designated habitats and features within the CHaMP area to adjust to process change, such as in response to sea level rise, poses a particular challenge for nature conservation. Accommodating any change requires a flexible approach that may involve further consideration of the importance and function of areas outside the boundary of the site.



Project	Title		Job No.	Date	Scale
Coastal Habitat Management Plans	Area Covered by the North Norfolk CHaMP	ROYAL HASKONING POSFORD HASKONING	G5472	January 2003	
			Drawn RS	Checked RC	Passed RC
			Drg. No. Figure 1.2		Rev.



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			Drg. No. Figure 1.2 ctd.		Rev.

2 INVENTORY OF FEATURES

2.1 Introduction

The North Norfolk coast provides the only classic British example of a barrier beach system. Extensive areas of saltmarsh, with characteristic creek patterns, have formed behind a protective barrier of sand and shingle bars. Large areas of clean mobile sand, subject to fully marine conditions, characterise the open coast. Communities vary form those typical of estuaries, to lugworm *Arenicola marina* dominated muddier sands in the lee of islands and spits, to a sparse infauna in more exposed open coast areas. The large amount of sand present along the frontage has led to the formation of significant areas of dune habitat, which demonstrate the full range of succession from embryonic, mobile dunes through to fixed, well vegetated dune. In places behind the shingle and sand barrier, saline lagoons fed by percolation of seawater through the barrier or via overtopping, have naturally developed or created artificially.

These marine and coastal habitats form a complex mosaic with several wetland habitats such as reedbed and grazing marsh. These more terrestrial habitats have been formed through reclamation and subsequent agricultural management of former saltmarsh habitat. The distribution and extent of the main habitat types of relevance to the CHaMP are shown in Figures 2.1-2.3.

The coast of North Norfolk is one of the most important wetland complexes in Britain for waterfowl. The mosaic of coastal, terrestrial and freshwater habitats support a rich invertebrate fauna which in turn supports internationally important bird assemblages throughout the year (e.g. breeding terns, wintering waders and wildfowl). The area is also important for breeding and moulting of one of Europe's largest populations of common seal *Phoca vitulina*.

2.2 The North Norfolk Coast Candidate Special Area of Conservation (cSAC)

The North Norfolk Coast qualifies as a cSAC for the following Annex I habitats, as listed in the EU Habitats Directive:

- Mediterranean and thermo-Atlantic halophilous scrubs (*Arthrocnemetalia fructicosae*);
- Coastal lagoons;
- Perennial vegetation of stony banks;
- Embryonic shifting dunes;
- Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes');
- Fixed dunes with herbaceous vegetation ('grey dunes'); and
- Humid dune slacks.

2.2.1 Mediterranean and thermo-Atlantic halophilous scrubs (*Arthrocnemetalia fructicosae*)

The North Norfolk Coast, together with The Wash and North Norfolk Coast, comprises the only area in the UK where all the more typically Mediterranean and thermo–Atlantic halophilous scrubs occur together. The vegetation is dominated by a shrubby cover up to 40 cm high of scattered bushes of shrubby sea-blite *Suaeda vera* (see Photo 1) and sea-purslane *Atriplex portulacoides*, with a patchy cover of herbaceous plants and bryophytes. This scrub vegetation often forms an important feature of the upper saltmarshes, and extensive examples occur where the drift-line slopes gradually and provides a transition to dune, shingle or reclaimed sections of the coast. At a number of locations on this coast perennial glasswort *Sarcocornia perennis* forms an open mosaic with other species at the lower limit of the sea-purslane community.

Photo 1. *Suaeda vera* dominated saltmarsh at Stiffkey.

2.2.2 Coastal lagoons

This site encompasses a number of small percolation lagoons on the east coast of England; together with Orfordness - Shingle Street and Benacre to Easton Bavents, it forms a significant part of the percolation lagoon resource concentrated in this part of the UK. The most notable of the lagoons at this site are Blakeney Spit Pools, a lagoon system of six small pools between a shingle ridge and saltmarsh. The bottom of each pool is shingle overlain by soft mud. The fauna of the lagoons includes a nationally rare species, the lagoonal mysid shrimp *Paramysis nouveli*.

2.2.3 Perennial vegetation of stony banks

The process of glacial drift has provided the North Norfolk Coast with numerous shingle structures. The two main shingle sites are Scolt Head Island, an extensive offshore barrier island with shingle ridges and dunes that are of national importance for their geomorphological interest, and Blakeney Point, a large shingle spit.

Blakeney Point comprises a series of recurves partly covered by sand dunes. This extensive site has a typical sequence of shingle vegetation, which includes open communities of pioneer species on the exposed ridge and more continuous grassland communities on the more sheltered shingle recurves. It also includes some of the best examples of transitions between shingle and saltmarsh, with characteristic but rare species more typical of the Mediterranean. These include one of the best examples of the transition from sand and shingle to vegetation dominated by shrubby sea-blite *Suaeda vera*. Blakeney Point is part of a multiple-interest site. The shingle structure forms a highly significant component of the geomorphological structure of the North Norfolk Coast and helps to maintain a series of interrelated habitats.

2.2.4 Embryonic shifting dunes

The North Norfolk Coast is one of two sites representing embryonic shifting dunes in the east of England (the other being Winterton – Horsey Dunes). It is a long, thin dune system, displaying both progradation and erosion. The exceptional length and variety of the dune/beach interface is reflected in the high total area of embryonic dune (over 40 ha or at least 14% of the national total). The process of continued progradation is central to the conservation of this habitat type at this site.

Along the foreshore the dunes are comprised of mobile windblown sand and are characterised by primary colonising plant species such as sand couch grass *Elymus farctus* and lyme-grass *Leymus arenarius*. These young dunes are held together by the rhizomes of marram grass *Ammophila arenaria* and several other species including sea holly *Eryngium maritimum*, sea sandwort *Honkenya peploides* and sand sedge *Carex arenaria.*

2.2.5 Shifting dunes along the shoreline with *Ammophila arenaria* (‘white dunes’)

Shifting dunes form a major component of the complex of often linear dune systems that make up the North Norfolk Coast, which is representative of shifting dunes along the shoreline with *Ammophila arenaria* in East Anglia. The site supports over 100 ha of shifting dune vegetation, 8% of the estimated total area of this habitat type in Britain. The shifting dune vegetation is also varied, containing examples of all the main variants found in the southern part of the geographical range.

2.2.6 Fixed dunes with herbaceous vegetation (‘grey dunes’)

Photo 2. Fixed dune vegetation at Titchwell

The North Norfolk Coast contains a large, active series of dunes on shingle barrier islands and spits and is little affected by development. The fixed dunes with herbaceous vegetation represents one of the principal variants of this vegetation type in the UK, as many of the swards are rich in lichens and drought-avoiding winter annuals such as common whitlowgrass *Erophila verna*, early forget-me-not *Myosotis ramosissima* and common cornsalad *Valerianella locusta*. The main communities represented are marram *Ammophila arenaria* with red fescue *Festuca rubra* and sand sedge *Carex arenaria*, with lichens such as *Cornicularia aculeata* (now *Coelocanlon aculeatum*).

At Holkham, the dunes have been stabilised through the planting of Corsican pine *Pinus nigra* var. *maritima*, which has spread through self-seeding. Under these pines are localised communities of creeping ladies’ tresses *Goodvera repens* and yellow bird’s-nest *Monotropa hypopitys*. The pine and associated secondary woodland provide an important resting habitat for migratory passerine birds.

2.2.7 Humid dune slacks

The slacks within this site are comparatively small and the Yorkshire-fog *Holcus lanatus* community predominates. The site represents humid dune slacks on the dry east coast of England and present an extreme of the geographical range and ecological variation of the habitat within the UK. They are calcareous and complement the acidic dune slacks at Winterton-Horsey Dunes. The dune slack communities occur in association with swamp communities. Unlike the rest of the dune system, dune slacks are generally wet and often support ephemeral pools of standing water. Such pools on the North Norfolk Coast are known to support viable populations of the natterjack toad *Bufo calamita*. Characteristic plant species include pennywort *Hydrocotyle vulgaris*, marsh helleborine *Epipactis palustris* and southern marsh orchid *Dactylorhiza praetermissa*.

2.2.8 Other qualifying species

The North Norfolk Coast cSAC has two Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Otter *Lutra lutra*; and
- The liverwort *Petalophyllum ralfsii*

2.3 The Wash and North Norfolk Coast cSAC

This cSAC in large part coincides with the North Norfolk Coast cSAC but has been designated to cover a range of other marine and coastal habitat types. Some of these features are of greater prominence within The Wash (e.g. large shallow inlets and bays) and although described here do not form part of the more detailed assessment within the main body of the CHaMP. This reflects the situation as originally defined by the structure and content of the preliminary CHaMP (see Section 1.4).

The Wash and North Norfolk Coast cSAC qualifies as a cSAC for the following Annex I habitats and Annex II species, as listed in the EU Habitats Directive:

- Sandbanks which are slightly covered by sea water all the time;
- Mudflats and sandflats not covered by seawater at low tide;
- Large shallow inlets and bays;
- Reefs;
- *Salicornia* and other annuals colonising mud and sand;
- Atlantic salt meadows (Glauco-Puccinellietalia maritimae); and
- Common seal *Phoca vitulina*

Of the above interest features, the CHaMP focuses on the intertidal features although the importance of the subtidal features from a geomorphological perspective is recognised within the CHaMP.

2.3.1 Sandbanks which are slightly covered by sea water all the time

On this site sandy sediments occupy most of the subtidal area, resulting in one of the largest expanses of sublittoral sandbanks in the UK. It provides a representative example of this habitat type on the more sheltered east coast of England. The subtidal sandbanks vary in composition and include coarse sand through to mixed sediment at the mouth of the embayment. Sublittoral communities present include large dense beds of brittlestars *Ophiothrix fragilis*. Species include the sand-mason worm *Lanice conchilega* and the tellin *Angulus tenuis*. Benthic communities on sandflats in the deeper, central part of the Wash are particularly diverse. The subtidal sandbanks provide important nursery grounds for young commercial fish species, including plaice *Pleuronectes platessa*, cod *Gadus morhua* and sole *Solea solea*.

2.3.2 Mudflats and sandflats not covered by seawater at low tide

The Wash, on the east coast of England, is the second-largest area of intertidal flats in the UK. The sandflats in the embayment of the Wash include extensive fine sands and drying banks of coarse sand, and this diversity of substrates, coupled with variety in degree of exposure, means that there is a high diversity relative to other east coast sites. Sandy intertidal flats predominate, with some soft mudflats in the areas sheltered by barrier beaches and islands along the north Norfolk coast. The biota includes large numbers of polychaetes, bivalves and crustaceans. Salinity ranges from that of the open coast in most of the area (supporting rich invertebrate communities) to estuarine close to the rivers. Smaller, sheltered and diverse areas of intertidal sediment, with a rich variety of communities, including some eelgrass *Zostera* spp. beds and large shallow pools, are protected by the north Norfolk barrier islands and sand spits.

2.3.3 Large shallow inlets and bays

The Wash is the largest embayment in the UK, and is connected via sediment transfer systems to the north Norfolk coast. Together, the Wash and North Norfolk Coast form one of the most important marine areas in the UK and the North Sea coast, and include extensive areas of varying, but predominantly sandy, sediments subject to a range of conditions. Communities in the intertidal include those characterised by large numbers of polychaetes, bivalve and crustaceans. Sublittoral communities cover a diverse range from the shallow to the deeper parts of the embayments and include dense brittlestar beds and areas of the reef-building worm (‘ross worm’) *Sabellaria spinulosa*. The embayment supports a variety of mobile species, including a range of fish and Common seal.

2.3.4 Reefs

The Wash contains extensive areas of subtidal mixed sediment. In the tide-swept approaches to the Wash, with a high loading of suspended sand, the relatively common tube-dwelling polychaete worm *Sabellaria spinulosa* forms areas of biogenic reef. These structures are varied in nature, and include reefs which stand up to 30 cm proud of the seabed and which extend for hundreds of metres. The reefs are thought to extend into The Wash where super-abundant *S. spinulosa* occurs and where reef-like structures such as concretions and crusts have been recorded. The site and its surrounding waters are considered particularly important, as it is the only currently known location of well-developed stable *Sabellaria* reef in the UK. The reefs are particularly important components of the sublittoral as they are diverse and productive habitats which support many associated species (including epibenthos and crevice fauna) that would not otherwise be found in predominantly sedimentary areas. As such, the fauna is quite distinct from other biotopes found in the site. Associated motile species include large numbers of polychaetes, mysid shrimps, the pink shrimp *Pandalus montagui*, and crabs. *S. spinulosa* is considered to be an important food source for the commercially important pink shrimp *P. montagui*.

2.3.5 *Salicornia* and other annuals colonising mud and sand

The largest single area of this vegetation in the UK occurs at this site, which is one of the few areas in the UK where saltmarshes are generally accreting. The vegetation is also unusual in that it forms a pioneer community with common cord-grass *Spartina anglica* in which it is an equal component. The inter-relationship with other habitats is significant, forming a transition to important dune, saltmeadow and halophytic scrub communities.

Photo 3. Annual *Salicornia* colonising mudflat at Stiffkey.

2.3.6 Atlantic salt meadows (Glauco-Puccinellietalia maritimae)

The cSAC has been selected both for the extensive ungrazed saltmarshes of the North Norfolk Coast and for the contrasting, traditionally grazed saltmarshes around the Wash. The Wash saltmarshes represent the largest single area of the habitat type in the UK. The Atlantic salt meadows form part of a sequence of vegetation types that are unparalleled among coastal sites in the UK for their diversity and are amongst the most important in Europe.

Photo 4. Puccinellia maritima dominated saltmarsh at Stiffkey.

The main saltmarsh areas have developed in sheltered positions behind sandbars and on sheltered parts of the coast and display a well developed successional mosaic from scarcely vegetated mud at the seaward boundary of the marsh to maritime grassland on the upper marsh. The foremarsh is characterised by pioneer species such as glasswort *Salicornia spp*. and cord grass. The lower marsh is often characterised by sea aster *Aster tripolium,* the mid marsh by sea lavender *Limonium vulgare* with sea purslane lining the banks of the creeks. Characteristic species of the North Norfolk Coast mid marsh community include annual seablite *Suaeda maritima* and sea wormwood *Artemisia maritima*. The upper saltmarsh is characterised by grasses such as sea couch grass *Elymus pycnanthus* and common saltmarsh grass *Puccinellia maritima.* At the saltmarsh-shingle interface there is often short, highly diverse vegetation that includes two rare species; matted sea lavender *Limonium bellidifolium* and sea heath *Frankenia laevis*.

2.3.7 Common seal *Phoca vitulina*

The extensive intertidal flats of the Wash and the North Norfolk Coast provide ideal conditions for common seal breeding and hauling-out. This site is the largest colony of common seals in the UK, with some 7% of the total UK population. In North Norfolk, the majority of the seals are present at Blakeney.

2.4 North Norfolk Coast Special Protection Area (SPA)

The complex mosaic of high quality coastal and wetland habitats along the North Norfolk coast support large populations of breeding waterbirds throughout the year. In the summer, the site holds large breeding populations of waders, four species of terns, bittern and wetland raptors such as marsh harrier. In winter, large numbers of geese, sea ducks, other ducks and waders use the coastal habitats. The coast is also important for its role as a staging site for spring and autumn migration of waterbirds. Terns, such as the sandwich tern and sea ducks regularly feed in the coastal waters adjacent to the SPA. The North Norfolk Coast 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 North Norfolk Coast SPA - Populations of qualifying Annex I species

Species	Population levels
Bittern (*Botaurus stellaris*)	Minimum 1 booming male representing at least 4.0% of the breeding population in Great Britain[1]; 5 individuals representing at least 5.0% of the wintering population in Great Britain (5 year peak mean 1993/4-1998/9)[2]
Marsh harrier (*Circus aeruginosus*)	14 pairs representing at least 8.8% of the breeding population in Great Britain (count as in 1995)[2]
Hen harrier (*Circus cyaneus*)	16 individuals representing at least 2.1% of the wintering population in Great Britain (5 year mean 1993/4-1997/8)[2]
Avocet (*Recurvirostra avosetta*)	177 pairs representing at least 30.0% of the breeding population in Great Britain (count as at 1998)[2]; 203 individuals representing at least 4.0% of the wintering population in Great Britain[3]
Golden plover (*Pluvialis apricaria*)	3473 individuals representing at least 1.3% of the wintering population in Great Britain[3]
Ruff (*Philomachus pugnax*)	79 individuals representing at least 1.5% of the wintering population in Great Britain[3]
Bar-tailed godwit (*Limosa lapponica*)	4041 individuals representing at least 7.6% of the wintering population in Great Britain[3]
Mediterranean gull (*Larus melanocephalus*)	2 pairs representing at least 20.0% of the breeding population in Great Britain (count as at 1996)[2]
Common tern *(Sterna hirundo)*	740 pairs[4] representing the equivalent of 6.0% of the breeding population of Great Britain[6]
Little tern (*Sterna albifrons)*	290 pairs[4] representing the equivalent of 12.0% of the breeding population of Great Britain[5]
Roseate tern (*Sterna dougallii*)	2 pairs representing at least 3.3% of the breeding population in Great Britain (5 year mean 1994-1998)[2]
Sandwich tern *(Sterna sandvicensis)*	4385 pairs[4] representing the equivalent of 34.5% of the breeding population in Great Britain[7]

[1] RSPB data (average 1999, 2000 & 2001 figures). National average 23 booming males based on 1999, 2000 & 2001 average figures.

[2] JNCC SPA Review data

[3] Source: WeBS data

[4] RSPB breeding data (average 2000/2001 figures)

[5] Great Britain population estimate based upon 1985-87 figure of 2,400 pairs (Stone *et al.* 1997). It is possible that British and Irish little tern numbers have fallen by up to 25% since 1986 (G. Pickerell, RSPB, pers. com.)

[6] Great Britain population estimate based upon 1985-87 figure of 12,300 pairs (Stone *et al.* 1997).

[7] Great Britain population estimate based upon 1985-87 figure of 14,000 pairs (Stone *et al.* 1997).

The site also supports breeding populations of other Annex 1 species, such as Arctic tern *Sterna paradisaea*, kingfisher *Alcedo atthis* and short-eared owl *Asio flammeus*.

The site also qualifies under Article 4.2 of the Directive by regularly supporting populations of European importance of the following migratory species (Table 2.2).

Table 2.2 North Norfolk Coast SPA/Ramsar - qualifying internationally important bird populations

Migratory Species	Population levels[1]
Dark-bellied brent goose (*Branta bernicla bernicla*)	9170 individuals representing at least 3.0% of the wintering Western Siberia/Western Europe population
Pink footed geese (*Anser brachyrhynchus*)	22,862 individuals representing at least 10.1% of the wintering Eastern Greenland/Iceland/UK population
Wigeon (*Anas penelope*)	15,164 individuals representing at least 1.2% of the wintering Western Siberia/Northwestern/ Northeastern Europe population
Pintail (*Anas acuta*)	1238 individuals representing at least 2.0% of the wintering Northwestern Europe population
Ringed plover (*Charadrius hiaticula*)	On passage 1,256 individuals representing at least 2.5% % of the breeding Europe/Northern Africa – wintering population[3]; 220 pairs representing at least 1.4% of the breeding Europe/Northern Africa – wintering population (count as at 1998)[3]
Knot (*Calidris canutus*)	26,580 individuals representing at least 2.4% of the wintering Northeastern Canada/Greenland/Iceland Northwestern Europe population
Redshank (*Tringa totanus*)	1492 individuals representing up to 1.0% of the wintering Eastern Atlantic - wintering population[2]

[1] Source: WeBS data

[2] Incomplete count in winter 1995/6

[3] JNCC SPA Review data

In addition, the area qualifies under Article 4.2 of the Directive (79/409/EEC) by regularly supporting at least 20,000 waterfowl.

Over winter, the area regularly supports 106,367 individual waterfowl (5 year peak mean 1995/6 - 1999/00) including: shelduck *Tadorna tadorna*, avocet, golden plover, ruff, bar-tailed godwit *Limosa lapponica*, pink-footed goose, dark-bellied brent goose, wigeon *Anas penelope*, pintail, knot *Calidris canutus*, redshank *Tringa totanus*, bittern, white-fronted goose *Anser albifrons albifrons,* dunlin *Calidris alpina alpina*, gadwall *Anas strepera*, teal *Anas crecca*, shoveler *Anas clypeata*, common scoter *Melanitta nigra*, velvet scoter *Melanitta fusca*, oystercatcher *Haematopus ostralegus*, ringed plover *Charadrius hiaticula*, grey plover *Pluvialis squatarola*, lapwing *Vanellus vanellus*, sanderling *Calidris alba* and cormorant *Phalacrocorax carbo*.

The site also supports nationally important breeding populations of several rare species, including gadwall, shoveler, garganey *Anas querquedula*, black-tailed godwit *Limosa limosa* and bearded tit *Panurus biarmicus*.

Within Britain, bitterns are confined to very few breeding sites, with the population considered to be largely sedentary. Regular nesting sites have been the coastal reedbeds at Cley, but numbers have declined at this site in recent years. Wintering birds include displaced Continental birds.

Marsh harriers have recolonised Britain since the mid-1970s, with part of this expansion possibly supported by the expansion of this species in the Dutch polders. Within the Norfolk CHaMP, breeding is now firmly established at Titchwell and Cley. In addition to this, the use of arable crops as breeding sites (first recorded in Britain in 1982) has become well established (Taylor *et al*. 2000).

Wintering hen harriers start to arrive in September, peaking in October, with passage continuing into November. A feature of harrier species is communal roosting, with the reedbeds at Titchwell being a favoured site for this practice. The largest roost recorded in the county was at Titchwell on 5th March 1982 when 22 birds were present (Taylor *et al*. 2000).

There are seven roost sites in the North Norfolk Coast SPA for dark-bellied brent geese. These are at Thornham Harbour, Scolt Head Island/Brancaster harbour, Burnham Overy Harbour, Wells Harbour, Warham and two in Blakeney Harbour. The roost sites within Blakeney Harbour are at the western and eastern ends of the harbour (Lawton, 1999).

All roost sites occupy large areas of open intertidal sand, mud and shingle. They have good all round visibility, which allows predators and other threats to be easily seen. The availability of freshwater for drinking and bathing is an important factor in choosing roost sites. All freshwater outflows either originating from rivers flowing out in to the sea such as the River Glaven in Blakeney Harbour, drainage sluices off farm land and grazing marshes or freshwater springs such as those in Brancaster Harbour are used. Those birds feeding in areas where freshwater is not available often revisit roost sites at low water during the day to drink and bathe. During high tide when the roost sites are covered, birds roost on the water, in the same area used as during low water (Lawton, 1999).

The numbers of dark-bellied brent geese using the majority of roost sites in the winter remain relatively stable. This relates to a change in daytime feeding areas as the winter progresses from saltmarsh to pasture and winter cereal (Lawton, 1999).

The principal sites for pink-footed geese within/adjacent to the North Norfolk Coast SPA are at Holkham, with regular wintering here since 1980-81. This area has been particularly attractive to wildfowl since controlled flooding of the grazing marshes from 1986 onwards. These birds use an area off the Lodge and Warham Marshes and on the Stiffkey High Sands as a nighttime roost. An established site is also present at Scolt Head. Combined roost totals at Snettisham, Scolt Head and Warham/Stiffkey totalled

76,355 individuals in 1997-98. There is considerable interchange between these roost areas. The birds feed principally on sugar-beet tops on adjacent inland fields between October and January-February, with the birds thereafter moving to permanent grassland, winter cereals and saltmarsh (Taylor *et al*. 2000).

Wigeon begin to arrive in the county from August onwards. A favoured site within the North Norfolk Coast SPA is at Holkham, where the raising of water levels since 1986 has resulted in dramatically higher numbers of wigeon (from a few hundred in the early 1980s to over 11,000 in 1995-96). Raising of the water table has also seen wigeon numbers rise at Holme Dunes to over 2,400 individuals in 1995. An another key site within the SPA is at Cley-Blakeney, which has held over 7,000 individuals (during the 1994-95 winter).

Cley and Blakeney Harbours are important locations for pintail, where there is much movement between sites, with up to 1,500 birds present. Smaller numbers of birds are found at Holkham and at Brancaster/Scolt Head. Small flocks of migrating pintail are regularly seen flying westwards along the north Norfolk coast during the autumn (Taylor *et al*. 2000).

Avocets began breeding in Norfolk in 1977 after a long absence as a breeding species. Cley is a favoured breeding location, with 85 pairs present by 1988. Other breeding colonies became established at Salthouse in 1981, Holme in 1982, Titchwell in 1984 and Holkham in 1990. Coastal breeding avocet in Norfolk use embanked brackish marsh for nesting (Titchwell) and islets within brackish lagoons (Cley). Both of these habitats have been created and improved, partly for these purposes. Post-breeding assemblages were first recorded in 1987, when over 100 birds were recorded at Titchwell during July. Wintering by this species became established in Norfolk in 1995-96, and has increased since then (Taylor *et al*. 2000).

Ringed plover autumn passage numbers peak from August to early October, with the highest recorded count of 1,000 at Snettisham in July 1987; but many sites have held more than 200 birds, notably Holme, Scolt Head/Brancaster Harbour and Blakeney Harbour. There are no sites holding nationally important numbers (more than 290 birds) in the winter (Taylor *et al*. 2000).

Ringed plover roost sites within the North Norfolk Coast SPA are found on shingle ridges and sand dunes, and on coastal arable land. Habitats used by ringed plover include sandy beaches, dunes, coastal arable land, man-made scrapes and pools, and, further inland, gravel pits (Rooney & Eve 1993). A 1993 breeding survey located 354 pairs of ringed plover within the North Norfolk Coast SPA (Rooney & Eve 1993). The majority of these breeding birds were nesting on beaches and sand dunes, particularly selecting open beach habitat and ridges of sand and/or shingle. Along part of the coast (e.g. between Titchwell Channel and Brancaster Golf Club, and Thornham Channel to Titchwell Channel), the direct loss of habitat through erosion has been identified as factor in reducing the available breeding habitat (Rooney & Eve 1993). The principle sites within the CHaMP regularly supporting more than 30 pairs in recent years are Gore Point to Holme and Scolt Head to Blakeney Point (Taylor *et al*. 2000).

Golden plovers begin to arrive back in the country during July and rise to a peak in November. Habitats occupied in winter include arable land, mudflats, saltings and coastal grazing marshes. Sites which hold nationally important numbers include Brancaster Harbour, Burnham Norton and Stiffkey (Taylor *et al*. 2000).

The main influx of knot into Norfolk occurs in August. The main sites are at Snettisham and Holme (Gore Point particularly in the autumn), where the maximum counts in August-November 1997 were 39,050 and 66,000 respectively. Once moult is completed in October some birds remain to winter and others disperse to estuaries around Britain and Western Europe. The north Norfolk saltwater marshes also hold significant numbers (a low tide count in November 1997 recorded 3,955 individuals).

During autumn and winter, ruff particularly favour newly-ploughed arable, stubble, tidal mudflats, coastal golf courses and playing fields. The first returning birds of the autumn appear in early July with passage peaking between August and October. The maximum autumn counts along the north coast have been up to 150 at Titchwell, 57 at Brancaster Harbour, 80 at Holkham Fresh Marshes and 150 at Cley. Up to 100 have been present at Titchwell during the winter (Taylor *et al*. 2000).

Bar-tailed godwits arrive at the beginning of July, although the main arrival takes place during August and continues through September. In north Norfolk, there are three major roosts – at Snettisham, Holme and Titchwell/Thornham Creek. In recent years, maximum counts have included 11,800 at Snettisham in 1987, 2,600 at Holme in 1990 and 5,200 at Titchwell in 1990. The other concentration of note is 200-400 birds which winter in the Brancaster Harbour/Scolt Head area, while smaller numbers also winter in the harbours at Burnham Overy, Wells and Blakeney, although usually less then 100 are present. A large increase in the numbers of birds on both the Wash and the north Norfolk coast has been noted since the 1970s. Atkinson (1996) noted that the largest increase has been in February, prior to birds leaving the British Isles to fatten on the Wadden Sea (Taylor *et al*. 2000).

Redshank start arriving on the North Norfolk coast in early autumn and peak during mid-winter. A low tide count of all intertidal habitat from Holme to Weybourne in November 1997 recorded a total of 3,556 birds, of which 70% were at Scolt Head/Brancaster Harbour, Wells Harbour, Warham and Blakeney Harbour (Taylor *et al*. 2000).

Mediterranean gulls started to breed in Norfolk in 1992, but the first successful breeding was at Blakeney Point in 1994. This has been a regular nesting site since then, and breeding behaviour has been recorded at a number of other sites. The increase in numbers is very apparent, with for example, in May 1995, 55 birds present (across the age classes) at various sites (Taylor *et al*. 2000).

Sandwich tern nests in colonies at Blakeney Point and Scolt Head, and both of these colonies have been carefully monitored since their establishment in the 1920s. There has been an overall increase in the size of the colonies since the early 1960s, with peak numbers of 5,600 breeding pairs in 1979. Stiffkey Binks has also previously been used as nest site. Birds can travel a considerable distance to feed. Favoured fishing areas include Seal Sand in the centre of the Wash and in the vicinity of Race Bank, 12km north of Blakeney Point. Those passing Sheringham and Cromer are thought to fish near Happisburgh Sands, ten kilometres offshore. Large groups of birds occur in post-breeding flocks (Taylor *et al*. 2000).

Roseate tern has always been a scarce breeding species in Norfolk, its preferred breeding habitat in Europe being small islands in sheltered bays and lagoons. This species usually frequents the Scolt Head and Blakeney areas. Breeding attempts were unsuccessful during 1996-98 (Taylor *et al*. 2000).

Common terns nest at a number of locations, including, Titchwell (few in recent years), Scolt Head (c. 150 pairs in recent years) and Blakeney Point (200-300 pairs since the mid-1980s). The colonies at Scolt Head and Blakeney Point were previously much larger than this (Taylor *et al*. 2000).

Little terns breed on open sand and shingle beaches, clear of any vegetation and often within a few metres of the high tide mark. Up to 30 pairs of little terns have bred at Holme and/or Thornham since at least the late 1970s, while at nearby Titchwell, the colony peaked at 67 pairs in 1981. Twenty pairs nest regularly at Brancaster. Birds also breed at Scolt Head and at Blakeney Point (generally 100-200 pairs) and there are several long-established colonies between Gun Hill and Stiffkey Binks (typically nowadays between 50 and 125 breeding pairs attempt to nest at these latter two sites). Post-breeding gatherings occasionally involve impressive numbers of birds, with Scolt Head attracting large numbers of birds in late July (Taylor *et al*. 2000).

With respect to tern species, notably little tern, the suitability of potential breeding sites is dependent on the maintenance of dynamic processes. The continual reworking and formation of new shingle structures or areas provides the open ground which these species rely on for breeding sites.

2.5 SPA supporting habitats

In addition to the coastal habitats described in previous sections dealing with the two cSACs there are also habitats to landward (designated SPA and Ramsar) of the shoreline that provide an important resource for breeding and wintering bird populations. These are briefly described below.

2.5.1 Reedbed

The main areas of brackish reedbed include Cley, Brancaster and Titchwell. The dominant species are reed *Phragmites australis*, mud rush *Juncus gerardii*, brackish water crowfoot *Ranunculus baudotii* and sea club-rush *Scirpus maritimus*. Management programmes for the reedbeds are in place to encourage and maintain favourable habitats for rare breeding birds.

2.5.2 Maritime Pasture and Grazing Marsh

Maritime pasture is present at Cley and Salthouse, where several plants characteristic of damp grazed areas occur, including fox-tail *Alopecurus geniculatus*, annual beard-grass *Polypogon monspeliensis*, jointed rush *Juncus articulatus*, hairy buttercup *Ranunculus sardous* and silverweed *Potentilla anserina*. Ditches within the grazing marsh also support species of tasselweed *Ruppia* sp.

Extensive areas of permanent grazing marsh derived from reclaimed saltmarsh are present at other locations along the coast, notably at Holme, Deepdale, Holkham and Blakeney. In these areas the dominant grass species in the sward are creeping bent *Agrostis stolonifera*, common fox-tail, and perennial rye grass *Lolium perenne*. The wet, rough grassland provides suitable breeding habitat for several species of wader and is a valuable feeding area for wintering wildfowl, notably species such as wigeon. The grazing marshes at Holkham were reclaimed (from saltmarsh) during the 17th-19th centuries. Within the marshes, a network of clear water dykes is present with a variety of marginal plants including reed, lesser spearwort *Ranunculus flammula*, water mint *Mentha aquatica* and gipsy-wort *Lycopus europaeus*. A number of uncommon plant species are present including soft hornwort *Ceratophyllum submersum* and blunt-leaved pondweed *Potamogeton obtusifolius*.

2.6 Interest Features of the Ramsar Sites

The low-lying barrier coastline of North Norfolk is designated as a Ramsar site for its diverse and extensive wetland habitats and associated species (notably waterfowl). The Ramsar site effectively covers the same area as the SPA and encompasses a variety of habitats including intertidal sands and muds, saltmarshes, shingle and sand dunes, together with areas of reclaimed freshwater grazing marsh and reed bed, which is developed in front of rising land. Both freshwater and marine habitats support internationally important numbers of wildfowl in winter and several nationally rare breeding birds (see description given in Section 2.3). The sandflats, sand dune, saltmarsh, shingle and saline lagoons habitats are of international importance for their fauna, flora and geomorphology. The site has been selected under the following Ramsar criteria:

1a - Good representative example of a (near) natural wetland, characteristic of the biogeographic region.
2a - Supports an assemblage of rare, vulnerable or endangered species or subspecies.
3a - Regularly supports at least 20,000 waterfowl.
3c - Regularly supports at least 1% of all the individuals in a waterfowl population.

2.6.1 Ramsar criterion 1a

The site is one of the largest expanses of undeveloped coastal habitat of its type in Europe. It is a particularly good example of a marshland coast with intertidal sand and mud, saltmarshes, shingle banks and sand dunes. There are a series of brackish water lagoons and extensive areas of freshwater grazing marsh and reed beds.

2.6.2 Ramsar criterion 2a

Supports at least three British Red Data Book and nine nationally scarce vascular plants, one British Red Data Book lichen and 38 British Red Data Book invertebrates.

2.6.3 Ramsar criterion 3a

Over the winter the site regularly supports over 20 000 waterfowl (see Section 2.3 for details).

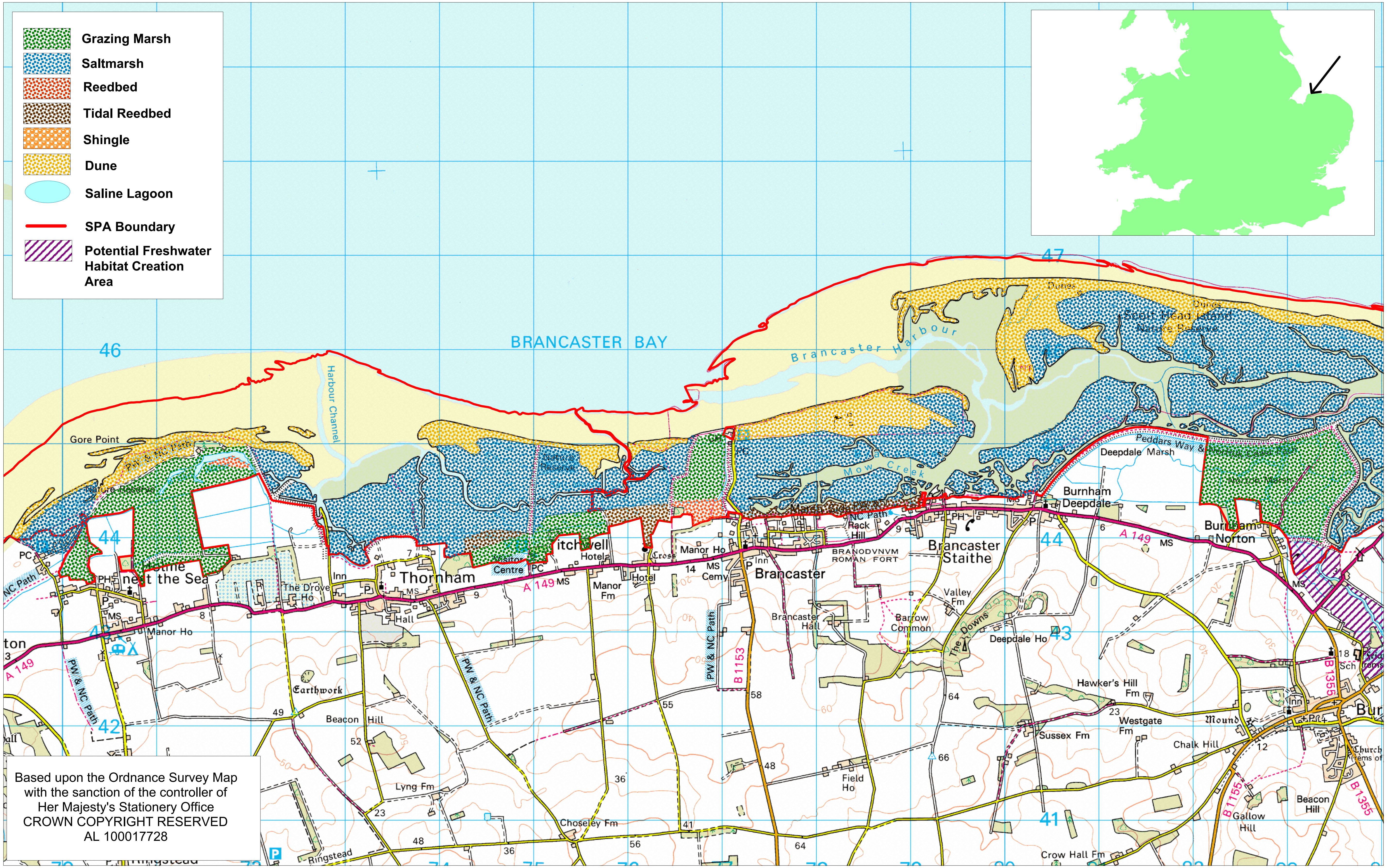
2.6.4 Ramsar criterion 3c

During the breeding season the site regularly supports:

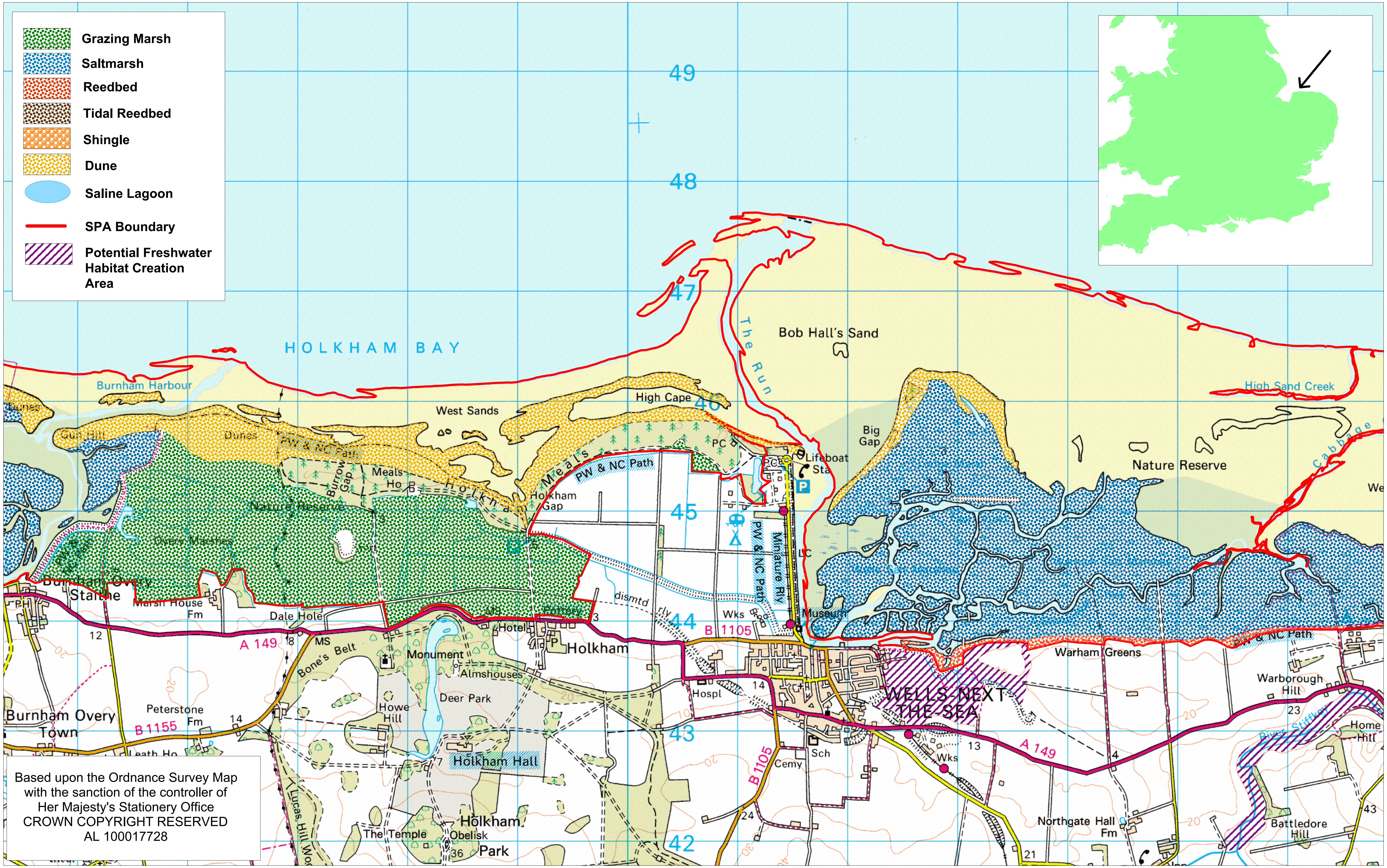
Little Tern, (Eastern Atlantic (breeding))
Common Tern, (Northern/Eastern Europe (breeding))
Sandwich Tern, (Western Europe/Western Africa)

Over the winter the site regularly supports:

Dark-bellied Brent Goose, (Western Siberia/Western Europe)
Knot, (Northeastern Canada/Greenland/Iceland/Northwestern Europe)
Wigeon, (Western Siberia/Northwestern/Northeastern Europe)
Pink-footed Goose, (Eastern Greenland/Iceland/UK)



Project	Title				
Coastal Habitat Management Plans	Indicative Habitat Map Norfolk CHaMP - Brancaster Bay to Burnham Norton	ROYAL HASKONING POSFORD HASKONING	Job No. G5472	Date January 2003	Scale
			Drawn RS	Checked RC	Passed RC
			Drg. No. Figure 2.1		Rev.



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Project	Title	
Coastal Habitat Management Plans	**Indicative Habitat Map** **Norfolk CHaMP - Burnham Overy to Stiffkey**	ROYAL HASKONING POSFORD HASKONING

Job No. **G5472**	Date **January 2003**	Scale
Drawn **RS**	Checked **RC**	Passed **RC**
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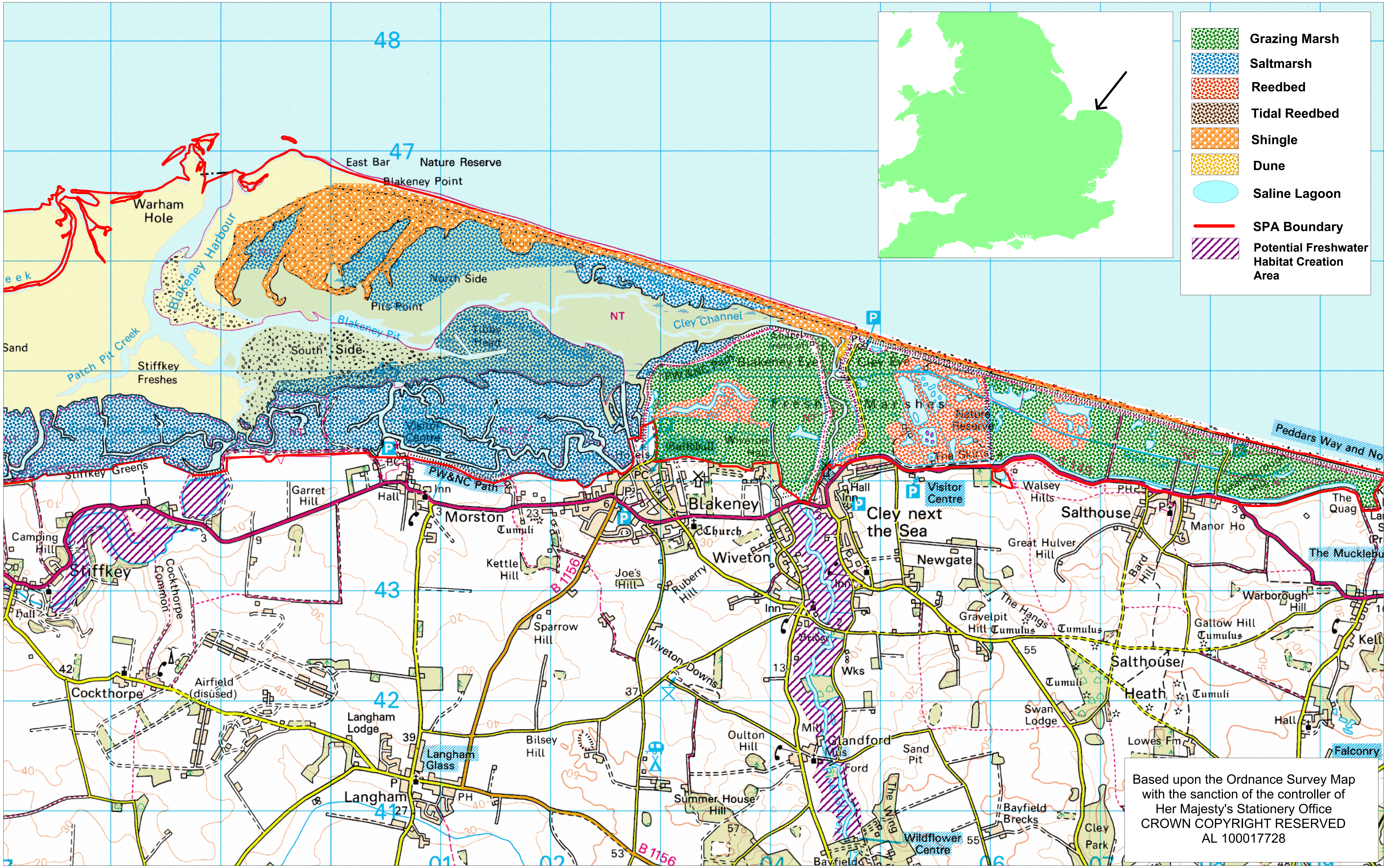

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Project
Coastal Habitat Management Plans

Title
Indicative Habitat Map

Norfolk CHaMP - Blakeney Point

ROYAL HASKONING
POSFORD HASKONING

Job No. **G5472**
Date **January 2003**
Scale
Drawn **RS**
Checked **RC**
Passed **RC**
Drg. No. **Figure 2.3**
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3 CONSERVATION OBJECTIVES

3.1 Introduction

This section provides a summary of the conservation objectives that have been developed for the designated European interest features of both the cSAC and SPAs. The situation as to how these conservation objectives apply is complicated by the fact that the European sites are comprised of a SSSI and a composite part of the SPA and cSACs is also a European Marine site. Both the SSSI and the European Marine Sites have conservation objectives developed for them. These objectives relate to the same interest features, but the sub-features to which the objectives apply may differ.

3.2 North Norfolk Coast cSAC

The conservation objectives for the European interests of the cSAC are given below:

To maintain, in favourable condition, the:

- Coastal lagoons;
- Fixed dunes with herbaceous vegetation (‘grey dunes’);
- Embryonic shifting dunes;
- Humid dune slacks Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*);
- Perennial vegetation of stony banks; and
- Shifting dunes along he shoreline with *Ammophila arenaria* (‘white dunes’).

3.3 The Wash and North Norfolk Coast cSAC

Subject to natural change, maintain the **large shallow inlet and bay** in favourable condition, in particular:

- subtidal sandbanks;
- intertidal mudflats and sandflats;
- subtidal boulder and cobble communities;
- subtidal mixed sediment communities (e.g. *Sabellaria spinulosa* reefs);
- glasswort and other annuals colonising mud and sand;
- Atlantic salt meadows; and
- Mediterranean saltmarsh scrubs.

Subject to natural change, maintain the **sandbanks which are slightly covered by seawater all the time** in favourable condition, in particular:

- gravel and sand communities; and
- muddy sand communities.

Subject to natural change, maintain the **mudflats and sandflats not covered by seawater at low tide** in favourable condition, in particular:

- sand and gravel communities;
- muddy sand communities; and
- mud communities.

Subject to natural change, maintain **Glasswort and other annuals colonising mud and sand** in favourable condition, in particular:

- annual *Salicornia* saltmarsh community;
- annual seablite (*Suaeda maritima*) saltmarsh community; and
- ephemeral saltmarsh vegetation with *Sagina maritima* saltmarsh community.

Subject to natural change, maintain **Atlantic salt meadows** in favourable condition, in particular:

- low marsh and low-mid marsh communities; and
- mid and mid-upper marsh communities.

Subject to natural change, maintain **Mediterranean saltmarsh scrubs** in favourable condition, in particular:

- shrubby seablite (*Suaeda vera*) saltmarsh community;
- shrubby seablite (*Suaeda vera*) and *Limonium binervosum* saltmarsh community; and
- transitional communities.

Subject to natural change, maintain in favourable conditions the habitats of **Common seals,** in particular:

- intertidal mudflats and sandflats.

3.4 North Norfolk Coast Special Protection Area and Ramsar site

Conservation Objectives for the Ramsar site have yet to be 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 population for which the SPA has been designated.

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, migratory waterfowl and wintering waterfowl.

Table 3.1 Habitats to which the Conservation Objectives for the North Norfolk Coast SPA and Ramsar site are applicable.

		Annex I (Avocet, sandwich tern, common tern, little tern)	**Migratory Species** (Dark-bellied brent goose, wigeon, knot)	**Wintering Waterfowl Assemblage**
Designated Site/area	**SPA (European marine site)**	– Coastal waters – Sand and shingle – Intertidal mudflats and sandflats – Saltmarsh – Tidal reedbed	– Sand and shingle – Intertidal mudflats and sandflats – Saltmarsh	– Sand and shingle – Intertidal mudflats and sandflats – Saltmarsh
	SSSI	– Coastal waters – Sand and shingle – Intertidal mudflats and sand flats – Intertidal mudflats and sandflats with *Zostera* – Saltmarsh – Swamp, marginal and inundation communities – Marshy grassland	– Coastal waters – Sand and shingle – Intertidal mudflats and sand flats – Intertidal mudflats and sandflats with *Zostera* – Saltmarsh – Swamp, marginal and inundation communities – Marshy grassland	– Coastal waters – Sand and shingle – Intertidal mudflats and sand flats – Intertidal mudflats and sandflats with *Zostera* – Saltmarsh – Swamp, marginal and inundation communities - Marshy grassland

4 GEOLOGY AND GEOMORPHOLOGY OF NORTH NORFOK

4.1.1 The Sedimentary Environments

The North Norfolk coast is comprised of a discontinuous series of beach barriers fronting extensive back-marsh areas, some of which have been reclaimed. The barriers are constructed of sand and gravels and vary from relatively high sand dune ridges to low shell and gravel cheniers. Most notable of the barriers are Scolt Head Island and Blakeney Ridge, but the dune ridge extending between Holme and Brancaster and the low sand and gravel ridge extending between Warham and Morston (the Meols) are also of critical importance in providing the framework within which the extensive mudflats and salt marshes of the coast have developed. To the north, that is seaward, of the barriers, lie extensive sand flats up to 2km wide and which form a crucial wave energy dissipation surface. The modern coast therefore comprises the following sedimentary environments:

- Inter-tidal sand flats with mega ripples and beach bars;
- Barrier and spit systems composed of gravel and coarse sand;
- Aeolian sand dunes located on the barrier systems;
- Back-barrier salt marsh and inter-tidal muds; and
- Sandy tidal channel deposits with small amounts of gravel.

4.1.2 The Chalk surface

Recent research (Andrews 2000; Funnel 1992 and Chroston 1999) have shown that the distribution of these sedimentary environments is closely related to a geological framework provided by the underlying Chalk and the glacial tills which overlie the Chalk foundations of the area. Chalk underlies the whole of the North Norfolk coast area although, due to the mantle of glacial till, it is exposed only in the cliffs at Hunstanton and on the wave-cut platform fronting the Weybourne to Cromer cliff section. The upper surface of the Chalk exhibits a long west to east trough extending shore parallel and located along the line of the back marsh area of the present coast (Fig 4.1). The trend of this trough, which is interpreted as a palaeo-valley (Chroston 1999), may have been determined by faulting within the Chalk. The palaeo-valley dips gently from Holme in the west to Salthouse in the east, where it trends offshore.

4.1.3 Interglacial shoreline

In several places along the coast the rising ground south of the present day High Water Mark (HWM) is formed by a low cliff which marks the probable higher sea level during the last interglacial period; the Ipswichian. This cliff line is particularly well marked at Stiffkey, where it forms the landward edge of the salt marshes and effectively prevents landward transgression of these marshes in response to sea level rise.

4.1.4 Devensian tills

Between the overlying Holocene deposits and the Chalk lies the glacial tills, of varying thickness but mainly between 2 and 5m, and mostly laid down during the last glacial period when the front of the Devensian ice sheet lay along the coast. The tills extend seaward beyond the present day barriers and have been, and perhaps still are, an important source of coarse-grained sediment for the Holocene coastal deposits. Although, in general the Holocene barriers and marshes cover the glacial deposits of the inter-tidal zone, in places the glacial till topography emerges from the Holocene mantle, forming till islands known locally as Eyes (Cley Eye, Blakeney Eye, Little Eye and Gramborough Hill).

4.1.5 Holocene sediments

The Holocene sediments resting on this glacial till consist mainly of sands and gravels and fine grained silts and clays. However, in places, more particularly in the west-east trough described above, the basal Holocene deposits are freshwater peats, laid down immediately prior to the incursion of the sea at around 8000 years BP. Freshwater peats have also been exposed on the inter-tidal area north of the beach barrier at Thornham and Brancaster Staithe but these appear to be much younger than elsewhere (3000 years Before Present (BP)) and suggest that here a fresh water lagoon had formed landward of a barrier system which prevented sea water access. The recent (1999) exposure of the Seahenge archaeological site here is of the same age and may also be associated with this impermeable barrier.

The existing line of the barriers and back marshes appears at first sight to be controlled by this west-east trough, with the barriers, including Scolt and the Blakeney ridge located on the northern lip of the valley and the marshes occupying the trough itself. The gravel barrier ridge between Blakeney Point and Kelling, for example, lies over a pronounced ridge in the Chalk, while the inter-tidal sand and muds of the Blakeney Harbour are formed in the valley to the south of the Chalk ridge (Fig 4.1). However, although the extreme eastern end of the Blakeney Ridge is grounded on a high in the underlying Chalk, most of the gravel barrier appears to be only coincidentally associated with the underlying Chalk ridge since between the Chalk and the Holocene gravels lies a thickness of till that effectively buries the Chalk topography.

This may be a crucial issue to future management of the North Norfolk coast, since if the present barriers are only associated with the underlying Chalk topography, due to a coincidence in time, and that in fact they have been migrating landwards over the Holocene period across a planar till surface, then they may be expected to continue to migrate landwards in the foreseeable future. On the other hand, if the barrier location is determined by the underlying Chalk ridge and valley sequence, then their location may be more permanent. In contrast with the Blakeney barrier ridge, evidence from Holkham and Burnham Overy suggests that here the barriers have already transgressed across the Chalk valley and it appears probable that the Blakeney barrier has not yet done so due to the pinning of its eastern end on the higher Chalk surface. However, even here at Salthouse-Cley the modern barrier ridge has moved landward over the Holocene salt marsh deposits filling the palaeo-valley which are often exposed on the seaward flank of the shingle ridge indicating that the location of this barrier is by no means a static one.

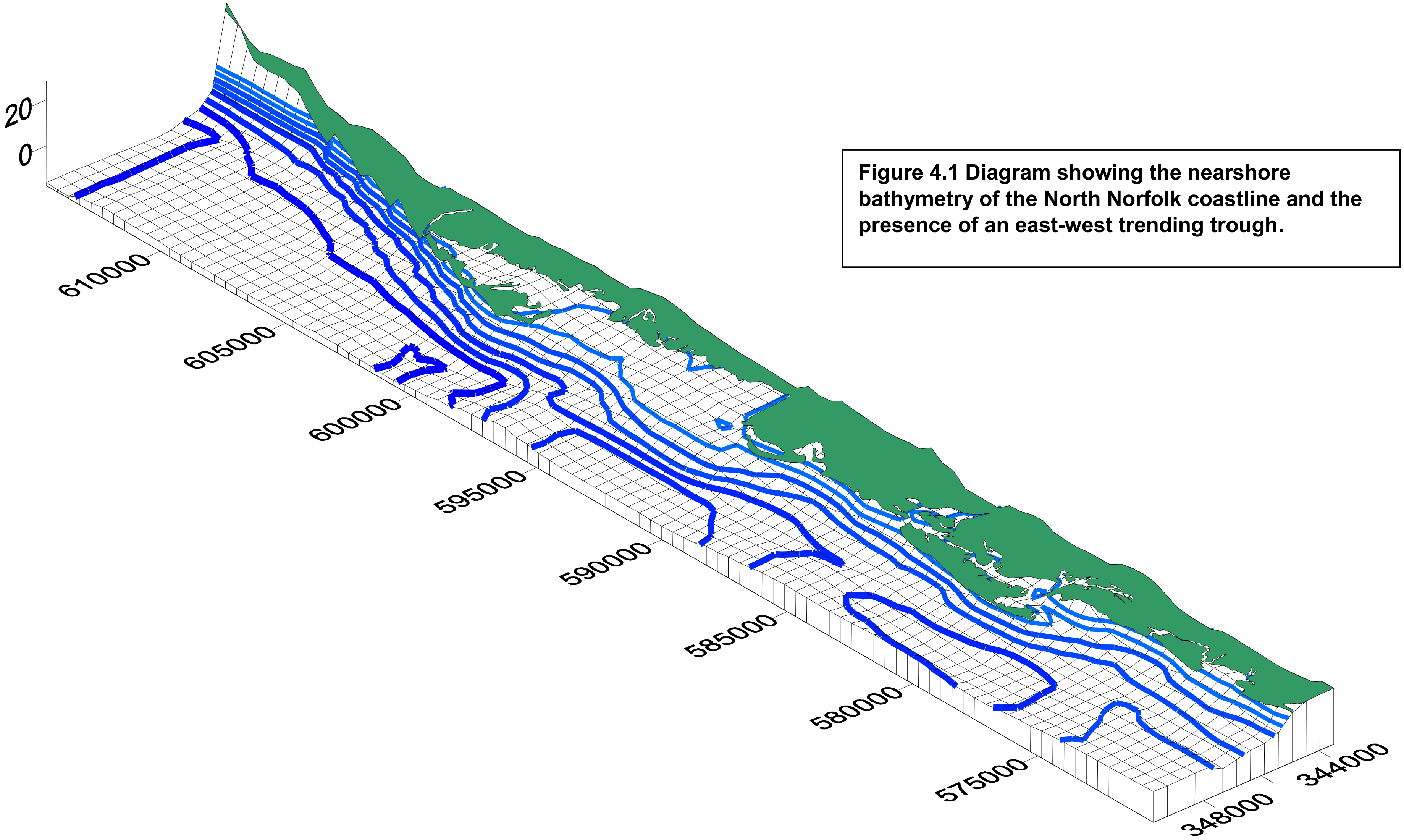


Figure 4.1 Diagram showing the nearshore bathymetry of the North Norfolk coastline and the presence of an east-west trending trough.

4.2 Holocene history

4.2.1 Sea level rise

The Holocene sea level curve for the North Norfolk Coast indicates a rapid rise in sea level, at an average rate of 4mm per year, during the period 8000 to 6000 years BP (Before Present) was followed by an abrupt fall in the rate at around 6000BP to 1.5mm per year, an average rate which has persisted to the present day.

4.2.2 Holocene geomorphology

In the early Holocene period while sea level was below -16m ODN, the coast was characterised by fluvial processes which resulted, in some places, in the formation of basal freshwater peats. These peats have upper surfaces that lie at around -6m ODN and this level appears to be associated with the onset of marine conditions at approximately 7000 to 6000 years BP. As the sea level rose after this period so the modern Holocene marine sequence was laid down landward of the outer barrier. An initial layer of mudflat sediment, up to 15m thick was formed between 7000 and 6500BP. At this stage lower salt marsh began to form succeeded by upper salt marsh at around 5000 to 4000 years BP.

The barrier beaches that protected these mudflat and salt marsh deposits appear to have migrated landward during the period between 6000BP and the present at rates of around 1m per year. This landward transgression of the barrier seems to be a response to sea level rise, which has averaged 0.0015m per year since 6500BP. Assuming that the inter-tidal slope has remained at its present gradient of 1:600 over this period landward transgression of the barrier would have occurred at 0.9m per year. Since the pre-Holocene surface slope-gradient is between 1:500 and 1:1000 the landward movement of the entire Holocene sedimentary prism appears to have been at the same rate as the movement of the barriers. A tidal range of 5m on a slope of 1:600 would result in an inter-tidal width of 3km, approximately the mean width of the modern inter-tidal zone. It is not until the HWM reached the rising ground of the Ipswichian shore that any loss of sediment would have occurred due to landward transgression and the width of the existing inter-tidal zone suggests that such loss has been relatively minor so far.

This analysis contrasts with that of Andrews et al (1999) who propose that the entire Holocene sediment prism is now only half its original width. They suggest that, although no trace of a wider shore zone is now extant, the sediments derived from its progressive thinning have been extensively reworked and re-deposited to landward.

These transgression rates may not apply in some areas of the North Norfolk coast. At Scolt for example, there are two sets of barriers, the inner barrier, comprised of the Ramsay Ridges and the Nod, and the present day Scolt Island. Andrews (1999), proposes that the Scolt Island barrier is relatively young, possibly less than 3000 years old, and developed as a spit emanating from Holkham and seaward of the older inner barriers. Similarly the western, distal, end of Blakeney Ridge was formed relatively recently, probably in the 16th century as a response to inter-tidal reclamation. This may explain why both these barriers, Scolt and Blakeney, lie much further seaward than the other barriers on the coast.

4.3 Present Day Geomorphology

4.3.1 Barrier beaches

The barrier beaches of the North Norfolk coast present a diverse morphology ranging from gravel ridges to sand dunes. In general these ridges appear to be transgressing landward at a rate of around 1m per year although in some cases new ridges are developing to seaward of these older barriers implying a more complex process than a simple onshore movement accompanied by progressive narrowing of the shore zone. Landward movement of the barriers is by sediment roll-over, where storm waves cause wash-over fans to develop on the landward flank of the beach ridge. Additional to these shore-normal movements the barrier beaches are also developing in the shore normal direction. Both Scolt and Blakeney have been experiencing accretion on their western extremities at a rate of around 3.5m per year, over periods of between 400 years (Blakeney) and 1100 years (Scolt) although evidence from early maps suggest that the Blakeney Ridge extended more rapidly in the 16th century probably by an average of 5m per year.

This westward growth of the two barriers has been attributed to longshore sediment movement from east to west along the coast (Vincent 1979), forming recurved laterals to the end of each barrier. This classic model fails to explain, however, the abrupt transition from shingle to sand on Blakeney, that, according to map evidence, occurred in the early 17th century and was contemporaneous with the reclamation of the Salthouse-Cley salt marshes.

An alternative model may be proposed that coarse grained sediment transport (mainly sand) is from west to east and that this sediment movement bypasses each of the major tidal channels along the coast (for example at Brancaster Staithe, Wells and Moreston) as episodic sand waves. These easterly moving sand waves then shore weld to the western extremities of the barriers forming the characteristic fulls and lows and recurved laterals of Scolt and Blakeney, but also to a lesser extent at Lodge Marsh to the east of Wells Harbour. The rapid extension of the Blakeney ridge following the reclamation of the Cley marshes may thus be explained by the reduction in tidal flow across the mouth of the Glaven estuary allowing more rapid transit of sand waves which followed a more landward pathway than previously.

4.3.2 Sand dunes

Although sand dunes are located along much of the coast there are few examples of sand dune fields with multiple dune ridges. For the most part the dunes exhibit single ridges colonised by *Ammophila* with occasional fore-dune and embryo-dune development, although the Gun Hill dunes at Burnham Overy and parts of the Blakeney and Scolt dune ridges are more extensive, with mature dune ridges colonised by a diverse dune flora.

Fore dune ridges are experiencing erosion along much of this coast at the present time with the exception of those between Wells and Holkham. The Holme and Brancaster Bay have been rapidly eroded over the past decade, although, as shown below, this dune erosion has been balanced by foreshore accretion. The dunes of both Scolt and Blakeney are experiencing erosion as these barriers roll landward. However, unlike the gravel barriers, the dunes do not reform by roll-over processes and the dune ridges are progressively narrowing as the barriers move landward.

4.3.3 Tidal deltas

Discharges from tidal inlets across the inter-tidal and nearshore zone of the coast cause the long shore pathway of sediment to be pushed seaward and its movement to become intermittent. The resultant sediment lobe with accompanying sand waves and a marked ebb tide bar constitutes the tidal delta. Seven such deltas are present along the coast at:

- Gore Point;
- Thornham;
- Titchwell;
- Brancaster Staithe;
- Burnham Overy;
- Wells Harbour; and
- Morston - Blakeney Far Point.

Each delta forms a pronounced lobe in the lower inter-tidal that is associated with a reduction in wave energy at the upper shore and the formation of sand dunes.

The size of these deltas, and therefore their effect on the upper shore, depends on the strength of the tidal currents from the inlets relative to the long shore sediment transport rate. Reduction in the tidal prism of an inlet due to reclamation or increase due to managed realignment can therefore have an effect both on the tidal delta and the adjacent shoreline. This effect was clearly illustrated by the breaching of a reclaimed marsh at Titchwell, during a storm in 1949. The subsequent growth of the tidal delta and the prograding of the dunes on the adjacent shore has locally reversed the erosion of this section of Brancaster Bay.

4.3.4 Saltmarshes

The saltmarshes of the North Norfolk coast are among the most extensive in Europe (2127ha, Lambley 1999) and are of extremely high geomorphological and ecological value. They make up 6.7% of the total England resource. Although no detailed mapping of changes in saltmarsh extent has been undertaken it is clear that the progressive landward migration of the barrier beaches coupled with the rising ground to landward often marked by the Ipswichian cliff, is resulting in a form of natural coastal squeeze by which the area of saltmarsh is being reduced.

This reduction in saltmarsh area is to some extent offset by the development of new marsh areas landward of several recently formed barriers. Thus, the saltmarsh development within the Holkham Gap which took place as recently as 1990, has resulted in some 20ha of *Puccinellia* marsh while a more extensive area of *Spartina* marsh has developed since 1950 in the shelter of the Stiffkey Meols.

The horizontal loss of saltmarsh due to barrier migration has not been offset by landward migration of the landward edge of the marshes due to the presence of rising ground, as discussed above, despite rapid vertical accretion of the marsh surfaces. Work by Andrews et al (1999) using Caesium isotopes as a sediment marker, showed that vertical accretion of the marshes averaged 4.55mm per year over the past decade (see Table 4.1). This rate is three times that of long term sea level rise and suggests that fine grained sediment supply would be adequate to keep pace with predicted sea level rise in the future (French & Spencer 1993).

Table 4.1 Vertical accretion rates on North Norfolk salt marshes (data from Andrews et al 1999)

Location	Vertical sedimentation rate (mma^{-1})
Stiffkey: Spartina marsh	6.4
Stiffkey: Mid marsh	3.6
Stiffkey: Upper marsh	2.1
Scolt: Great Aster marsh	5.4
Scolt: Plantago marsh	3.9
Scolt: Plover marsh	3.2
Scolt: Hut marsh	3.9
Scolt: Missel marsh	7.9

4.3.5 Reclaimed marshes

Despite a widely held impression that the North Norfolk coast is a natural system, untouched by human interference, over 50% of its salt marsh area has been reclaimed over the past 300 years (Pye, 1992). The total area of grazing marshes is put at 867ha (Lambley 1999) which is 41% of the extant saltmarsh area. The principal areas of reclaimed grazing marsh on the coast are shown in Table 4.2.

Table 4.2 Principal areas of reclaimed marsh on the North Norfolk coast (data from Lambley 1999)

Location	Area (ha)
Cley-Salthouse	171
Blakeney Freshes	142
Holkham	295
Burnham Norton	121
Thornham-Brancaster	54
Holme	84

These grazing marshes exhibit a complex hydrology, with saline seepage and fresh water springs resulting in a range of salinities in both soil and drainage ditches that is central to their ecological importance. Nevertheless, a reduction in local water tables coupled with the increase in sea level means that these hydrological conditions are changing rapidly.

The elevation of the reclaimed marshes today lies at between 1.1 and 2.5m ODN, that is between 0.6m and 2.0m below the extant upper saltmarshes, which have surface elevations of between 1.7m and 3.1m ODN (Pye 1992; IECS 1993). This means that these marshes have a sediment deficit of approximately 9x 10^6 m^3 and this will increase rapidly as sea level rise accelerates. Moreover, the grazing marsh surface elevation lies on average 2.5m below the level of the 10 year flood and some 3.5m below embankment crest elevations protecting these marshes that are typically at 5.5m ODN

(IECS 1993). The grazing marshes therefore appear to be one of the susceptible and most fragile of the habitats of the North Norfolk coast.

4.4 Sediment Budgets

4.4.1 Shore profile analysis

Work by Newcastle University (1999) on Environment Agency beach survey data within 12 sediment cells along the North Norfolk coast has been reviewed and extended as part of this report. Time series analysis of the sediment volumes in each of the cells 3 to 8 (Kelling to Holme) has been undertaken for the period 1992 to 2002. The results are shown in Figure 4.2. Using the regression coefficient as an indication of the trend in sediment volumes allows the compilation of a figure (see Figure 4.3) showing the spatial distribution of sediment trends along the entire North Norfolk coast.

The results of this analysis of the Environment Agency data sets are:

- Fig 4.3 shows that the centre of the North Norfolk coast (at Holkham) gained sediment over the past decade at the rate of approximately 300,000m^3 per year. Moving away from this central location, the figure shows that sediment gains decreased to both east and west. Cell 8 (Holme) experienced a net loss (-100,000 m^3 per year);
- The behaviour of cell 4 and 3 (Stiffkey and Western Blakeney Spit) is crucial. The evidence suggests that the Stiffkey shore was extremely volatile (rapid shifts from positive to negative sediment budgets) with a net trend that is indistinguishable from zero. Cell 3 in contrast shows a strong positive signal and here the individual profile analyses (Newcastle University 1999) show that these gains were due to the onshore movement of discrete sand bars that shore-welded to the distal end of Blakeney Ridge;
- It appears, therefore, that cell 3 and 4 may be linked so that losses in 4 are reflected in gains in 3 and that over the decade 1992-2002 the balance lies towards cell 3. This may be a reflection of the data series rather than a long term trend;
- If these figures are accepted, then the North Norfolk coast demonstrates a positive sediment budget over the past decade. The source of the sediment appears to be from the nearshore north of Holkham and therefore possibly associated with the Docking shoal; and
- The conclusion must be that the North Norfolk coastal system looks extremely healthy at the present time with abundant sediment input and an accretionary trend. The implications of these conclusions for the sediment budget are considered in section 4.4.2.The sources of this sediment are discussed below in section 4.4.3.

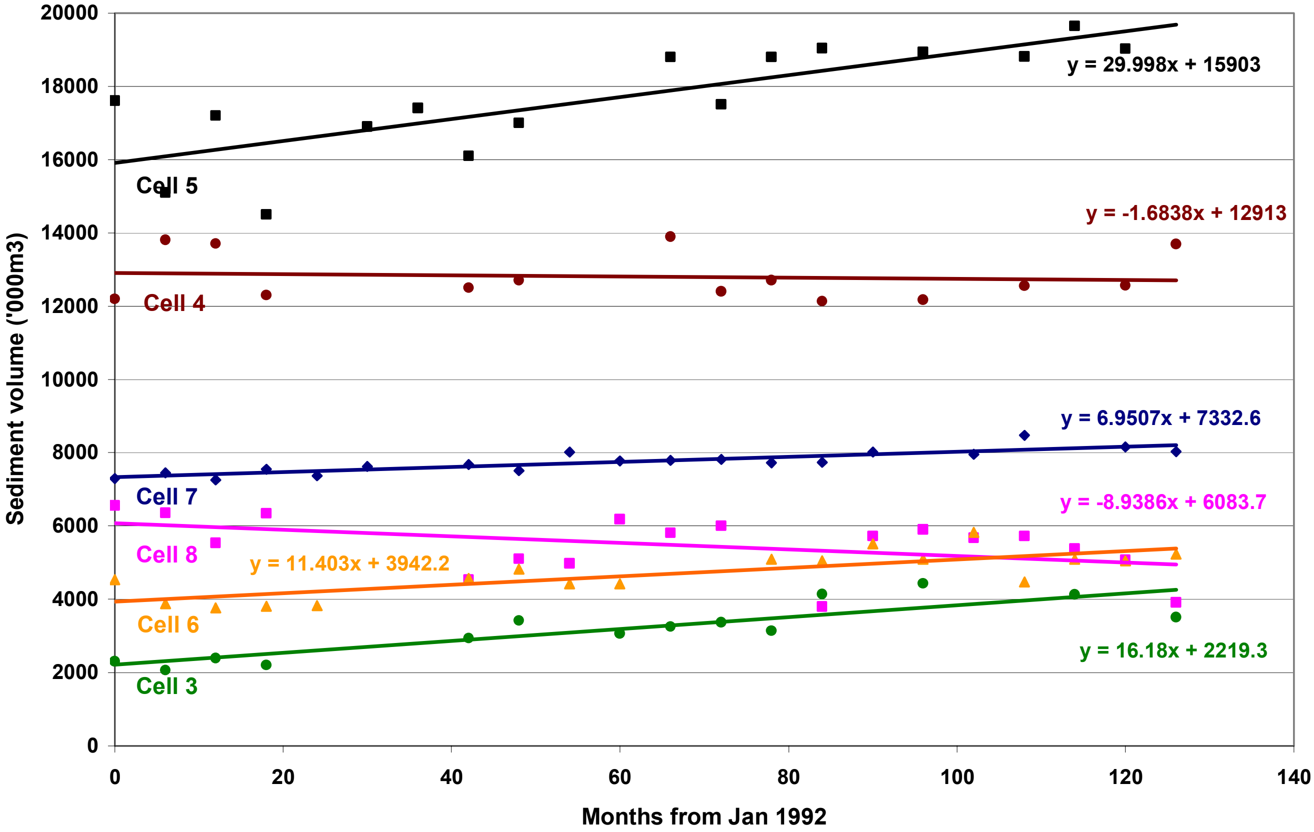


Fig 4.2: time series for cells 3 to 8 (see section 3 for cell location).Best fit regression coefficient to time series data for each cell indicates rate of volumetric change in 1000m^3 per month

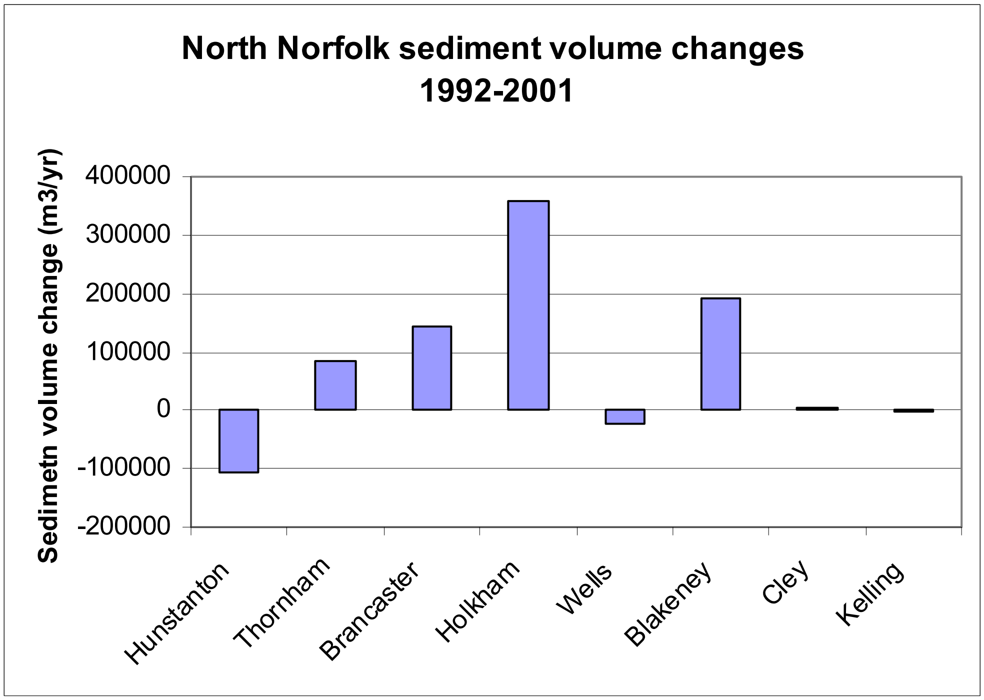


Figure 4.3: spatial distribution of sediment volume trends over the past decade in cells 3 to 8.

4.5 Sediment demand

The North Norfolk coast is characterised by two distinct sediment types: a coarse grained sand and gravel suite that makes up the outer sand flats, barrier beaches and sand dunes and a fine grained silt and clay suite that makes up the inner salt marshes and associated mudflats. The total Holocene sediment prism was calculated by Andrews (1999) to be 685 x 10^6 m^3. Of this total the coarse sediment suite made up 48% or 329 x 10^6 m^3 while back barrier fine sediment made up the remaining 356 x 10^6 m^3.

The coarse sediments are derived from several sources, including the nearshore seabed, cliff erosion and recycling of inter-tidal sediments. Fine grained sediments are derived ultimately from erosion of the cliffs at Holderness (McCave 1978) although some of this material this will be recycled through The Wash as well as moving directly to the North Norfolk coast. A small amount of fine grained sediment is derived from the erosion of cliffs along the Norfolk coast.

The sediment demand for coarse grained sediment is difficult to calculate with any accuracy. The spatial variability of accretion and erosion processes mean that estimates for the whole coastal zone must be treated, at best, as rough approximations.

The long term average for sediment demand on the North Norfolk coast can be calculated from the data provided by Andrews et al (1999). They estimate that a total of 685 x 10^6 m^3 of sediment has accreted on the coast during the last 7000 years of the Holocene. The long term annual mean is therefore 97,857m^3 a^{-1}.

The inter-tidal area of the North Norfolk coast is approximately 5500ha. If the long term annual mean is averaged over this area, the annual vertical accretion rate equates to 0.0018m a^{-1}, which is similar to the long term rate of sea level rise of 0.0015ma^{-1}.

If the data provided by Andrews et al (1999) for saltmarsh accretion over the past 40 years is examined, however, a different annual mean value is produced. Table 4.1 shows the variation in salt marsh accretion derived from Caesium isotope profiles. The mean vertical accretion rate derived from these data is 0.00455ma^{-1} a figure that is 3 times greater than the long term rate of sea level rise. The total area of salt marsh on the coast is 2127ha (Lambley 1999) so that the annual volume of fine grained sediment accumulating on the marshes is 96,778m^3 a^{-1}. This total sediment volume for salt marsh alone is equivalent to the long term average for the entire North Norfolk coast inter-tidal area including both saltmarsh and inter-tidal sand flats, barrier islands and sand dunes. If the vertical accretion rate of 0.00455m a^{-1} were to be applied to the entire inter-tidal area the total annual volume accumulation would be 250,250m^3a^{-1}.

This apparent increase in the annual volume of sediment accreting on the coast over the past few decades is supported by calculations derived from the Environment Agency shore profiles as reported in the previous section. These data suggest that an annual total of 600,000m^3 of coarse grained sediment has accreted on the North Norfolk coast during the past decade while approximately 150,000m^3 per year has been eroded. It is not possible to ascertain whether the eroded sediment is re-deposited within adjacent accreting areas and therefore a minimum estimate for net accretion will be 450,000m^3 per annum. This represents an average vertical accretion rate of 0.0018ma^{-1} over the entire inter-tidal area of the coast, a figure that is 5 times greater than the long term rate of sea level rise. The conclusions that may be drawn from this analysis of the sediment demand are:

- There appears to have been an exponential increase in the rate of sediment accumulation on the North Norfolk coast over the past 50 years;
- The long term, Holocene, annual sediment input of approximately 100,000 ma^{-1} had apparently risen to 250,000 ma^{-1} in the period 1950-1999 and to 450,000 in the period 1992-2000 (Figure 4.4);
- This increase in the spatially averaged vertical sediment accretion derived from these recent data are much higher than the long term rate of sea level rise; and
- No data are available for the period prior to 1950 so that the abrupt increase shown by these data may in fact have been part of a much longer term increase in sediment accumulation.

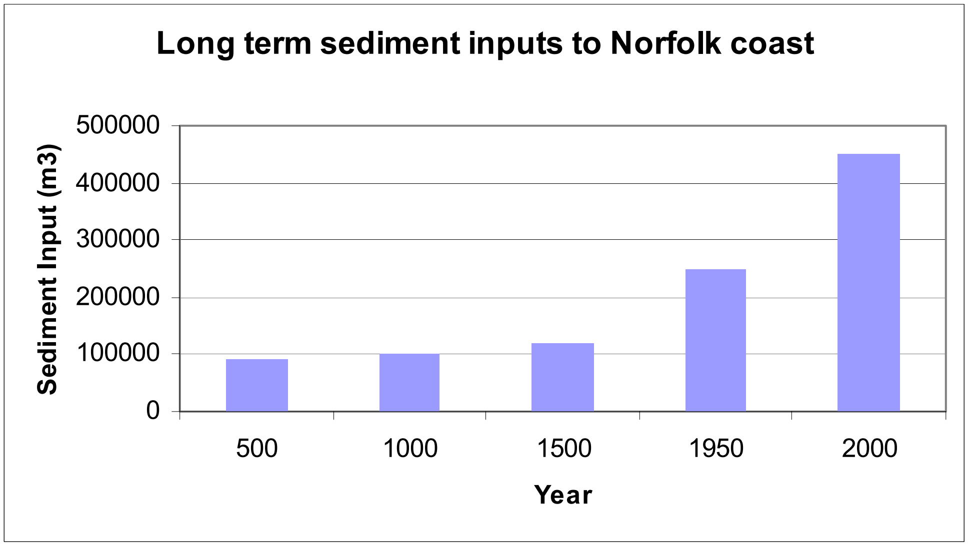


Fig 4.4: Long term sediment input rates to the North Norfolk coastal zone.

Explanations for the apparent increase in sediment accumulation include:

- Some or all of the data are in error;
- The rate of sea level rise on the coast has accelerated over the recent past and the increased sediment accumulation rate is keeping pace with this rise; and
- The recent data are unduly influenced by episodic storm events that are averaged out in the long term Holocene data.

Despite the potentially controversial nature of these results, there appears to be two conclusions that can be drawn with some certainty

- The North Norfolk coast sediment budget is positive; and
- Sediment is presently available to the coastal system.

4.5.1 Sources of sediment

The identification of sources of sediment to the North Norfolk coast has been, and remains, a major problem. The Southern North Sea Sediment Study (SNSSS 2002) admits to ‘conflicting evidence’ although its general conclusion is that sediment is derived from the erosion of the Weybourne to Cromer cliffs and is transported westwards along the coast.

This conclusion of SNSSS (2002) is difficult to reconcile with the evidence presented in the report both from seabed indicators and from modelling studies. All such evidence points to a west to east movement of sediment and a source area defined by the Burnham Flats and the Docking Shoal, indeed SNSSS (2002), p 55, states that 'Offshore seabed indicators show both nearshore and offshore (over the Burnham Flats and Docking Shoal) movement in an easterly direction'. The report includes evidence from the British Geological Survey (BGS) that also conflicts with the hypothesis that sediment is moved westwards along this coast, for example SNSSS (2002), p 52, states 'BGS data suggests that although sand and shingle is being transported to the west on the beach face, sand is transported to the east if it is carried offshore of the steep beach face onto Burnham Flats, perhaps during storms'.

The difficulty of accepting the hypothesis of a net westward sediment movement is exacerbated by the evidence presented in SNSSS (2002) for the rates of such westward movement. The morphological evidence presented above (section 4.4.2) based on annual surveys of the shore profiles by the Environment Agency, indicates an annual accretion rate on this coast of around 400,000m^3. This represents the net accretion and therefore, presumably, underestimates the gross movement of sediment along the coast. The estimates presented in SNSSS (2002) for westward longshore drift are, in contrast, relatively small and cannot be equated with the present day accretion rates of 450,000m^3 /year or, for that matter, with the long term accretion rates shown by Andrews et al (1999) to average 100,000m^3 per year throughout the Holocene. For example, the SNSSS states that 'When the proportion of sand and gravel is taken into account, the calculated transport rates are of the order of 10,000-15,000 m^3/year of sand and the same volume of shingle transported from the west of Weybourne towards the base of Blakeney Point. Along the Point, the transport rates rise to values of the order of 40,000-60,000m^3/year of potential sand transport and 20,000-40,000m$_3$/year of shingle longshore transport. These figures are re-interpretations of old model predictions, so should be taken as indicative only.' (SNSSS 2002), p 52.

It may be concluded that the conflicting evidence presented here could be resolved by assuming that a westward sediment transport pathway is developed on this coast during low magnitude, high frequency events involving relatively small volumes of sediment. This movement therefore probably represents a redistribution of sediment already present within the North Norfolk system and does not imply a major source to the east, Although some sediment derived from cliff erosion to the east of Weybourne may enter the system during these low magnitude events, this is not and indeed cannot be seen as the principle source of sediment for the North Norfolk coast.

In contrast, during high magnitude, low frequency events, a strong north to south movement develops across the Burnham Flats and Docking shoal, as shown in all the model predictions of the SNSSS (2002) and moves large volumes of sediment onshore. Nearshore sediment movement during such events is from west to east, principally in the region between -5m and -15m with accretion occurring as this material moves into the tidal deltas along the coast. From these accretionary centres, sediment is then redistributed to the inshore regions during the low magnitude events as outlined above. Such a model is clearly shown in the summary diagram produced by SNSSS (2002) and reproduced here as Fig 4.5. This diagram shows the contrast between sediment movements during low and high magnitude events. It is clear from this diagram that the major source of sediment is the extensive fine sand deposits within the Burnham Flats and Docking Shoal, extending north to the Race Bank. A secondary source may be the sand deposits within the Wash embayment although, as shown in the SNSSS figure, these deposits are themselves ultimately derived from the Burnham/Docking Shoals.

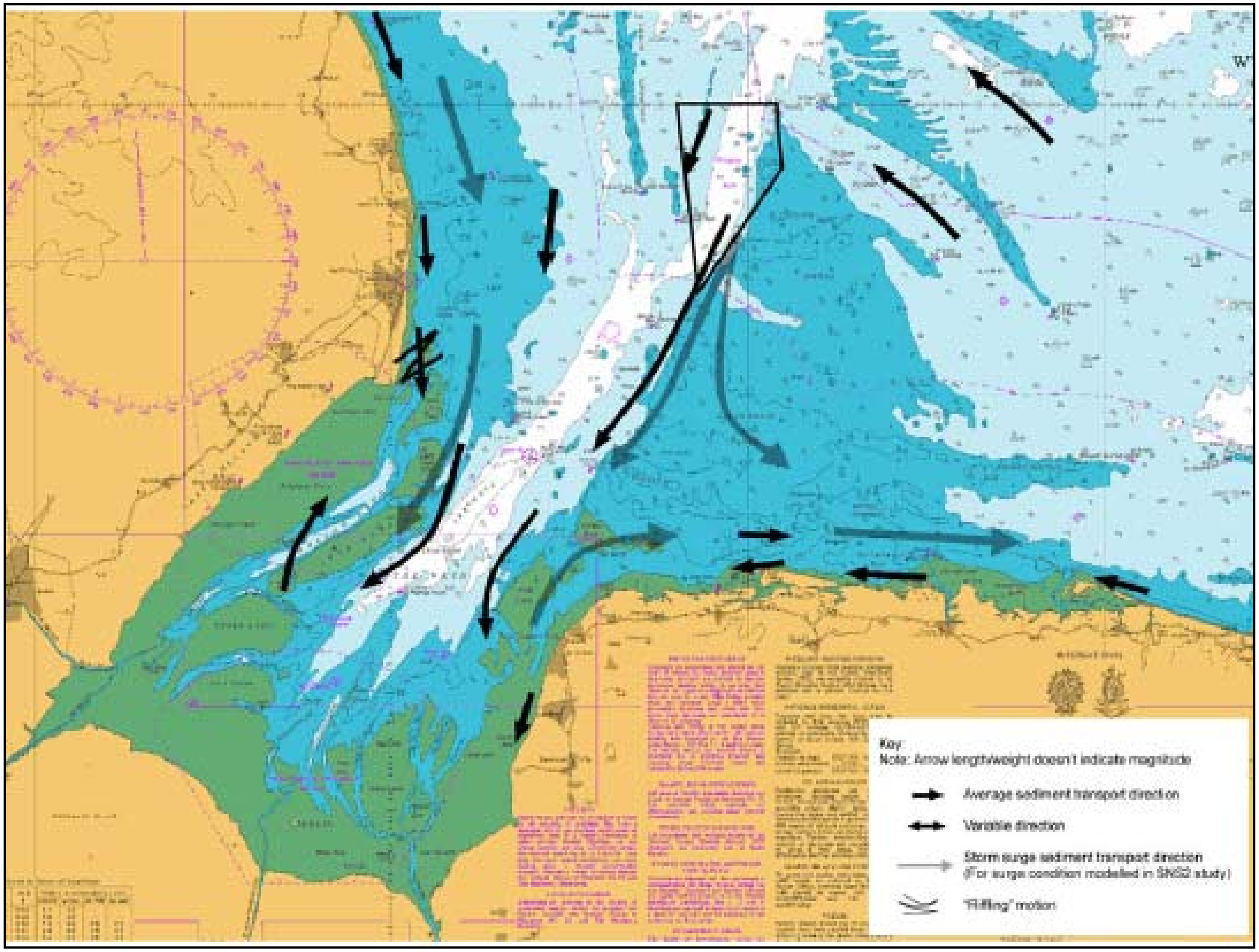


Fig 4.5 Schematic sediment transport pathways (North Norfolk) for average conditions and interpreted for extreme water level (surge), wind and wave event, overlain on Admiralty Chart 1408. From Southern North Sea Sediment Transport Study (HR 2002 Fig 3)

5 DIVISION OF THE CHAMP AREA INTO BEHAVIOURAL UNITS

5.1 Introduction

The CHaMP area has been divided into a number of units in order 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 has been divided into six Behavioural Units (BUs). These units focus on the designated sites but are defined broadly enough to take in supporting areas of habitat and or land. The BUs are set out in Table 5.1 (and shown in Figure 1.2) which also briefly 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 connection 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 system. Comparative units used in the SMP are given in Table 5.2.

Table 5.1. Divisions of the North Norfolk Coast used in the CHaMP assessment process. The corresponding units used in the preliminary CHaMP (English Nature 1999) are shown in brackets.

HBU	Heacham (Unit 8)	Brancaster Bay (Unit 7)	Scolt (Unit 6)	Holkham (Unit 5)	Stiffkey (Unit 4)	Blakeney (Units 2&3)
Designation	NNR/SAC/SPA	NNR/SAC/SPA	NNR/SAC	NNR/SAC/SPA	NNR/SAC	NNR/SAC
Morphology	Wash coast / nourished shingle	Dunes	Dune marsh	Dune/ beach/ Reclaimed saltmarsh	Marsh	Shingle/ dune
Sediment transport	North	?West	?	East	East	East
Threats	Erosion	Erosion	?	Erosion/ Beach mud	None	Recession
Opportunities	Back-marsh	Re-alignment		Re-alignment		Free-up

Table 5.2 Units used within the SMP, subcell 3a (for comparison with CHaMP BUs)

Coastal Cell	**Location**		**Geomorphology**
	From	To	
1	Sheringham	Kelling Quay	Cliff
2	Kelling Quay	Cley Coastguards	Shingle ridge
3	Cley Coastguards	Blakeney Point	Sand headland
4	Stiffkey Marshes	Wells Harbour	Dissipative beach
5	Wells Harbour	Gun Hill	Barrier island
6	Gun Hill	Brancaster Staithe	Barrier island
7	Brancaster Staithe	Thornham	Barrier island
8	Thornham	Hunstanton Golf Course	Salt marsh and dune
9	Hunstanton Golf Course		Beach
10	Hunstanton Cliffs		Cliff
11	Hunstanton and Heacham Hard Defences		Man-made
12	Heacham	Snettisham Scalp	Shingle beach

6 ASSESSMENT OF BEHAVIOURAL UNITS

6.1 Blakeney - (Kelling Quag to Cley coastguard/Cley Coastguard to Blakeney Point)

The shingle ridge extending from Weybourne to the Blakeney Watch House is underlain by a glacial till ridge which is separated from the rising ground of the Salthouse-Weybourne scarp by a valley filled with Holocene alluvium. The location of the shingle ridge is, however, not entirely dependent on this underlying structure since it is eroding into its surface as it retreats landward. The long term rate of retreat of the ridge is estimated at 1m per year. However, as the ridge moves landward away from the underlying till structure, so this rate of movement may increase significantly. The shingle, of which the ridge is comprised, appears to be largely fossil material with only a very small proportion emanating from the present day erosion of the Weybourne cliffs. To the west of the Watch House, the Blakeney spit is composed of sand forming extensive sand dunes at the Far Point.

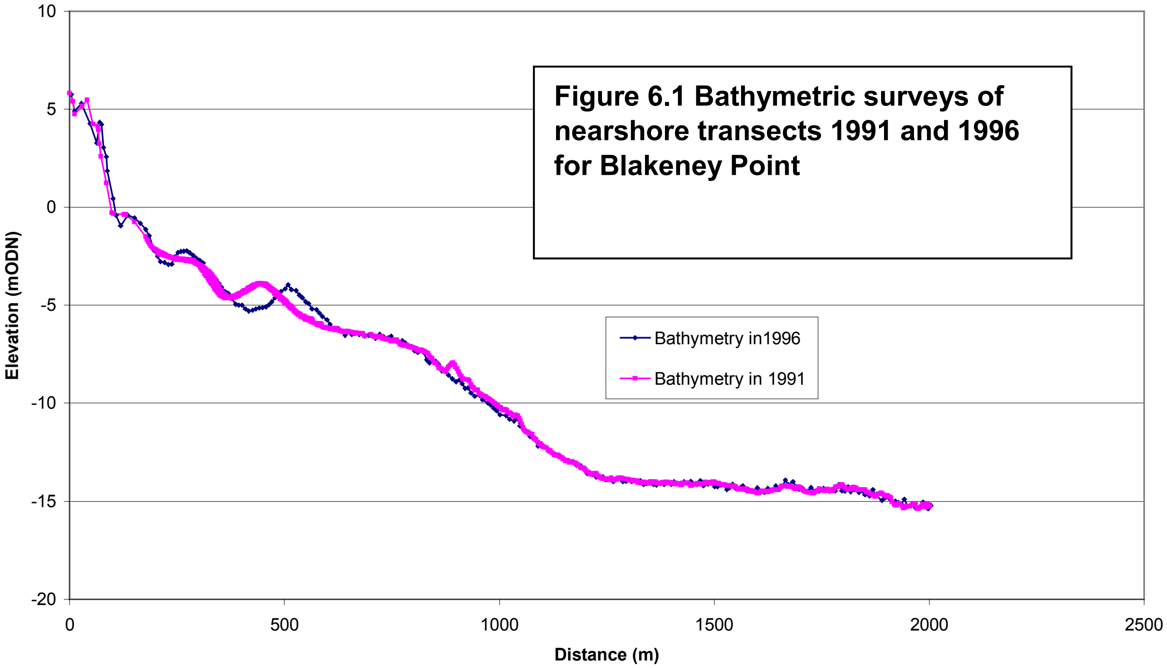
A map of 1586 (Cozens Hardy 1929) showed the shingle ridge extended only to the entrance to Blakeney Harbour. The Morden map of 1698 appears to show the far point of Blakeney spit approximately at its present location, implying a rate of advance of 18m per year during the period 1586-1698. This rapid advance is contemporaneous with, and may be caused by, the reclamation of the Cley-Kelling salt marshes.

There is some evidence to suggest that, during storm events, the Far Point receives large sand waves moving eastward from the Stiffkey inter-tidal sands to the west and shore-welding to the Point forming the characteristic dune ridges with intervening salt marsh. The Far Point and the tidal delta, as well as the entire estuarine channel of the Glaven and Blakeney Harbour have become adjusted to the reduced tidal regime introduced by reclamation of the Cley-Kelling marshes. Restoration of these marshes would entail a similar scale of readjustment.

The onshore movement of the shingle ridge is presently causing sedimentation within the outfall of the Glaven channel, north of the Blakeney Eye. The bank of the Glaven at Cley Coastguard is eroding and this may be a potential breach site, something that could occur during a major storm event. Dredging shingle from the channel to prevent such a breach would prevent the ridge form moving landwards and thus cause dislocation of its longitudinal form. However, re-routing of the Glaven south of the Blakeney Eye would provide an alternative strategy to deal with this issue.

Breaching of the shingle ridge at Salthouse occurred in 1996, probably, in part, as a result of continued re-profiling for flood defence, a process that destroys its internal structure and weakens the ridge. Allowing the ridge to attain a natural profile, one that is lower and wider than the artificial profile recently adopted, would enable a more natural and consolidated internal structure to develop which would increase the strength of the ridge. If this were the case, then it is likely that the frequency of small wash-over events would increase but the frequency of potential major breaches would decrease.

The bathymetric surveys undertaken by the Environment Agency during the period 1992 to 1996 show significant accretion in the nearshore section (0 to 1km from the upper shore) but a slight steepening of the profile in the region between 1km and 2km from the shore (Figure 6.1). While this data only covers a relatively short time period, the changes observed are characteristic of response to sea level rise, with the nearshore accreting in pace with sea level while the increased energy in the offshore causes profile migration onshore leading to steeper sea bed slopes. Further data collection and analysis would be required to confirm the nature of this response and determine whether the observed changes reflect short term perturbations of form part of a longer term pattern.



6.2 Stiffkey - (Blakeney Point to Stiffkey marshes/ Stiffkey to Wells Harbour)

The entrance to the Blakeney-Glaven estuary is marked by a large tidal delta with pronounced ebb and flood tide ramparts. The sand waves moving across this deltaic area define flood and ebb channels and also provide protection to the Morston salt marshes.

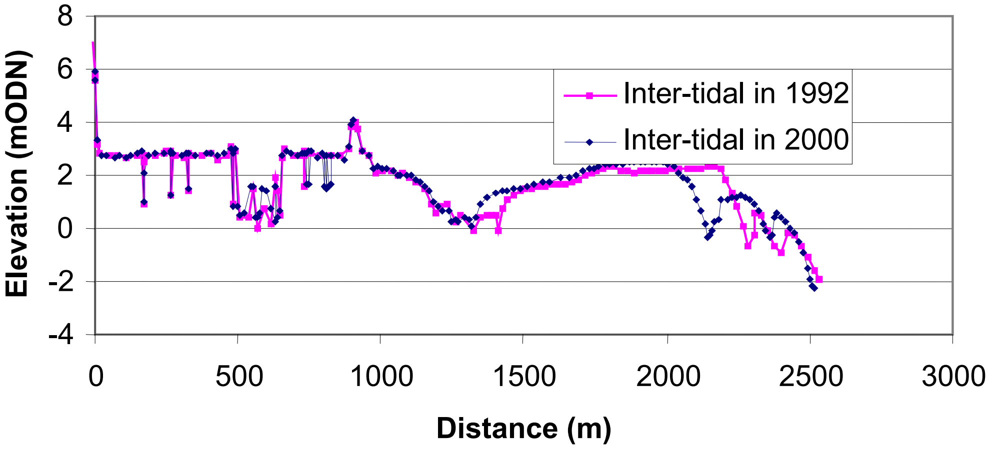
Further west the Stiffkey and Warham salt marshes make up one of the most extensive and important inter-tidal marsh areas in the country. One of their most important attributes is the fact that they merge with the rising ground along the Stiffkey and Warham Greens forming a transitional habitat that, elsewhere, has been lost to reclamation. The rising ground in some cases forms a low cliff, possibly of Ipswichian age, which effectively prevents salt marsh landward incursion as sea level rise occurs; a form of natural coastal squeeze.

The western end of this salt marsh area forms the Lodge marsh, formerly reclaimed but now largely restored to salt marsh. This area forms the ramparts of the Wells Harbour tidal delta which is the largest of five deltas along the North Norfolk coast and which forms extensive sand waves and sand flats between Lodge marsh and Holkham Gap.

The shore profiles surveyed by the Environment Agency over the period 1992 to 2000 for this region of the coast show accretion in the upper shore, that is the higher salt marshes, but a significant erosion of the lower inter-tidal, that is the sand flats and Meols (Figure 6.2). This appears to be a response to sea level rise, and would be expected to result in an onshore transgression of the entire inter-tidal profile with salt marsh advancing over the previous supra-tidal zone. In the case of the Stiffkey to Warham inter-tidal zone however, the fossil cliff described above may restrict this development.

The Environment Agency bathymetric surveys of this area of the coast, conducted during the period 1991 to 1996, show that the tendency for onshore migration of the profile extends to the nearshore zone. The marked drop-off in the seabed profile here, at 3km from the shore is shown to have migrated landward during this period, although individual sand bars do offset this movement in some places (See figure 6.3)

Figure 6.2 Intertidal profile change 1992-2000; Stiffkey



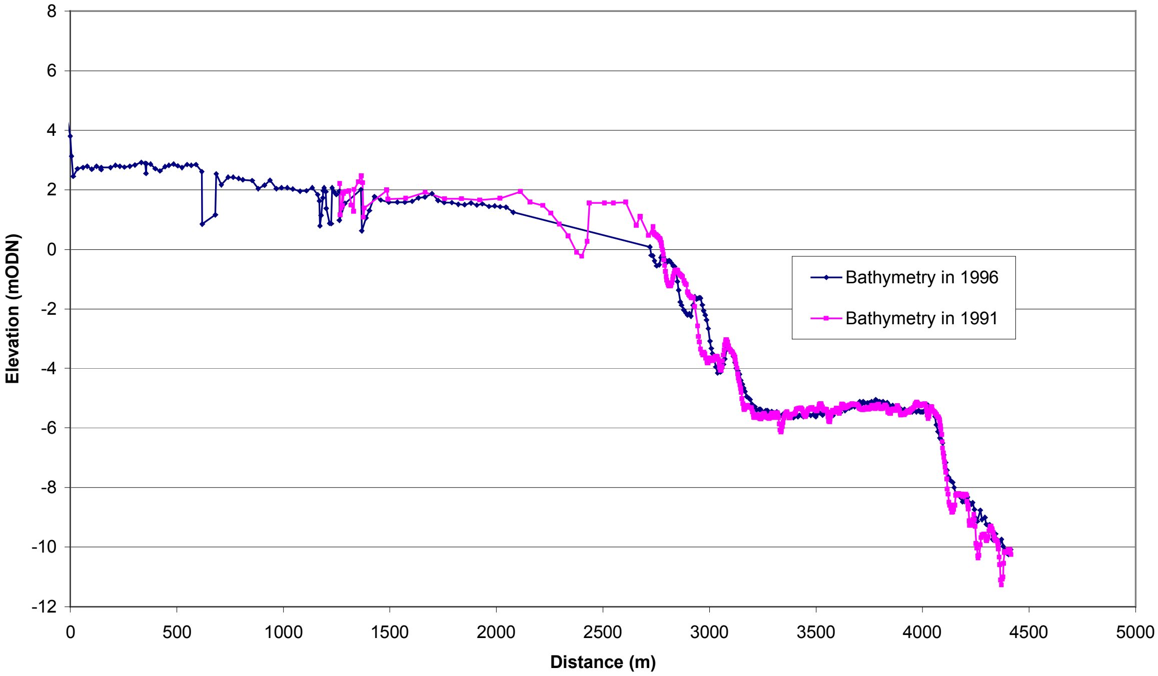


Figure 6.3 Bathymetric surveys of nearshore transects 1991 and 1996: Stiffkey-Warham

6.3 Holkham - (Wells to Gun Hill)

The coast between Wells and Burnham Overy is most notable for its extensive reclaimed marshes. Reclamation began in 1660 and continued until 1860 at which time 800ha of former salt marsh had been enclosed. The seaward margin of this reclaimed land is marked by a line of sand dunes, some of which were planted with conifers between 1853 and 1891. Some of this reclaimed area is now in arable production.

The shore and inter-tidal zone of this area forms extensive sand flats, with new dune ridges forming on the upper shore. Landward of the embryo dunes a line of fore dunes developed in the 1980s, in the shelter of which a new area of saltmarsh has formed. The rapid advance of this section of the Norfolk coast is shown both in the EA profiles and in the sediment budget for the cell which shows annual accretion rates here of 300,000m^3 per year over the past decade.

Fig 6.4 shows the Environment Agency inter-tidal surveys for this region over a decade of observations. The complexity of the movement of the profile makes interpretation difficult but it may be seen that while the lower inter-tidal area has been accreting over this period, the upper shore and particularly the dune face, has been retreating. This is again a typical response to sea level rise, with an onshore migration coupled with an overall accretion keeping pace with sea level.

The bathymetric surveys undertaken by the Environment Agency during the period 1991 to 1996 (Figure 6.5) for this region of the coast emphasise the onshore migration seen in the inter-tidal zone. Fig. 6.5 shows that the seabed slope between 1.5km and 3.0km has steepened appreciably over the 5 year period while the inner shore between 0km and 1km has remained relatively stable. As with the comments given previously, further data is required in order to determine and confirm the future rate and direction of this observed trend.

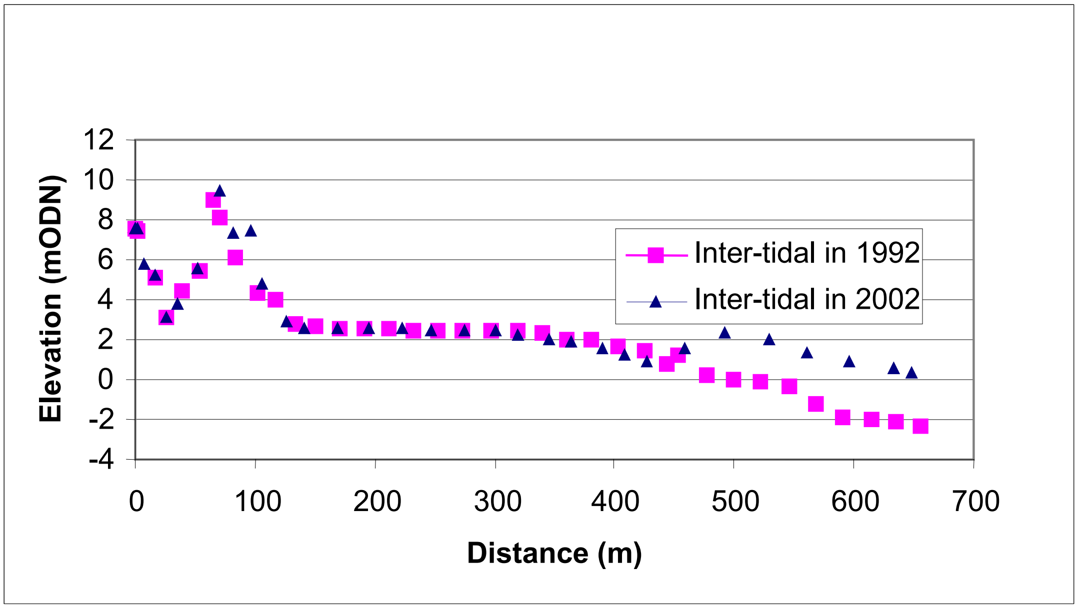


Figure 6.4 Intertidal profile change 1992-2002: Holkham

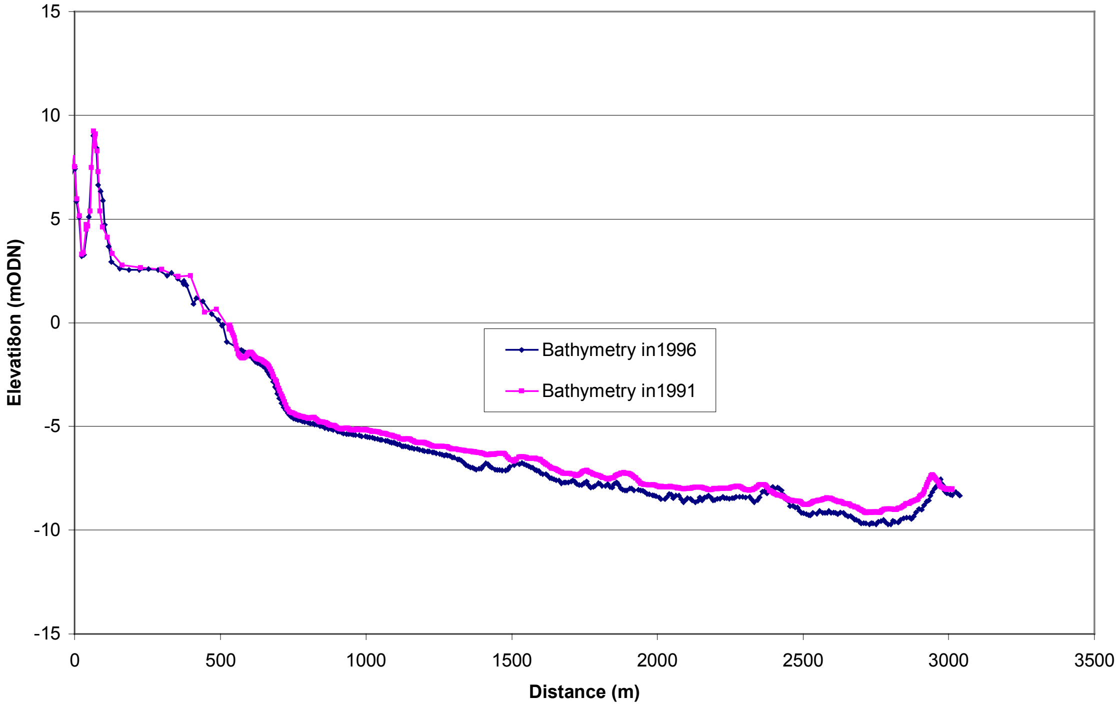


Figure 6.5 Bathymetric surveys of nearshore transects for 1991 and 1996: Holkham

6.4 Scolt - (Gun Hill to Brancaster Staithe)

The western end of the Holkham dunes, at Gun Hill is suffering erosion of its seaward margins, a development that appears to be part of a general adjustment to sea level changes, since the inter-tidal zone itself is advancing while the dune ridge retreats. The Harbour at Burnham Overy has been gradually decreasing in depth over the past 50 years, possibly as a response to the deceased tidal prism following the extensive reclamation of the Holkham salt marsh areas.

Scolt Head Island is composed of a number of sand and shingle ridges running shore normal from the longitudinal dune ridge and enclosing areas of salt marsh. The longitudinal ridge is itself suffering wash over and progressive landward migration, at a rate of 1m per year. The western end of the Scolt Island is marked by a tidal delta formed by the combined tidal discharge from Norton Creek and Brancaster Marsh.

In contrast with the adjacent area of the coast, the bathymetric surveys at Scolt show a significant accretion over the period 1991 to 1996 (Figure 6.6). This may be due to the fact that the focus of onshore sediment movement appears to be here so that sediment is temporarily stored in the Scolt nearshore area prior to its movement eastwards along the shore.

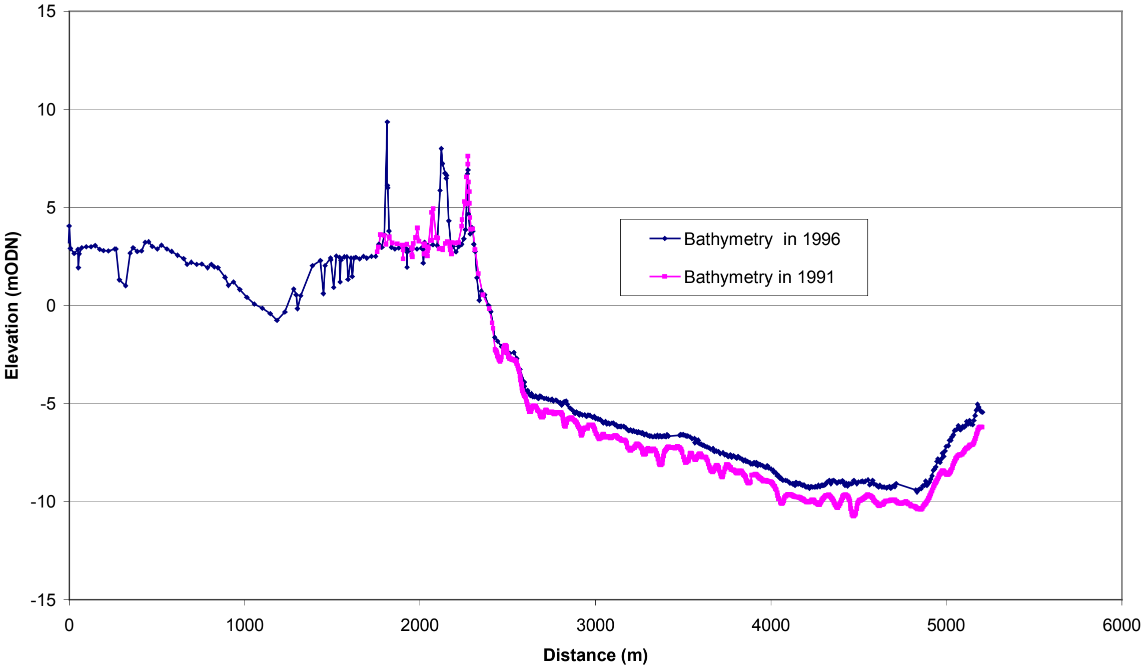


Figure 6.6 Bathymetric surveys of nearshore transects for 1991 and 1996: Scolt (Hut Marsh)

6.5 Brancaster Bay - (Brancaster Staithe to Thornham)

The landward retreat of the outer coastal dune ridge between Brancaster Staithe and Titchwell threatens the integrity of the important salt marsh area of Brancaster Marsh. Analysis of the EA shore profiles between 1992 and 2001 suggest that, overall, the area has gained rather than lost sediment, indicating that the coastal retreat around the eastern end of Brancaster Bay may be part of a general re-orientation of the shoreline rather than erosional loss. The re-orientation of this shore may itself be a response to the reclamation of the salt marshes between the shore access road and Holme.

The beaching of the Titchwell flood embankment in 1949 offers an interesting example of the manner in which restoration of such areas may proceed. The areas inundated after the breach have been colonised by salt marsh vegetation, although the density of the vegetation cover is less than that of the other Norfolk marshes. The development of a small tidal delta and the emergence of a stable tidal entrance to the marsh are also of importance as an example of the potential restoration process.

The Environment Agency inter-tidal profiles for the Thornham region during the period 1992 to 2001 indicate slight erosion of the upper inter-tidal and dune face but a significant accretion of the lower inter-tidal zone (Figure 6.7). As before, this is seen as a response to sea level rise, with the inter-tidal slope flattening and migrating landward in response to increased wave energy as water depths increase offshore.

The bathymetric surveys over the 5 year period 1991 to 1996 show that the lower inter-tidal accretion is not carried into the nearshore and an overall landward migration of the seabed would appear to be occurring as shown in Figure 6.8 resulting in a slight steepening of the seabed slope.

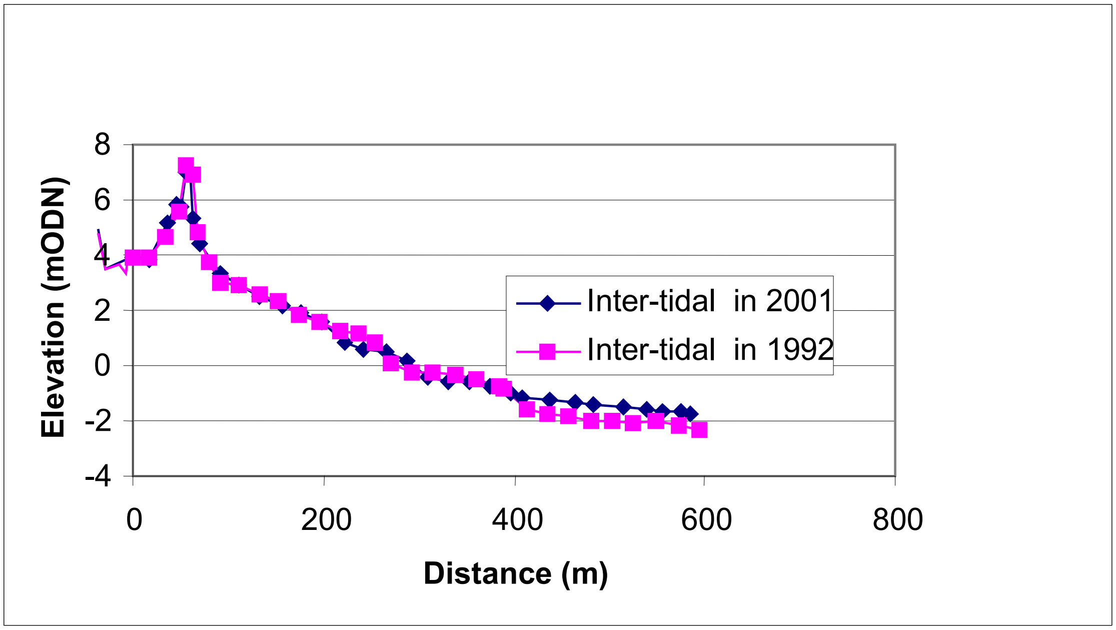


Figure 6.7 Intertidal profile change 1992-2002: Thornham

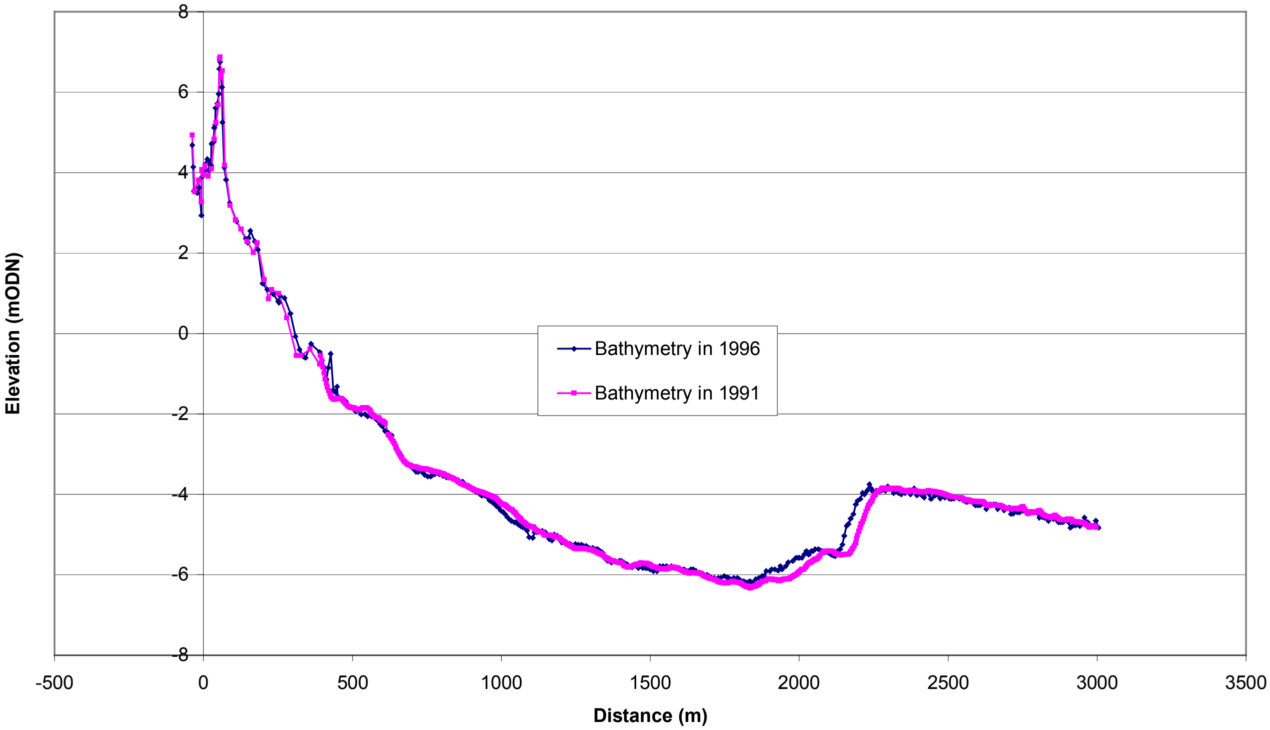


Figure 6.8 Bathymetric surveys of nearshore transects for 1991 and 1996: Thornham

6.6 Holme - Thornham to Hunstanton Golf Course

The extensive (250ha) salt marshes of the Thornham area are separated from the reclaimed Holme marshes by an embankment along the Thornham Harbour Channel. The tidal discharge from the Harbour Channel has resulted in a large tidal delta whose ramparts form a dune ridge, enclosing the Thornham marshes, on the east and Holme Dunes on the west.

The Holme dunes have been suffering rapid erosion over the recent past and, uniquely on the Norfolk coast, this dune erosion is paralleled by erosion of the inter-tidal beach and nearshore area. Analysis of the EA shore profiles between 1992 and 2001 shows that approximately 100,000m^3 per year of sediment was lost from this sub-cell. Figure 6.9 shows that dune face retreat here is much more rapid than anywhere else along the North Norfolk coast. However the Environment Agency surveys also demonstrate that a significant amount of accretion has taken place in the lower inter-tidal zone here over the past decade (Figure 6.9). This complex movement of retreat of the dune face and advance of the lower in is identical to that elsewhere along the coast (see for example discussion of the Holkham dune region above) with the difference that the rates of advance and retreat are far higher at Holme than elsewhere. Bathymetric surveys over the period 1991 to 91996 (Figure 6.10) show that a slight erosion of the entire seabed has taken place to a distance of 3km offshore.

Reasons for the more rapid inter-tidal changes here than elsewhere are difficult to define. It may be that the focus of wave energy, previously located at Hunstanton, is moving eastward in response to the deeper water over the Burnham Flats as sea level rise occurs. If this is so, then the progression of the wave focus may mean that the erosion front itself will move into Brancaster Bay over the next decade. The more pronounced response of the inter-tidal here may however be due to the effects of the reclamation of the Holme marshes in the last century and the resultant retreat of the tidal delta, which formerly offered protection to the Holme dunes from wave attack.

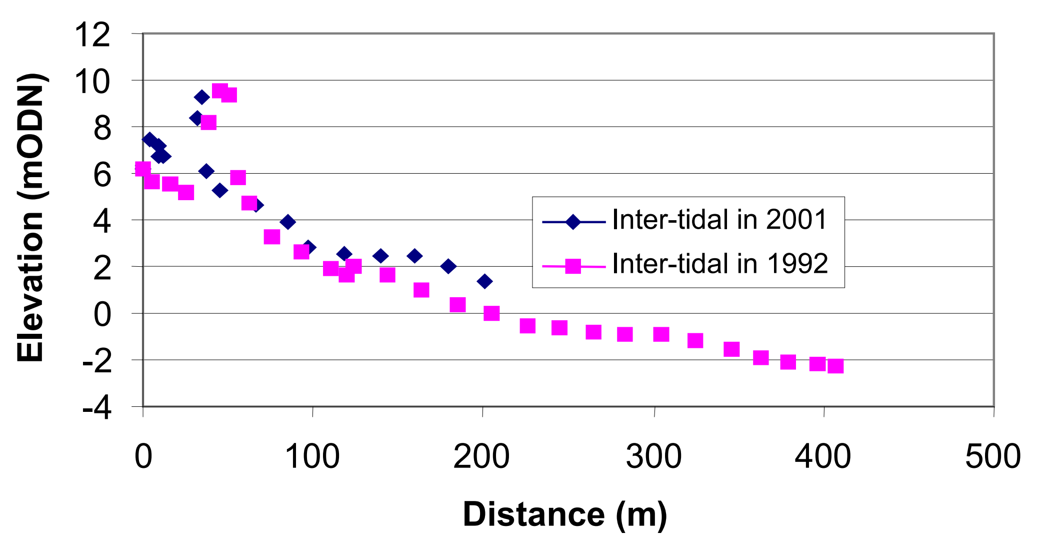


Figure 6.9 Intertidal profile change 1992-2002: Holme

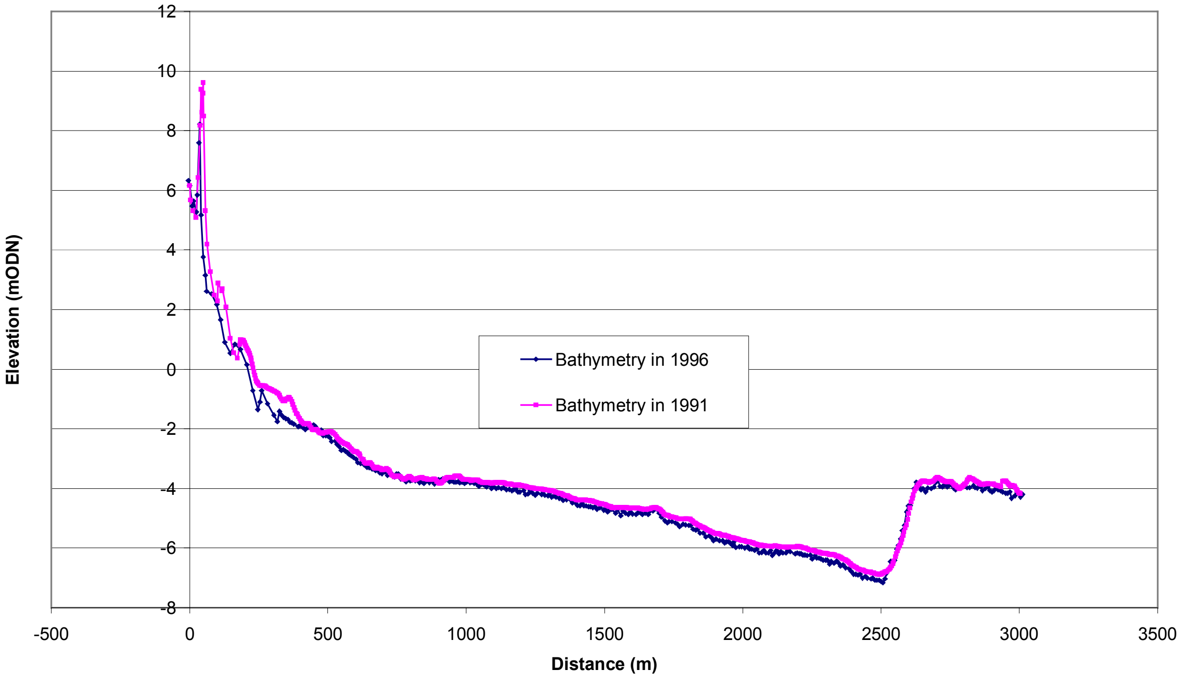


Figure 6.10 Bathymetric surveys of nearshore transects for 1991 and 1996: Holme

6.7 General assessment

6.7.1 Accretion in the central part of the coast

During the past decade (1992 -2002) the EA shore surveys, reviewed above, suggest that the coastal section in and around Holkham (Unit 5) increased in volume by around 300,000m^3 per year. The upper profile (dune edge) is, however, rolling landwards at a rate of >1m per year. At the same time the lower profile is accreting, usually by shore welding of sand bars. This can be seen in profile N1A6 (Fig 6.11) where upper shore retreat is ‘balanced’ by lower beach advance.

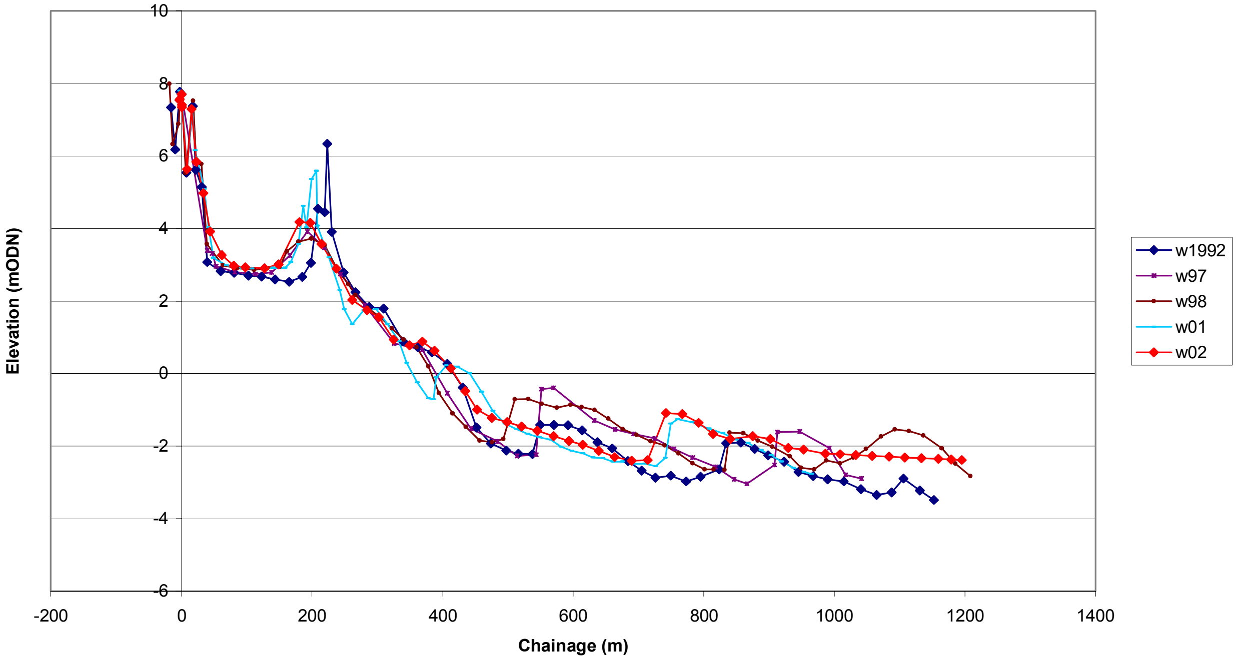


Figure 6.11 – Shore profiles for Holkham Dunes (1992-2002) showing erosion along the upper shore and accretion on the lower shore.

Based on this analysis it is predicted that the area between Scolt Far Point and Warham Meols will continue to advance as sea level rises and assuming continued sediment availability. This means that new salt marsh (since 1949 an additional 100ha has been added at Warham) would develop as well as additional areas of sand flats and shingle bars.

6.7.2 Erosion at peripheries

EA surveys show a loss in sediment in Unit 8 (Holme) amounting to 100,000m^3 per year. Note that Brancaster Bay is not shown as having a negative sediment budget despite pronounced erosion at the Golf Clubhouse. It may be that this erosion is merely part of a general re-distribution of sediment within the Unit. Overall Brancaster Bay is gaining sediment at the rate of 100,000m^3 per year.

Blakeney-Cley-Kelling shingle ridge will continue to roll back in common with other upper shore landforms along the N Norfolk coast. This may not imply loss of sediment however, since the nearshore may, again in common with other areas, be gaining even though the upper inter-tidal is losing sediment.

6.7.3 Realignment

Brancaster Bay seems to be realigning, possibly in response to sea level rise, possibly to sediment inhibition. There does seem to be some sediment redistribution rather than erosion about this change.

Lateral drift due to bathymetric changes under sea level rise must be re-examined. The overall process appears to be one of re-alignment both horizontally (i.e. change in plan-form) and vertically (i.e. upper shore rollback, lower shore accretion). This could be in response to sea level rise or to wave energy increase (i.e. flatter and wider shore in response to increased energy levels).

6.7.4 Increase in delta size

There are five major deltas along the North Norfolk coast at: Thornham, Brancaster, Burnham, Wells and Blakeney, with two minor ones at Titchwell and Warham. The response of these deltas to sea level rise should be to increase in volume.

6.7.5 Sediment availability

Sediment appears to enter the nearshore system along the Scolt ‘headland’ (see Andrews 1999). The source for this is sediment is probably Docking Shoal. The transport of sediment may be decreased by sea level rise, but the scale of change is likely to be relatively small and result in a limited reduction in volume coming onto shore.

The increase in sediment volume noted from Environment Agency surveys may represent redistribution along the coast rather than the introduction of new sediment.

7 PREDICTED CHANGE : EXISTING MANAGEMENT

7.1 Findings of the preliminary CHaMP

The preliminary CHaMP for North Norfolk (English Nature 1999) sets out the importance of the European designations and outlines the current draft set of conservation objectives for the management of the area. Against these, the impact of preferred coastal defence options (as outlined in the SMP) is identified, providing an assessment of the losses or gains to European species and habitats over the next 50 year period.

Taking the SMP as a guide, but modified by site protection where feasible, and available information, the preliminary CHaMP uses the balance of European interests lost or gained to identify the requirements for habitat replacement on the North Norfolk coast to ensure that the integrity of the European sites are maintained. Finally the plan identifies the location(s) where habitat replacement could occur to replace habitat where *in situ* protection is not possible, using a set of defined criteria.'

The findings of the preliminary CHaMP with respect to designated habitats and SPA bird populations are summarized in Tables 7.1 and 7.2. The overall synopsis is that if the defence options as set out in the SMP are continued with over a 50 year timescale then there would be a loss of freshwater and lagoon habitats with gains of marine habitats, although it is recognized in the preliminary CHaMP that the figures for the marine and sand dune element of the SAC are tentative. It is calculated that there could be a net loss of approximately 3ha of lagoons, 24ha of sand dune, 145ha of saltmarsh, a gain of 60ha of shingle and a loss of freshwater-brackish marsh and reedbed of between 70-235ha, which forms part of the 'terrestrial' element of the SPA. The preliminary CHaMP recognises that as schemes are progressed (e.g. Cley-Salthouse) that there could be changes to the estimated figures of habitat change.

7.2 Re-assessment of implications of SMP policy on habitat change

In light of the assessment of predicted geomorphological evolution of the North Norfolk coastline and proposed changes to coastal defence schemes (Cley-Salthouse) a basic re-assessment of the potential impact of SMP policy on designated features has been undertaken.

A limited amount of additional data on the North Norfolk coast (e.g. shoreline profiles) has been collected since 1999 and some further interpretation of the geomorphology of the area has been undertaken (e.g. information from the Southern North Sea Sediment Transport Study). Interpretation of this data, as set out in Sections 4-6, consolidates the general view of predicted changes to the shoreline presented in the preliminary CHaMP, although further detail on specific changes within some of the units (see description and discussion in Section 6) is presented.

With respect to the process and geomorphological data presented in this CHaMP it is therefore considered that the assessment provided in the preliminary CHaMP represents a reasoned analysis of likely changes to habitats on the basis of implementation and long-term maintenance of adopted SMP polices.

Table 7.1. Predicted habitat change for the North Norfolk coast cSAC based on continuation of SMP policy. Data as given in English Nature (1999)

Unit	Prognosis	Predicted change in area of European Habitat (50 years)				
		Sand dunes	Shingle	Lagoon	Saltmarsh	Sand and mud
Kelling Quag to Cley coastguards	Retreat the line of defence	None present	+60ha (based on doubling in width of existing bank)	+1.7ha	Not feature of dune cSAC	None present
Cley coastguards to Stiffkey marshes	Hold the line in the short term consider retreating the line in the medium term	Unknown – possible indirect loss at Blakeney Point if Blakeney fresh marsh becomes intertidal (saltmarsh)	Unknown – possible indirect loss at Blakeney Point if Blakeney fresh marsh becomes intertidal (saltmarsh)	None present	Partial re-alignment at Blakeney freshes – gains may range from 20ha to 75ha	Unknown, possible changes which may be gains or losses if Blakeney Fresh marsh becomes intertidal
Stiffkey marshes to Wells Harbour	Hold the existing line where coastal defences occur	No change	No change	None present	No change	No change
Wells Harbour to Gun Hill	Hold the line where coastal defences occur	No change	None present	No change	No change	No change
Gun Hill to Brancaster Staithe (excluding Scolt Head)	Hold the existing line of defence where coastal defences occur in the short to medium term	No change	None present	None present	No change	Unknown
Brancaster Staithe to beach access road	Hold the existing line of defence where coastal defences occur in the short to medium term	No change	None present	None present	No change	No change
Beach access road to Thornham (includes Brancaster West Marsh)	Hold the existing line in short term, retreat the line in medium term (partial re-alignment at Brancaster west marsh	c. 2ha gain	None present	None present	+8ha	Unknown
Thornham to Hunstanton golf course	Hold the existing line in short to medium term where coastal defences occur, consider retreat the line in medium to long term	Partial re-alignment, loss possibly 24ha	None present	Worst case loss of 4.5ha	Partial re-alignment at Holme – gain may range from 0-106ha	Unknown

Table 7.2. Predicted habitat change for the North Norfolk coast SPA based on continuation of SMP policy. Data as given in English Nature (1999)

Unit	Prognosis	Habitats (Changes Ha)			Birds (Max. population in each unit not allowing for habitat change)
		Reedbed	Grazing Marsh	Lagoon & other open water	
Kelling Quag to Cley coastguards	Retreat the line of defence	-0.3	-33ha (includes salt and fresh marsh)	+1.7ha	Bittern – 2 pairs breeding (reedbed) Marsh harrier – 2 pairs breeding (reedbed) Avocet – breeding; 60-80 pairs @ Cley, 34 pairs @ Salthouse (lagoon, grazing marsh) Brent goose – 1834 wintering Wigeon – 2492 wintering Pink-footed goose – 28 wintering
Cley coastguards to Stiffkey marshes	Hold the line in the short term consider retreating the line in the medium term	-3.0 possible	Partial re-alignment losses will range from 20-75ha	None present except ditches	Bittern – 1 pair breeding Marsh harrier – 1 pair breeding Avocet – 1-2 pairs breeding Brent goose – 1519 wintering Wigeon – 1518 wintering Pink-footed goose – 13 wintering
Stiffkey marshes to Wells Harbour	Hold the existing line where coastal defences occur	None present	None present	None present	No freshwater habitats in this unit
Wells Harbour to Gun Hill (includes Holkham)	Hold the line where coastal defences occur	No change	No change	No change	Bittern – 1 pair breeding Marsh harrier – 5 pairs breeding Avocet – 19-48 pairs breeding Brent goose – 5000 wintering Wigeon – 8000 wintering Pink-footed goose – 12000 wintering

Table 7.2 Continued

Unit	Prognosis	Habitats (Changes Ha)			Birds (Max. population in each unit not allowing for habitat change)
		Reedbed	Grazing Marsh	Lagoon & other open water	
Gun Hill to Brancaster Staithe (includes Burnham Norton marshes)	Hold the existing line in the short to medium term	No change	No change	No change	Bittern – 1-2 pairs breeding Marsh harrier – 2-3 pairs breeding Avocet – 25 pairs breeding Brent goose – 2135 wintering Wigeon – 3095 wintering Pink-footed goose – 50 wintering
Brancaster Staithe to beach access road	Hold the existing line in the short to medium term	None present	None present	None present	No freshwater habitats in this unit
Beach access road to Thornham	Hold the existing line in short term, consider retreat the line in medium term Partial re-alignment at Brancaster west marsh	+2. Possible losses at Titchwell	-10	Possible losses at Titchwell	Bittern – feeding Marsh harrier – 2-3 pairs Avocet – 25 pairs Brent goose – 481 wintering @ Titchwell; 500 @ Brancaster Wigeon - 435 wintering @ Titchwell; 100 @ Brancaster Pink-footed goose – 10 wintering
Thornham to Hunstanton golf course (includes Holme grazing marsh)	Hold the existing line in short term, consider retreat the line in medium to long term	Potentially –9ha	0-106ha loss	Potentially loss of 4.5ha	Bittern – feeding Marsh harrier – no data Avocet – 6-22 pairs wintering Brent goose – 673 wintering Wigeon – 1731 wintering Pink-footed goose – 230 wintering
Total		Approx. 10ha loss	63-224ha loss	Approx. 2.8ha loss, possibly slightly more	

However, since production of the preliminary CHaMP there has been a re-assessment of the proposed flood defence scheme at Cley-Salthouse. One possible outcome of the re-assessment is that a scheme could be advanced which results in the development of a habitat complex different to that that originally envisaged. The basic differences are set out in Table 7.3. It should be noted that this re-assessment is made on the basis of a proposed flood defence scheme (November 2002) and therefore the predicted habitat changes represent a preliminary estimation that may be subject to change.

Apart from the proposed changes to the Cley-Salthouse scheme there have been no other changes to the adopted SMP policies. The general broad natural function of the North Norfolk coast, analysis of the geomorphological processes and likely evolution of the coast suggests that there are no significant changes to the situation presented in the preliminary CHaMP. However, this does not necessarily lead to the conclusion that all of the habitats present on the coast are sustainable in the longer term as it is based on consideration of the existing SMP policies with respect to a multitude of other factors. Taking a more dynamic and functional approach towards consideration of the development of the coast and its associated habitats leads to potentially different scenario for the overall management of the coast. This is presented and discussed in more detail in the following sections.

Table 7.3 – Differences in habitat change between original and potential schemes at Cley-Salthouse. Figures for original provided in English Nature (1999).

Scheme	**Habitat**						
	Sand dune	**Shingle**	**Lagoon**	**Saltmarsh**	**Sand & Mud**	**Reedbed**	**Grazing marsh**
Original scheme	None present	+60ha	+1.7ha	Not feature of North Norfolk cSAC	None present	-0.3ha	-33ha (including salt and fresh marsh)
Possible revised scheme	None present	+60ha	Increase in area	+225ha	Increase	-55ha	-170ha

Predicted change: development towards a restored natural system

7.3 Long term predictions

The analysis presented in section 6 suggests that the North Norfolk coast sediment budget is a positive one and that sediment input may even have accelerated over the past few decades. One conclusion that may be drawn from these results is that the coastal system and associated habitats is not deteriorating at the present time, but appears to be keeping pace with environmental change. While this does not mean, of course, that the mosaic of habitat on this coast is unchanging it does indicate that the North Norfolk coast is in a healthy functioning condition. There are localised areas where change is occurring, notably erosion of the dune frontage at Holme, but aspects such as this may be a response to larger scale change resulting from previous reclamation. However, it is apparent that unlike other areas of the East Anglian coast, the issue of coastal squeeze and loss of saltmarsh habitat is not an issue in North Norfolk. This could be due to the fact that the Norfolk coast is relatively ‘natural’ (in comparison with Essex) and that there is a positive sediment budget. Together, these elements perhaps provide the coast and its constituent habitats with a greater ability to respond to large-scale change such as sea-level rise.

There is one exception to this positive report and that is the grazing marsh habitat. These reclaimed marshes can be regarded as removed from the otherwise healthy functioning coastal system and, as discussed previously in Section 4.3.5, are becoming increasingly out of phase with the remainder of the coast.

The long term future of these grazing marshes in the face of sea level rise and within the context of a functional and dynamic coastal system must be questioned. It is difficult to escape the conclusion that their continued maintenance against the trend of the surrounding system will become increasingly difficult and expensive. It may be that, over the short term, including perhaps the 30-100 years of the CHaMP predictive period, some if not most of these important habitats should be maintained, but nevertheless consideration should be given to their context within the rest of the system and opportunity for return to an integral part of the natural tidal function. It is therefore considered that one of the purposes of this CHaMP should be to provide some guidance as to the procedures that are necessary in the next 30-100 years to allow a gradual transition from grazing marsh to tidal marsh without major disruption to the ecology of the North Norfolk coast and its internationally designated nature conservation interests.

7.4 The reclaimed marshes

The North Norfolk coast has been considerably modified by reclamation over the past three centuries. The resultant mosaic of freshwater marshes, salt marshes, dunes, beaches, sand and mudflats is of international ecological importance. Nevertheless, as sea level rise and climatic change progress, the maintenance of the freshwater grazing marshes will become increasingly difficult (see section 4.3.5) and may threaten the ability of the coast to respond to such changes:

- Drainage of the freshwater marshes will become increasingly difficult as sea level rises. This will be (and is) exacerbated by increased wash-over across beach ridges (e.g. Cley-Salthouse) Freshwater habitats are also likely to become increasingly brackish due to saline intrusions;
- The enclosure of these freshwater marshes removed a significant proportion of the envelope of Holocene sediment from the coastal system and in some areas this has inhibited the natural adjustment of the coast to changes in sea level.

While there appears (from Environment Agency surveys) to be sufficient sediment entering the system at the present time to allow such response, this may not continue into the future; and

- The reduction in tidal prism caused by the enclosure of tidal marshes, has also led to a reduction in the size and extent of tidal deltas, and may be one reason for the apparent re-alignment of some sections of the coastline (such as Brancaster Bay) or even the loss of some habitat as at Holme.

It is apparent from the existing ecology of the freshwater/brackish grazing marshes of the North Norfolk Coast, particularly their ornithological interest, that this habitat is of key importance to the overall conservation status of the area. This is reflected by their designation as part of the North Norfolk Coast SPA and Ramsar site. Given this importance, it could be undesirable to restore the marshes to tidal processes within the time frame of the CHaMP. This stems from consideration of the overall ecological resource that the area represents and the balance of interests between coastal and 'terrestrial' features. Allowing full reinstatement of the marshes to tidal processes over the time period of the CHaMP could result in an effective resource loss with respect to freshwater/brackish grazing marsh habitat, particularly if replacement habitat to maintain the level of ecological interest is not available or provided within this time framework.

The CHaMP therefore proposes that a phased, long term approach (i.e.>100 years) to the restoration of the entire North Norfolk coastline to natural processes should be undertaken. Rather than allow such restoration to become an imperative, the concept of phased action is introduced into the management of the coast so that ultimately the transition from enclosed to open process is a smooth one. This would entail the eventual restoration of five major areas of freshwater marsh: Cley-Salthouse; Blakeney Freshes; Holkham; Deepdale; and Holme. Each of these areas are examined in the following section to assess how far action should be taken in the next 100 years to facilitate the transition from freshwater/brackish to tidal/saline conditions. This approach also allows consideration of the balance of interests, incorporating habitat creation to replace freshwater/brackish marsh, to be taken in a flexible and ultimately more responsive manner.

8 PROPOSED PHASED HABITAT RESTORATION

8.1 Introduction

For each of the enclosed marsh areas a brief analysis has been made of the existing situation and likely future evolution of the area with respect to the nearshore coastal system. This is then followed by an assessment of the timing of any required action, the type and extent of habitat that would change and any potential requirement for habitat replacement.

8.2 Cley-Salthouse

As noted in Section 6.1 the shingle ridge along the Kelling to Cley frontage has been retreating landward at the approximate rate of 1m/yr and is also currently re-profiled as a flood defence measure. However, it is considered that the re-profiling operation contributes to instability in the ridge and may have been a causal factor in the breach of the ridge and scale of the flooding in 1996.

To enable the long-term return of the marshes to a more integral element of the dynamic coast it is proposed that the ridge should be allowed to adopt its ‘natural’ form and function. This could be achieved through active intervention by re-profiling the ridge to a more stable form (i.e. wider and lower) and then allowing wave-driven erosional and accretional processes to modify and re-form the ridge. Alternatively, the ridge could be allowed to attain its natural form through the action of coastal processes alone, although with this option there is a greater possibility of short-term failure of the ridge under storm conditions. With either technique, the result would be a much wider and stable structure. A potential comparison of the resulting structure could be made with the shingle ridge to the west of the access road. This is significantly wider that the Cley-Kelling section and, noticeably, provides suitable habitat for the growth of annual and perennial vegetation. There is currently very little or no vegetation along much of the Cley-Kelling section.

As a result of the re-forming of the ridge, the potential for overtopping and flooding of the marshes to landward may not actually be significantly altered. Much of the site is already subject to brackish conditions, and indeed part of the site is a saline lagoon cSAC. However, some changes to the existing ecological interests can be anticipated over the next 50 years. This impact would only be of short-medium term consequence (probably less than 30 years) as the habitats and species adjust to a more ‘natural‘ regime. However, in order to enable management of the ecological interests in the short term and promote successional change, it is suggested that more efficient and extensive drainage facilities should be constructed in order to enable the rapid egress of floodwater from the site.

Over the longer term, the aim would therefore be to enable the existing suite of ‘terrestrial’ habitats to succeed to habitats typical of intertidal or coastal barrier systems. Potentially a mosaic of dynamic coastal habitats could be created typified by saltmarsh, areas of mudflat, saline pools and lagoons and shingle washover fans from the ridge. From an ecological perspective such habitats could contribute to the overall dynamic functioning of the coastline and to the totality of designated features.

8.2.1 Timing

- Artificial maintenance of the shingle ridge should be discontinued within <5 years. This would lead to the development of a wider but more stable structure and an increase in smaller overtopping events, but a decrease in large-scale

inundation. Adequate drainage to allow the egress of flood waters would need to be installed;
- The area should then be allowed to develop naturally, flood management being controlled through improved drainage arrangements. The saline-brackish-freshwater transition marsh would evolve over the next 50 years; and
- There would be a presumption that, after this 50 year transition period, full restoration to tidal habitats would be a possibility.

8.2.2 Techniques

- Sluice management;
- Warping; and
- Phased, partial restoration

Further information on techniques for managed realignment are given in Appendix A.

8.2.3 Habitat implications

Over the longer term, the aim would therefore be to enable the existing suite of habitats to succeed to habitats typical of intertidal or coastal barrier systems. This scenario should not be viewed as one of ecological impoverishment or detriment, but one of restoration and change. In fact a reversion to the state of the site pertaining about 50 years ago when flood management of the shingle ridge was first introduced. There are likely to be some habitats and species that would effectively lose out, but conversely there would be gains for others, as highlighted below:

- \- 55ha reed bed;
- \- 170 ha ‘terrestrial’ wetland habitat to landward of shingle ridge;
- \+ 60 ha shingle, due to re-profiling of ridge; and
- +170-225ha brackish marsh

8.2.4 Provision of replacement habitat

The marshes at Cley-Salthouse provide habitat for breeding birds (avocet, bittern and marsh harrier) and wintering birds (brent goose, wigeon and pink-footed goose). These species make differing uses of the habitats present in the area and all would be affected to one extent or another by the change from a prevalently freshwater wetland complex to one that would be more tidally dominated. It is likely that bittern would be lost from the site as this species makes use of the reedbed (breeding) and the freshwater marshes (for feeding). On a purely areal basis, if there were a potential requirement to address impacts on the use of the area for breeding bittern then an area in the region of 40-50ha of reedbed may need to be replaced.

The impact on the wintering species is more difficult to discern. Potentially, pink-footed goose, brent geese and wigeon will make use of saltmarsh for both feeding and roosting and therefore one might expect that either numbers would be maintained or possibly reduced, but that the potential of the site to support these species would not be lost. The existing level of use of the area by pink-footed goose is very low compared with other sections of the North Norfolk coast and given this factor the change in habitat would be unlikely to have a significant impact on population levels of this species. The numbers of brent goose and wigeon are much higher and the fields behind the shingle ridge provide good, relatively undisturbed feeding areas for these species. Following more frequent tidal inundation and conversion to saltmarsh it is likely that the overall suitability of the site as feeding habitat for these species would be reduced, but there is no reason why birds would not use the marshes for roosting, particularly if significant areas of open water are present. There is also the possibility that over time that a shift in feeding patterns could occur, as has happened with brent geese, which have moved onto estuarine pastures following the die-back and loss of large areas of eelgrass (*Zostera*) to disease in the 1930's-1940's, and a greater use of saltmarsh as a feeding habitat could be made.

The use of the site by breeding avocet would be unlikely to be diminished and could be enhanced. The potential creation of a mosaic of saltmarsh, saline pools and lagoons and shingle wash over structures would provide ideal habitat for breeding and feeding avocet. Within such an area though, breeding success would depend on the frequency and full extent of tidal inundation.

This brief analysis therefore suggests that there would be a requirement to replace the loss of habitat used by bittern, particularly as reedbed habitat is limited along the coast and other areas could also be threatened by potential tidal inundation. In order to support a breeding population of two pairs of bittern an area of approximately 40ha of reedbed would be required (20ha/pair). However, bittern also make extensive use of grazing marsh dykes and pools for feeding and ideally a combination of these habitats would provide a more suitable supporting site. Potentially, an area of approximately 100ha of riverine valley floor habitat could be available in the Glaven valley. This is adjacent to the existing site and the potential for relocation of these species would therefore be maximised. Other areas along the coast are also suitable for the creation of wetland habitat and are mentioned in subsequent sections.

It should also be noted that the change from freshwater/brackish marsh to saltmarsh/lagoons and shingle may favour a number of other bird species present within the SPA area (e.g. breeding terns).

8.3 Blakeney Freshes

The River Glaven outfall is increasingly unsustainable between Blakeney and Cley Eye due to the roll back of the shingle ridge. Artificial maintenance of the channel (by dredging) is likely to cause the shingle ridge to either breach or develop an inflexion at this point. Inflexion would ultimately result in a breach in adjoining sections of the ridge and the tidal inundation of land behind the ridge. In order to deal with this issue it is considered that there are two potential management options:

- Allow the Glaven to breach the shingle ridge between Blakeney Eye and Cley Eye. This would have implications for the siltation of Blakeney Harbour and for access to Blakeney Point; and
- Allow the Glaven to reach Blakeney Harbour via the Blakeney Freshes. This could be achieved by (1) creating an artificial embanked channel immediately south of the Blakeney Eye (2) embanking and restoring Great Barnett Creek (3) restoring the entire Freshes to tidal processes.

8.3.1 Timing

- In view of the ultimate necessity (as maintained in this report) for restoration of the freshwater marshes of the North Norfolk coast, and in view of the urgency of finding a managed solution to the problems of the Glaven outfall, it is recommended that the re-routing of the Glaven be considered as an immediate priority.

- A major difficulty involved in any plan to re-route the Glaven through the Blakeney Freshes would be the incorporation of the outfall from the Cley-Salthouse marshes. This problem is detailed below in a discussion of the techniques that could be adopted under each option. In view of this, it is proposed that a phased approach would be necessary in which the first stage would incorporate the existing enclosed Cley-Salthouse marshes and an embanked channel for the Glaven crossing the Blakeney Freshes. This embanked channel could not be sustained over the long term since the shingle ridge would eventually migrate into it. Before this happens, and possibly within the next 200 years, the second stage would involve the restoration of the Freshes to full tidal processes.

8.3.2 Techniques

A new embanked channel running east-west immediately south of the Blakeney Eye would need to incorporate the tidal sluice outfall from the Cley marshes. This means that the new channel would enter the Freshes approximately 200m south of the present location of the shingle ridge. The channel would exit from the west of the Freshes approximately 300m north of Great Barnett Creek, so allowing it to avoid cutting across existing saltmarsh and facilitating its junction with the existing Blakeney Channel. This configuration would minimise loss of fresh water habitat (see below) but would be affected by shingle ridge migration blocking its entrance to the Freshes within an estimated period of 200 years. At this stage, a more southerly route would be necessitated. The new channel could be designed to incorporate a natural meander wavelength and thus reduce the bank erosion that would occur on a straight cut.

The Great Barnett Creek provides a natural pathway across the Freshes that may at one time have acted as an outfall for the River Glaven. Restoring this creek by embanking and connecting it to the Glaven would mean that the existing Cley tidal sluice would outfall into a southerly flowing spur of the realigned Glaven and may suffer increased sedimentation and blockage. The realigned Glaven would flow via Great Barnett Creek to exit the Freshes some 400m north of Blakeney Quay, but a secondary cut would need to be made across existing saltmarsh in order for it to enter the Blakeney Channel. This would allow the realigned river to scour the approach channel into Blakeney. The embanked channel would not be affected by shingle ridge migration for an estimated period of 350 years at which stage a more southerly route would again be necessitated. In view of the problems associated with the Cley tidal sluice under this option, it could only be adopted if Cley marshes were restored to full tidal processes (see previous section for discussion in relation to this aspect).

Restoration of the entire Blakeney Freshes would allow the Glaven to be re-routed along the course of the Great Barnett Creek, but without the necessity for embankments. The realigned river channel would then be free to migrate across the restored marshes and would therefore respond naturally to shingle ridge migration. The outfall discharge from the Cley marshes would again present a difficulty since it would need to flow through a natural tidal creek to meet the realigned Glaven and may be subject to accretion and blockage. This means that the option of restoring the Blakeney Freshes should only be considered as an integral part of a wider plan to restore the Cley-Salthouse and Blakeney Freshes.

8.3.3 Habitat implications

- A breach by the River Glaven through the shingle ridge at Blakeney Chapel would result in siltation of the existing Cley Channel to the north of the Blakeney Freshes. This would eventually result in a change of up to 300ha brackish/freshwater grazing marsh to saltmarsh.

- Re-routing the R Glaven through an artificial channel south of the Blakeney Eye would involve the loss of up to 10 ha of grazing marsh habitat. Although the grazing marshes in the Freshes are generally relatively species-poor semi-improved grassland, they become more species-rich towards the north where the channel would run (under this option). Saltmarsh vegetation also increases in extent towards the north of the site, particularly in depressions immediately behind the sea wall. This option, as with all of the options involving re-routing the Glaven, would result in siltation of the existing Cley Channel north of the Freshes and potential change of 300ha of brackish/freshwater grazing marsh to saltmarsh.

- Re-routing the Glaven across the Freshes via the Great Barnett Creek would result in a loss of 7.6 ha of reedbed habitat, some open water habitat in the main creek and associated channels, and a small area of grazing marsh beneath the new walls. This option results in the overall loss of only 5% of the site area, but 75% of the total reedbed area (10 ha) of the site (i.e. that lying within Great Barnett Creek). This option results in a potential gain of 300ha of salt marsh in the Cley Channel as discussed above; and

- Restoration of the entire Blakeney Freshes would involve the loss of 170ha fresh water marsh including 157ha of grazing marsh, 3ha of open water habitat, mainly in the main Great Barnett Creek and associated channels, and 10 ha of reed beds. Under this option there would be a potential gain of 470ha of salt marsh, including 170ha within the Freshes themselves and 300ha in the Cley Channel area.

8.3.4 Replacement Habitat

- Approximately 35ha of freshwater marsh in Stiffkey and Wells East valleys could potentially be suitable for the replacement of existing freshwater ecological interests of the marshes at Blakeney. This is in addition to other sites mentioned in following sections.

8.4 Holkham

The 800ha of reclaimed saltmarsh (comprising grazing marsh and arable land) between Wells Harbour and Burnham Overy Staithe is relatively stable. There are no reasons for urgent action to restore this area to tidal processes, apart from the necessity to maintain existing defence standards as sea level rises.

An National Rivers Authority report (IECS 1992) examined several options for the future management of the flood defences for this area (do nothing, maintain, total restoration, partial restoration and tiered defences) and concluded that maintain was the preferred option.

In addition to the arguments presented by IECS (1992) there is the possibility that the observed retreat of the Gun Hill dunes could be offset by restoration of Holkham marshes. This would increase the tidal prism, lead to ebb delta progradation and allow the dunes to develop seaward. However, this goal could be achieved equally by restoring Deepdale marshes (see below). Given the conservation importance of Holkham marshes the preferred option would be to restore the marshes at Deepdale.

8.4.1 Timing

- It may be concluded that progress towards restoration of the Holkham area may be postponed until after the 100 year period under consideration in this CHaMP.

8.4.2 Techniques

- None necessary

8.4.3 Habitat Implications

- None.

8.5 Deepdale

The 250 ha of freshwater marsh lying between Brancaster Staithe and Burnham Overy Staithe is currently mainly used for arable cultivation (approximately 60% of area). It represents therefore a major potential habitat area that could be realised. Restoration of this area would:

- Improve navigation in the Brancaster and Overy harbours;
- Enlarge the ebb delta (either at Brancaster or Overy – or possibly both) with consequent habitat increase on upper shores;
- Provide an additional area of salt marsh/intertidal habitat (250ha); and
- Lead to the loss of existing SPA/Ramsar wetland habitat (grazing marsh) in either Overy or Brancaster/Norton creeks.

8.5.1 Timing

In view of the potential difficulties in maintaining the coastal defences at this site, and consideration of the habitat gains that could be advanced, it may be that a programme for restoration of these marshes may be developed within the first 50 years of the CHaMP.

8.5.2 Techniques

- Warping up of marsh surface (see Appendix A for description);
- Tiered defence as first phase; and
- Outfall into Overy and Eastern Norton.

8.5.3 Habitat Implications

- Loss of 100ha grazing marsh;
- Gain of 250 ha salt marsh;
- Gain of sand dune habitat; and
- Loss of a small area of existing salt marsh within Overy Creek.

8.5.4 Replacement Habitat

- 10ha within the River Burn; and
- 200-300ha of potentially suitable land in the Heacham/Snettisham area.

8.6 Holme

The erosion of the Holme dunes and foreshore over the past decade is documented by Environment Agency beach profile survey data. The recession may be due to the gradual adjustment of this end of Brancaster Bay to the progressive reclamation of the marshes at Holme (but perhaps including Titchwell Lagoons and the Brancaster (golf) marsh).

The enclosure of 150ha of fresh marsh lying immediately seaward of Holme village would have reduced tidal prism by 1.5 million m^3 which may have represented 40% of the total prism prior to reclamation.

Restoration could:

- Increase the ebb delta area;
- Prevent further loss of sand dunes; and
- Prevent further modification of Brancaster Bay.

8.6.1 Timing

- In view of the practical problems involved in preventing further dune erosion on this frontage, the potential exists for both loss of dune habitat and, if an unmanaged breach occurs as a result, of freshwater habitat to landward. As a consequence there is the possibility that relatively urgent geomorphological engineering may be required along this frontage; and
- It may be necessary to consider restoration immediately, that is within the next decade.

8.6.2 Techniques

- Secondary defence needed at Golf Course (western) end of the fresh marsh;
- Breach the existing defences south of Broad Water; and
- Warping not recommended, as this would significantly decrease the tidal prism

8.6.3 Habitat Implications

- Change of 150ha fresh/brackish marsh to saltmarsh;
- Gain of sand dune (1 to 2 ha); and
- Gain in sandflat.

8.6.4 Replacement habitat

- 200-300 ha Heacham/Snettisham (but see Deepdale provision above)
- Potential relocation of SPA designated freshwater interests further inland (e.g. The Fens). Further information on this aspect is provided in Section 10.3.

9 HABITAT CREATION REQUIREMENTS

9.1 Introduction

On the basis of the analysis undertaken for the CHaMP it is apparent that with a continuation of existing SMP policy and implementation of the potential scheme at Cley-Salthouse that there may be a requirement to replace the loss of freshwater/brackish grazing marsh. In total (i.e. for the entire CHaMP area) this would equate to approximately 65ha of reedbed and 360ha of wet freshwater/brackish grassland and 2.8ha of open water/brackish lagoon. Potential locations for the replacement of this habitat are mentioned under each of the unit discussions (see Section 9) and this section therefore concentrates on the ecological aspects of the habitat creation requirement, particularly with respect to the issue of the integral maintenance of all of the various ecological interests. This aspect is also considered in the discussion of the Cley-Salthouse unit (Section 9.1).

9.2 Grazing marsh and wetland habitat

It is considered that the maintenance of existing designated areas of freshwater/brackish marsh within the North Norfolk CHaMP area may not be sustainable in the long term (e.g. the marsh and lagoon complex at Cley-Salthouse). If these areas are allowed to revert to intertidal and more saline influenced habitats then there may be a requirement to replace the designated terrestrial interests that would be lost. This aspect has been touched upon and discussed briefly with respect to individual areas in the description of each of the Units above (see Section 9). This section therefore concentrates on the generic issues associated with this factor and discusses some of the principles that could be involved.

9.3 Grazing marsh

While it is apparent from managed re-alignment schemes that have been undertaken that the creation of intertidal habitat is feasible and ecological interest can be relatively rapidly re-created (see information in Appendix A), the re-creation of wetland grazing marsh habitat may be more difficult. Criteria for the restoration and re-creation of wetland grassland are briefly outlined in Appendix A and will also be contained in the habitat creation guide being produced as part of the Living With the Sea project.

One of the key criteria is to ensure that a suitable source of freshwater is available and that the physical topography of the land enables a network of slowly draining dykes and ditches to be established. Although the vast majority of agricultural land along the Norfolk coast has been improved and drainage infrastructure put in place there is certainly scope for the installation of new drainage systems. Land with underground drainage may pose more of a problem and would require blocking up in order to establish surface water features.

From an ecological perspective the creation of grazing marsh/grassland habitat with transition to coastal habitats would be the most beneficial. However, this would require specific physical parameters to be met (e.g. topographic levels which would prevent frequent tidal inundation) and may therefore not be achievable within the confines of the CHaMP area. Creation of grazing marsh habitat adjacent to the open coast would also have to take into account predicted sea-level rise so that future tidal flooding was not going to be a significant management issue and detrimental to the habitats created. The likely specific nature of trying to create natural coastal-terrestrial wetland habitat transitions therefore suggests that the creation of wetland low-lying grassland would have to be undertaken landward of existing flood defences or in areas where topography enabled such transitions to occur naturally. From a sustainability perspective it would also therefore make sense to ensure that identified areas for freshwater habitat creation were protected in the long term by tidal flood defences.

The alternative to the creation of large areas of grazing marsh habitat adjacent to the coast is to examine the ecological interests of the habitat and determine whether an estuarine location is actually required. Effectively, a coastal location provides a saline influence and leads to the establishment of plant and animal communities, which occupy the niches developed in brackish-freshwater transitions. These communities are quite specific and are not found in grazing marsh habitat occurring in freshwater floodplain areas. This particularly applies to the plant and invertebrate communities of dykes and ditches and areas of grassland over which infrequent tidal inundation or saline seepage occurs. Re-creating grazing marsh which supports these brackish water communities requires a coastal location and could effectively only be undertaken in such locations. However, many of the bird species associated with coastal grazing marshes are also typical of lowland wetland grassland habitat within the UK.

The situation may therefore require that the focus on the coast should be on the recreation of terrestrial areas lost to re-alignment where transitional saline-freshwater habitats (e.g. borrowdykes, inundation grassland etc.) are re-created rather than the expansive areas of grazing marsh which support wider ranging and mobile bird populations. The exact re-creation of areas such as Cley-Salthouse or Holme Marshes may therefore not be required if ecological niche replacement is progressed. In this instance the re-creation of the brackish-freshwater habitats in order to support plant and invertebrate communities could be undertaken under two slightly differing scenarios:

- Re-creation of natural brackish-freshwater habitats through the restoration of coastal-terrestrial grassland transitions. This would require rising land and areas where freshwater sources/seepages were open to tidal inundation. Such areas adjacent to the open coast may be limited but are present where springs issue from the base of the relict cliff section that runs behind the existing areas of grazing marsh. This type of re-creation would be self-sustaining and require minimal management through traditional agricultural grazing practice. However, the longevity of any transitional habitats created in this situation could be relatively short due to the effects of sea-level rise and ‘natural’ landward transgression and squeeze of intertidal against areas of higher relief; and
- Re-creation of brackish-freshwater habitats through the artificial restoration of coastal-terrestrial grassland transitions. Small areas could be restored behind flood embankments where some saline intrusion, either through overtopping or seepage occurred. Ideally these areas would be re-created as part of managed re-alignment schemes, located behind new defence lines in order to ensure that the sites were not isolated from the estuarine system through the longer term effects of sea-level rise. The excavation of new dykes and areas of standing water would be required but could be engineered to provide a range of conditions in order to support typical plant and invertebrate communities. As part of a wider habitat creation scheme such areas of grazing marsh habitat could be relatively sustainable with minimal management through traditional agricultural practice.

The two scenarios outlined above could be utilised to provide replacement habitat for the saline influenced terrestrial features which could be lost to managed re-alignment. However, it is likely that a slightly different approach may be required in order to ensure that bird species and populations utilising existing grazing marsh habitats could be sustained. For birds of designated SPA interest, four potential scenarios can be advanced:

- Although the areas that could be created to support plant and invertebrate communities may be relatively small compared with some existing terrestrial sites they may provide suitable niche space for some bird species. Areas of grassland above mean high water can provide roost sites for wintering waterfowl, particularly if located in areas of limited or no human disturbance. In addition, reed-lined dykes etc. may support species such as reed and sedge warbler and even relatively small areas of grassland will provide feeding areas for wildfowl such as wigeon and dark bellied brent-geese;
- The creation of extensive areas of low-lying grazing marsh (i.e. a like for like habitat replacement) adjacent to the open coast could provide all the necessary conditions to support bird species and population levels for which existing areas are designated. For some species such as brent geese and wigeon, the creation of suitable areas can be quickly undertaken through the conversion of arable to grassland, as geese will make use of reseeded improved grassland for feeding. For other species the creation of suitable conditions may take longer, but there are no apparent technical and management reasons why the correct ecological conditions cannot be created. Clearly this option would require the selection of areas where flood embankments would be maintained in position (e.g. potentially for wider coastal morphological or socio-economic purposes). Such areas may therefore become more isolated from the coastal system in the longer term under a scenario of sea-level rise. However, given that their prime purpose would be to act as sites to support bird populations that do not require saline influenced habitats, then this isolation has limited ecological consequences. Of course, there may well be other factors which lead to such an option being unsustainable, such as the economic cost of maintaining flood defences or limited freshwater supply. Large sites, as envisaged under this option, would also have the capability to support the diverse plant and invertebrate populations of brackish-freshwater habitats. However, longer term isolation due to the need to maintain flood defences (unless conditions were engineered) could lead to a reduction in suitability over time;
- Many of the species that currently use areas of grazing marsh for feeding and roosting (e.g. wigeon, brent geese) will also make use of saltmarsh and tidally influenced grassland for these activities. Certainly, the use of grazing marsh by species populations would change following the conversion of land to saltmarsh or brackish grassland. However, it is considered unlikely that, apart from purely freshwater specialists (e.g. bittern), that any of the species present on the North Norfolk coast would be lost from the site. There is the possibility, with time, that a shift in feeding patterns could occur, as has happened with brent geese, which have moved onto estuarine pastures following the die-back and loss of large areas of eelgrass (*Zostera*) to disease in the 1930's-1940's, and a greater use of saltmarsh as a feeding habitat could be made. Ultimately it may be possible to create significant areas of grazed saltmarsh and brackish grassland, similar to those that occur around estuary systems in parts of northern England and which support large populations of grazing waterfowl.
- As the majority of bird species using coastal grazing marsh for feeding and breeding are wetland specialists rather than estuarine intertidal feeders there is the possibility that replacement grazing marsh habitat for terrestrial species (e.g. bittern/marsh harrier) could be located away from the estuaries. Suitable locations would be in river floodplains feeding into the coastal area and or areas of extensive low-lying land (e.g. Snettisham-Heacham). Restoration and creation of grazing marsh away from the coast may lead to a loss or reduction in the population levels of some

species present in the existing SPA. However, with appropriate planning and the location of suitable sites overall species population levels could be safeguarded.

In the context of the overall restoration policy being advanced in this CHaMP, the above discussion suggests that there are several options that could be advanced to replace designated SPA/Ramsar wetland habitat landward of flood defences, if such areas were realigned and intertidal habitat created as part of a functioning estuarine and open coast system. The decision to effectively sacrifice one designated habitat for another is a difficult decision to make, but if a site is broken down into its ecological components then replacement, given time, of the ecological interest of an area may be more easily fulfilled.

Further information on the creation of grazing marsh habitat is provided in Appendix A.

10 MONITORING

10.1 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.

10.2 Physical monitoring

10.2.1 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.

10.2.2 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.

10.2.3 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.

10.2.4 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 11.4). 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.

10.2.5 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.

10.3 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).

10.4 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.

10.4.1 Monitoring of intertidal habitats

Table 11.1 provides a summary of the biological monitoring that could be undertaken of the intertidal habitats (mudflat and saltmarsh) within the North Norfolk CHaMP area.

Table 11.1 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.

10.4.2 Monitoring of saline lagoon habitat

Table 11.2 provides a summary of the biological monitoring that could be undertaken for saline lagoon habitat within the North Norfolk CHaMP area.

Table 11.2 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

10.4.3 Monitoring of grazing marsh habitat

Table 11.3 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.

10.5 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.

11 REFERENCES

Andrews, J., Boomer, I, Bailiff, I. Balson, P., Bristow, C., Chroston, P., Funnell, B., Harwood, G., Jones, R., Maher, B., Shimmield, G. (1999) Sedimentary evolution of the north Norfolk barrier coastline in the context of Holocene sea level change. In Shennan, I. & Andrews, J. (Eds.) Holocene Land-Ocean Interaction and Environmental Change around the North Sea. *Geological Society, London, Special Publ*. **166**, 219-251.

Atkinson, P. A. (1996). The origins, moult and movements of Bar-tailed godwits on the Wash, England. *Bird Study* **43**: 60-72.

Chroston, P., Jones, R. & Makin, B. (1999) Geometry of Quaternary sediments along the north Norfolk coast UK: a shallow seismic study. *Geological Magazine* **135**, 465-474

French, J & Spencer, T. (1993). Dynamics of sedimentation in a tide-dominated back-barrier saltmarsh, Norfolk UK. *Marine Geology* **110**, 63 -81.

Funnell, B.M. (1992). A geological heritage coast: north Norfolk In Stevens C., Gordon, J., Green, C & Macklin, M. *Conserving our landscape; evolving forms and ice-age heritage*. Crewe, 59-62.

Jones, R., Maher, B., Shimmield, G. (1999) Sedimentary evolution of the north Norfolk barrier coastline in the context of Holocene sea level change. In Shennan, I. & Andrews, J. (Eds.) Holocene Land-Ocean Interaction and Environmental Change around the North Sea. *Geological Society, London, Special Publ*. **166**, 219-251.

IECS (1993) Burnham-Overy/Wells-next-the-Sea. Tidal defences. Report to Environment Agency. Hull University.

Lambley P. (1999) Coastal Habitat Management Plan for European sites on the North Norfolk Coast. English Nature and Environment Agency.

Lawton, N. M. (1999). Survey of Dark-Bellied Brent Goose Roost Sites in the North Norfolk Coast SPA. Winter 1998/1999. Report to EN/RSPB.

McCave, I (1978) Grain size trends and transport along beaches, an example form eastern England. *Marine Geology* **28**, M43-M51.

Newcastle University (1999) Coastal data analysis: north Norfolk. Report to Environment Agency No STCG13.

Pye, K. (1992). Saltmarshes on the barrier coastline of north Norfolk eastern England. In Allen, J.R.L. & Pye ,K. (Eds.) *Saltmarshes: morphodynamics, conservation and engineering significance*. Cambridge University Press. 148-178

Rooney, M. E. S. & Eve, V. (1993). The Number, Distribution and Breeding Success of The Ringed Plover in Norfolk. Report to RSPB & Norfolk Coast Project.

Southern North Sea Sediment Transport Study (SNSSTS) (2002). Phase II. Report produced for Great Yarmouth Borough Council by HR Wallingford, CEFAS/UEA, Posford Haskoning & Dr Brian D'Olier. EX4526.

Taylor, M., Seago, M., Allard, P. & Dorling, D. (2000). *The Birds of Norfolk*. Pica Press, East Sussex.

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

APPENDIX A – HABITAT RESTORATION AND CREATION TECHNIQUES

1 MANAGED RE-ALIGNMENT: TECHNIQUES AND IMPACTS

1.1 Managed re-alignment

Managed re-alignment or managed retreat involves the restoration of reclaimed inter-tidal areas by the partial or complete removal of the existing flood embankment (or flood defence structure). In many cases the process must be complemented by construction of a secondary flood defence landward of the initial embankment, in order to prevent flooding of adjacent land and infrastructure. The benefits of managed re-alignment include:

- A reduction in the wave attack on the retreated, secondary flood defence involving a more sustainable defence and decreased maintenance costs; and,
- An increase in inter-tidal habitat.

Possible dis-benefits include:

- The loss of reclaimed land. Areas that appear geomorphologically suitable for restoration may be valuable for agriculture or other purposes and, in addition, may be designated under the Birds Directive (SPA) or Ramsar Convention, such as the majority of the grazing marsh along the North Norfolk coast.
- The impact of restoration of a reclaimed area on the adjacent coastal areas may be as great as that caused by the initial reclamation, involving enlargement of feeder channels, loss of areas of existing saltings and changes in water levels.

Managed re-alignment techniques depend in detail on the site involved but basically may take one of two general forms:

Breach retreat: in which tidal access to the site is provided through one or more breaches in the existing embankment which otherwise is left substantially unaltered. Breach retreat allows the restoration of the tidal processes within the site to take place, but prevents the restoration of natural processes in the wider estuarine environment which must adjust instead to an increased tidal prism without a commensurate increase in tidal channel area.

Bank retreat: in which the entire existing defence is removed down to the level of the site floor. Bank retreat allows restoration of tidal process to take place both within and without the site so that the increase in tidal prism is accommodated by an increase in the surface area of tidal channel.

1.2 Sediment nourishment

The potential impacts of managed realignment on immediate and wider coastal and estuarine areas can be offset to a certain degree through the use of sediment nourishment. This is particularly applicable in areas where the land to be realigned is at a significantly lower level than the adjacent intertidal and where inundation would result in a large increase in the volume of water coming into and out of the realignment site (i.e. increase in the tidal prism).

The technique effectively involves the deposition or pumping of suitable sediment (dredged sediments from port works have been used in some schemes) behind the flood defences and directly onto the land surface. Once settlement of the sediment has occurred and the desired level achieved then realignment through removal of part or all of the defence can then be undertaken.

1.3 Regulated Tidal Exchange

Regulated Tidal Exchange (RTE) is a technique to develop intertidal habitats behind permanent sea defences, particularly where walls will remain in place and/or as part of a phased realignment strategy (Lamberth and Haycock 2002). In many respects this technique is similar to the practice of ‘warping’.

The technique involves the regulated exchange of seawater to an area behind fixed sea defences through engineered structures such as sluices, tide-gates or pipes. RTE differs from managed realignment in that RTE does not directly involve the establishment of a new defence line. RTE is a short-term option with a limited lifetime and is not sustainable unless used as part of a longer-term coastal strategy. In the long term, RTE may act as a more effective coastal defence strategy if it is undertaken in three phases:

- RTE to facilitate land level accretion through sedimentation of low-lying areas. In this way land levels on the site can be raised as a rate equal to or greater than sea-level rise;
- Breach of coastal defences to result in a more natural tidal regime with unregulated tidal flows into the site once the land levels have risen and saltmarsh has developed; and
- Progressive and extensive removal of the remaining coastal defences through natural erosion with subsequent restoration or the coastal environment made of extensive marsh buffers offering a more natural sea defence.

1.4 Managed Re-alignment Impacts

Although managed re-alignment appears to offer a practical solution to the creation of intertidal habitat; there are four major issues that should be considered in its potential implementation:

- The impact on existing intertidal habitat;
- The impact of an increase in tidal prism on ebb tidal deltas and open coast processes;

Managed re-alignment, by increasing the tidal prism, sets up a positive feedback loop in which, first, the existing tidal channel enlarges to accommodate the increased tidal prism. This channel enlargement occurs by recession of the upper inter-tidal, principally the salt marsh – mudflat boundary so that an increase in inter-tidal area results and, consequently, an additional increase in tidal prism. The channel must enlarge further in order to accommodate the secondary increase in tidal prism and a positive loop is set up that can only be broken when the mean depth of the channel decreases to below a critical level as additional shallow inter-tidal areas are added to the cross section.

- Re-alignment may lead to the loss of designated features (SPA/Ramsar) or significant ecological change. Such change with respect to the designated status of these areas may require the creation of compensatory habitat elsewhere within the CHaMP area (or possibly further afield); and
- Suitable agricultural land for re-alignment is likely to be largely in private ownership.

Further information

Additional and more detailed information on the practice of managed realignment is available through a number of practical case studies and published reports. The following are a selection of the main and most pertinent publications:

Centre for Ecology and Hydrology (2001). Managed realignment at Tollesbury and Saltram, Annual report for 2000, edited by DEFRA. CEH Project C 00356.
English Nature (1995). Managed Retreat: A practical guide. Report written by Fiona Burd. 26pp.

Environment Agency (1999). Managed Realignment: A guide to consents and licences. R & D Technical Report W155 by Carpenter, K.E. and Gibson, J.N.K. 27pp.

Environment Agency (1999). The Restoration of vegetation on saltmarshes. R & D Technical Report W208 by Brooke, J, Landin, M., Meakins, N. and Adnitt, C. 84pp.

Hayes, D.F., Olin, T.J, Fischnich J.C. and Palermo M.R. (1998). Handbook of Wetlands Technology: Engineering foe wetlands restoration and creation. Technical Report WRP-RE-21. US Army Corps of Engineer Waterways Experiment Station. Vicksburg. Mississippi. 1000pp.

Lamberth, C., Haycock, N. (2002). Regulated Tidal Exchange: An Intertidal Habitat Creation Technique. Report to RSPB and Environment Agency by Haycock Associates Limited, St. Albans.

National Rivers Authority (1995). Managing Coastal Realignment: Case Study at Orplands Sea Wall, Blackwater Estuary, Essex. 22pp.

Pethick J.S. (2001). Rivers Crouch and Roach: Estuary Modelling Study 3: Geomorphological implications of managed retreat onto Flood Compartments. Report to Environment Agency.

2. CRITERIA REQUIRED FOR GRAZING MARSH HABITAT CREATION AND MAINTENANCE

2.1 Site selection

It is essential that restoration and re-creation of grazing marshland does not replace the management and conservation of existing natural or semi-natural habitats. Restoration should ideally be aimed at areas adjacent to existing grazing marsh or in areas where fragmented habitats can be linked in order to maximise colonisation potential and to reduce the isolation of existing floral and faunal communities.

2.2 Ecological Considerations

Assess the current status of the habitat compared to the predicted development of future habitats in terms of the establishment of flora and fauna (especially those of Community or International importance), eutrophication, disturbance, contamination of soil or groundwater etc.

2.3 Environmental Considerations

Consideration must be taken of the potential environmental benefits and drawbacks of any regeneration or habitat creation project. Potential benefits may include the reduction of eutrophication or the preservation of groundwater resources. Potential drawbacks would include the removal or destruction of the current habitat to make way for grazing marsh or the release of stored nutrients or pollutants into the system.

2.4 Restoration techniques

2.4.1 Natural regeneration

It is not always necessary to artificially recreate a habitat. Although persistent seed banks of typical grazing marsh plant species do not normally survive and new growth may not be able to compete with aggressive, monoculture forming agricultural plants or annual arable weeds, it is sometimes possible to allow natural regeneration in specific circumstances. Natural regeneration is likely to be slow and unreliable in areas where existing habitats are fragmented or isolated. The longer a site has been cultivated or altered and the more isolated it is, the greater the need for artificial regeneration.

2.4.2 Species reintroduction

Where artificial regeneration of grazing marsh is necessary, strict criteria need to be followed when deciding on the floral species that are to be introduced. As a rule any plant species should be ecologically suited to the new habitats substrate and hydrological conditions, perennial, non-invasive, native and quick to germinate.

2.4.3 Habitat transplant

This technique is often used to create new habitats or to diversify existing threatened habitats. However special treatment of transplanted species is required. Gaps need to be created in existing vegetation to allow the transplant to establish without competition. Transplanted species often fail to establish themselves due to differences in environmental conditions between their native and receiving sites, the management of the site and through damage during the transplant process. Also, in general, communities from wetter habitats such as grazing marsh are more difficult to establish than those from drier habitats.

2.4.4 Seeding

Seedbeds can be created from numerous sources such as commercial production, hay bales and existing habitats. Careful management is required to ensure adequate drainage and aeration of soils, as well as allowing germination free of encroaching plant litter and weeds. Seed mixtures representative of natural assemblages are essential as is the rate, duration and timing of sowing.

2.4.5 Restoration of Associated biotopes

The introduction of many species unique to grazing marsh habitats will depend upon the presence and quality of the habitats for associated biotopes. Permanent water bodies such as ponds, dykes and oxbows will aid in more rapid establishment and the creation of diverse species assemblages and will facilitate the immigration of species from other sites.

2.5 Restoration for wildlife

2.5.1 Botanical diversity

Grazing marshland plants rely on strict water regimes and specific soil habitats to influence competitive balance and diversity in the habitat. Maintaining low nutrient availability through vegetation management creates less opportunity for highly competitive species to become established leading to a more diverse plant assemblage and prevents succession from grazing marsh to coarse grassland or scrub.

2.5.2 Birds

Grazing marsh provides a key habitat for breeding waders such as snipe (*Gallinago gallinago*), lapwing (*Vanellus vanellus*) and curlew (*Numenius arquata*) and wintering waterfowl such as wigeon (*Anas penelope*) and dark-bellied brent goose (*Branta bernicla bernicla*). Therefore creating associated habitats such as water bodies, gravel islands and flooded areas allows for feeding, roosting and breeding in areas safe from predators.

2.5.3 Invertebrates

Grazing marsh supports a wide diversity of invertebrate species from dragonflies to molluscs. Regeneration or creation of new habitats requires careful management for invertebrates, as they are highly specialised and very sensitive to environmental change. Maintaining habitat continuity and vegetation structural variety is essential to promote a diverse invertebrate assemblage, as is the creation of standing water, dykes and seasonally flooded land.

3. Criteria Required for Vegetated Shingle Habitat Creation and Maintenance

3.1 Site selection

Restoration should ideally be aimed at existing shingle sites, where creation or stabilisation of shingle would benefit the existing habitats, or in areas where fragmented habitats can be linked in order to maximise colonisation potential and to reduce the isolation of existing floral and faunal communities. Vegetated shingle is a scarce habitat in the UK, supporting a unique assemblage of flora and fauna. Its creation and preservation should be given considerable priority.

3.2 Ecological Considerations

Assess the current status of the habitat compared to the predicted development of future habitats in terms of the establishment of flora and fauna (especially those of Community or International importance), disturbance, contamination of soil or groundwater etc.

3.3 Environmental Considerations

Consideration must be taken of the potential environmental benefits and drawbacks of any regeneration or habitat creation project. Issues such as the release of stored pollutants and nutrients and the preservation of groundwater quality have to be addressed from the outset.

3.4 Restoration techniques

3.4.1 Natural regeneration

Vegetated shingle generally occurs under stressful environmental conditions. Natural recolonisation is a slow process and young plants are prone to high mortality due to drought, salt spray and burial during storms. In the short term, natural regeneration may not be a suitable option for this particular habitat. Experiments on areas of bare, disturbed shingle are currently being undertaken on Dungeness using broom as a source of humus for colonisation by other species.

3.4.2 Natural seed-banks

Vegetated shingle forms a very poor natural seed bank and many of the seeds that are present are not of typical vegetated shingle species. It is very unlikely that the seed bank will provide enough seeds to establish a characteristic community. However when creating these habitats it is important to use local materials to create an authentic substrate.

3.4.3 Sown seeds

Seeds can be collected from various sources, such as existing habitats and commercially produced examples. Emergence of seedlings occurs over a long time period and success varies between species and substrate type. Seed sowing is highly prone to catastrophic failure and should only be used where success is confident.

3.4.4 Container grown plants

Container grown plants have the advantage of size and strength compared to younger seedlings. Mortality during the crucial first year after planting is low, although some species are more vulnerable than others. Selecting the right plants for the right substrate is important, as this will directly influence the success, or failure of the project. Using fertiliser is not advised as coastal shingle is a very porous substrate and any added nutrients will leach into the surrounding environment, possibly contributing to eutrophication. Rapid establishment of container grown plants is key to a successful vegetated shingle project. However, the costs of restoration are high, as is the chance of total failure. Careful consideration and planning is required, taking into account issues such as sea-level rise and erosion, before a project such as this can take place.

3.4.5 Landscaping

Landscaping of the shingle substrate may well be one of the significant factors in the success or failure of habitat creation. Beach profiles should be created as close as possible to natural conditions to prevent any subsequent re-contouring by winter storms and therefore, potential loss of introduced vegetation.

3.5 Restoration for wildlife

3.5.1 Botanical diversity

Botanical diversity will be initially governed by the choice of introduced species. Over time, ensuring that a variety of sediment sizes are used will facilitate the establishment of new species as the habitat establishes.

3.5.2 Birds

Certain species of birds may use vegetated shingle for breeding and roosting. Ensuring a good vegetation cover and adequate anti-predator controls should encourage birds to use the site.

3.5.3 Invertebrates

Many species of invertebrates are associated with vegetated shingle habitats. Creating a heterogeneous environment will promote a higher diversity of species.

4. CRITERIA REQUIRED FOR SALINE LAGOON HABITAT CREATION AND MAINTENANCE

4.1 Site selection

Restoration should ideally be aimed at existing saline lagoon sites, where lagoons have deteriorated or been lost through anthropogenic processes, or in areas where fragmented habitats can be linked in order to maximise colonisation potential and to reduce the isolation of existing floral and faunal communities. Different types of lagoons exist and priority should be given to the creation of the rarer forms such as percolation lagoons.

4.2 Ecological Considerations

Assess the current status of the habitat compared to the predicted development of future habitats in terms of the establishment of flora and fauna (especially those of Community or International importance), eutrophication, disturbance, contamination of soil or groundwater etc.

4.3 Environmental Considerations

Consideration must be taken of the potential environmental benefits and drawbacks of any regeneration or habitat creation project. When creating a saline lagoon it is important to consider whether there is any risk of cross contamination with other sites or the release of stored pollutants from the dredging process. A key issue will be water management as a lagoon could potentially interfere with the existing water table, flow regime and water supplies of the area as well as interfering with local drainage.

4.4 Restoration techniques

4.4.1 Natural regeneration

It will be impossible to promote natural regeneration of a deteriorated saline lagoon habitat. However, if improvements are just cosmetic, then once the site is cleaned and cleared it may be possible to allow natural succession to occur, under strict monitoring criteria.

4.4.2 Artificial creation

The principal construction requirement is to excavate a basin or adapt an existing basin. Machinery must be chosen carefully, dependent on the nature of the ground being worked on

4.4.3 Substrate introduction

After the basin is created the appropriate substrata must be considered. The origin of any material needs to be traced to ensure that it5 did not come from a polluted site. Suitability for colonisation and succession must be assessed (i.e. compact sediments can inhibit primary succession). Organic material addition is unnecessary, as the lagoon will be, by nature, a sink for nutrients and fine particulate matter.

4.4.4 Water inlet/outlet

This is critical to the hydrodynamics of the lagoon. Sea-level rise should be considered before creating inlets/outlets. The options for the inlet/outlet are: percolation barrier; sill or weir; narrowed inlet; pipeline or culvert, and sluices, sea doors etc.

4.4.5 Landscaping

Peripheral landscaping of the lagoon is not required for the conservation benefit of the lagoonal environment. Therefore other conservation objectives can be met, such as saltmarsh creation. Landscaping in the lagoon (such as island creation) will be useful for wildlife habitats and predator avoidance havens.

4.5 Restoration for wildlife

4.5.1 Botanical diversity

Creating or restoring a new lagoon basin and associated inlets will facilitate the establishment of many floral species. It is important, however, to ensure that depth and salinity are carefully planned and monitored to create ideal habitats for floral establishment.

4.5.2 Birds

Creation of lagoon islands (both vegetated and non-vegetated) is essential to promote the establishment of bird colonies such as avocet. Ensuring that water doesn’t fluctuate dramatically will aid in the creation of nesting habitats.

4.5.3 Invertebrates

Invertebrates will require special site-specific planning. Different species have different tolerances to salinity. Creating a lagoon with a balanced, non fluctuating salinity and of a suitable depth and geomorphology will be crucial in the development of the invertebrate community.

4.6 References

The key reference for saline lagoon creation, providing a more in-depth explanation of the criteria and considerations can be found in:

Bamber, R.N., Gilliland, P.M., and Shardlow, M.E.A. (2001) *Saline lagoons: a guide to their management and creation*. Peterborough, English Nature.

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 1 m), 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.

4.0 SAND BANKS

The important geomorphological parameters of sandbanks with respect to habitats are their sediment character, topography and differences in the depth, turbidity and salinity of the surrounding water. Sediment character is vital to the structure of the feature and reflects all the physical processes acting on it. The depth and distribution of sandbanks reflects the energy conditions and stability of the sediment, which is the key to the structure of the feature. The depth of a sandbank is a major influence on the distribution of communities throughout.

4.1 Morphology

The changing shape and form of the sandbank can be measured by repeat bathymetric surveys using multibeam echosounder equipment.

4.2 Sediment composition and distribution

Sediment composition and distribution can be evaluated by a campaign of seabed 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. Sediment characteristics can be used to indicate spatial distribution of sediment types reflecting the stability of the feature and the processes supporting it.