Natural Area: M4. Bridlington to Skegness	**Geological Significance:** Notable **(provisional)**

General geological/geomorphological character and *Geological History:* The solid geology of the Natural Area is composed entirly of Upper Chalk, a fine grained limestone deposited in a tropical sea during the Cretaceous around 88-74 million years ago. Throughout most of the Natural Area the chalk is obscured by a thick layer of Quaternary deposits (laid down during the last 2 million years). Because of this, the Cretaceous chalk is only exposed in sections along the banks of the Humber and plays little part in determining the overall character of the Natural Area.

Quaternary History: Overlying the Upper Chalk are Quaternary deposits which show a complex record of cold (glacial) and warmer (interglacial) periods. Many of these deposits yield evidence of ancient faunas and floras which record past climatic changes and are important in determining the age and timing of such events in the area. The Cretaceous chalk is so deeply buried in most places beneath these later deposits that it plays little or no part in fashioning the landscape. Instead the landscape is dominated by a series of glacial deposits consisting of tills, boulder clays and glacial lake clays. These were deposited during the Devensian glaciation, during a period of glacial advance known as the Dimlington Stadial which took place between 26,000 and 13,000 years BP. The glacial deposits form a more or less continuous lowland plain, characterised by poorly sorted and poorly consolidated stony material. In places, the boulder clay plain is capped by peat filled depressions (known as meres) which mark the existence of former lake beds. Some of these are kettle holes formed due to the differential melting of glacial ice and their peat and pollen remains provide important information about Quaternary environmental change and archaeological settlement patterns in the area over the last 13,000 years. Where the boulder clay plain meets the sea in coastal sections, the Natural Area is dominated by rapid marine erosion with rates of cliff recession measured at up to 2 metres per year in places.

Geomorphological evolution and processes: The coastline from Bridlington to the mouth of the Humber is largely undeveloped and agricultural extending to a spit at Spurn Head. It displays some of the longest stretches of unbroken till cliffs in England, attaining hieghts of 33metres near Dimlington. The boulder clay cliffs of the Holderness coastline are more exposed southwards towards the Humber with an associated increase in erosion. Rapid and persistent cliff erosion over the whole of the frontage of this part of the maritime Natural Area is causing long term retreat, leading to loss to agricultural land and threat to cliff top dwellers. [The mean annual rate of retreat over the century (1852-1952) rises in places to 2.75metres which is an extreme figure globally. Its length and volume reflects the massive longshore transport from the Holderness coast]. The sediment released into the system from the Holderness coast is of paramount importance to the rest of the Natural Area. Extensive areas of accreting saltmarshes exist on the north shore of the Humber, sheltered by Spurn Head. South of the Humber down to Skegness the coastline is lightly developed and extremely low lying susceptible to both flooding and erosion. A massive scale beach nourishment project is currently being carried out between Mablethorpe and Skegness. The dominant littoral process is a southward drift on the open coast, with waves in combination with tidal currents transporting material derived from cliff erosion seawards and southwards, forming the spit at Spurn Head. There is particularly high littoral drift from Bridlington to Spurn Head with Tidal currents and waves redistributing material across the Humber estuary to Lincolnshire, where there is moderate southward littoral drift of fine sand down to Skegness.Some feed to the coast is believed to be taking place via flood dominant currents from the off shore banks NE of Skegness. Similar processes working on the retreating cliffs north of the Humber work on the easily erodible low lying coast to the south. Accreting sand flats at Donna Nook provide a source of sediment to the Lincolnshire coast but an overall deficit of supply further along the coast. Erosion of the clay substrate is leading to beach lowering and steepening towards Skegness, hence the nourishment scheme.

Key geological/geomorphological features:

- Chalk cliffs
- Quaternary sediments and glacial deposits
- The 3.5 mile (approx.) sand and shingle spit of Spurn Head - no comparable spit in form or length is found in a macro-tidal environment in the British Isles.
- The Holderness coast has one of the highest retreat rates globally (2.75m between 1852 and 1952)

Number of GCR sites:

Pleistocene/Quaternary of E England: 3 Holocene sea level: 1
Coastal Geomorphology of England: 1

Geological/geomorphological SSSI coverage: There are 5 coastal (P)SSSIs in the Maritime Natural Area containing 5 GCR SILs representing 3 GCR networks. The coverage represents various sites with important Quaternary deposits. For example South Ferriby Cliffs SSSI provides exposures of glacial deposits which are used in correlations of the glacial history of Eastern England, whilst Dimlington Cliff SSSI is recognised as the type site for the Dimlington Stadial (a time when a glacial advance into the area has been dated accurately to 26,000 to 13,000 years before present). Withow Gap, Skipsea SSSI is also an important Quaternary site, showing links with archaeology and human settlement of the area. Spurn Head is an area of special geomorphological importance since there is no spit of comparable form or length to Spurn Head in a macro-tidal environment in the British Isles. The spit has an unusual recurring 250 year cycle of breaching and regrowth.

Key geological/geomorphological management issues:

- Maintain natural processes eg. the threshold of minimum longsgore drift required to maintain the spit must be attained.
- Incomplete information on non-SSSI area.
- Off shore sand banks provide a source of sediment for the coast towards Gibralter Point and therefore dredging off this coast should be disallowed.
- Consider mitigation measures for coast protection works

Key geological objectives:

1. **Control/limit development of coastal defence** and reference should be made to the shoreline management plan.

2. **Encourage documentation of non-SSSI areas**, to facilitate strategic approach to conservation of whole coastal area.

3. **Maintain natural processes** through a) ensuring a sediment supply, that is as a minimum, at levels equivalent to the present i.e. disallow offshore dredging of sand banks and hard defences and b) any mitigation measures such as beach replenishment schemes, north of Spurn Head should use coarse grained sediment wherever possible.

Useful guides/references:

KENT, P. 1980: British Regional Geology, Eastern England from the Tees to the Wash London. HMSO

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Withow Gap, Skipsea
- Dimlington Cliff
- Humber Flats & Marshes: Spurn Head to Salt End Flats
- South Ferriby Cliffs
- Chapel Point

Natural Area: M5. Skegness to Old Hunstanton	**Geological Significance:** Notable **(provisional)**

General geological/geomorphological character: The Skegness to Old Hunstanton Maritime Natural Area encompasses The Wash which, if a line from Gibraltar Point in Lincolnshire to Hunstanton in Norfolk is taken as the outer boundary, covers approximately 610km^2.

Geological History: The solid geology of the area is dominated by Upper Jurassic limestones and clays including the Kimmeridge clay (formed around 157-152 Ma) and by Cretaceous chalk and sands (formed around 125-90 Ma). Generally speaking, the rock sequence increases with age towards the interior of The Wash.The Jurassic clays were laid down in relatively deep tropical seas and are often rich in fossils including important giant marine reptile remains and ammonites. These clays give way eastwards to younger Cretaceous rocks in the area are around Hunstanton where Lower Cretaceous shallow sea deposits, including sands of the Lower Greensand ('Carstone'; approximately 125-97 Ma) are overlain by Upper Cretaceous chalk. This latter deposit is a very pure limestone laid down on a tropical sea floor between 97 and 90 Ma. Other than the exposures in the cliffs at Hunstanton, the solid geology is obscured by a thick layer of Quaternary deposits (see below).

Quaternary History: Much of the solid geology of the Maritime Natural Area is obscured by the more recent Quaternary deposits formed during the last 2 million years. The area was glaciated in the Anglian glaciation (around 300,000 to 250,000 years BP) and glacial erosion beneath the ice sheet is probably responsible for the scouring of the inland Fen Basin and the area now occupied by The Wash itself. The ice sheet deposited glacial sands, gravels and clays across the area, and in the shallow basin of The Wash peats and marine clays accumulated. The most recent of these record important fluctuations in sea level over the Holocene (the last 10,000 years). The deposits include a cyclic succession of peats, estuarine and marine clays deposited in both terrestrial and marine environments. The clays formed at periods when sea levels were higher in the recent geological past.The peats formed at times of lower sea levels when Fenland and the adjoining Wash were predominantly terrestrial. The sequence of deposits therefore demonstrates a detailed record of climatic change over the last 10,000 years and is important for the contribution to discussions of future climate change and global warming. These early deposits form cliffs at Hunstanton, but elsewhere in the MNA, the coast is characterised by recent coastal features such as saltmarsh and wind-blown sands. The Wash in particular is an area of Holocene subsidence and has many features typical of such an area such as extensive mudflats.

Geomorphological Evolution and Processes: The whole coastal frontage of this MNA is low-lying rising on the eastern side of the Wash to Hunstanton, where erosion has formed the first cliffs south of Cleethorpes. Immediately south of Skegness, where accretion occurs, the dunes (in part a golf course), continues into the sand and marsh formation of Gibraltar Point. Gibraltar Point is the distal part of a spit developing in a southerly direction at the north-west corner of the Wash. It has developed in a macro-tidal environment, with a spring tidal range of over 7.0 metres and with an abundant source of sand brought to the site by processes of longshore and off-shore transport.

The beach at Gibraltar Point shows a series of ridges and funnels. The ridges are formed by a series of low energy, waves creating a 'mini' beach on the sand flat, capable of absorbing all the incident wave energy. These ridge move landward under wave action until it become protected by the development of a new ridge in front of it. The old ridge then begins to accumulate wind blown sand and forms a foredune. Off-shore the bed forms, including ripples and bars, are more a function of the tidal flows in and out of the Wash, although long period wave energies do shape the sand bars. The general movement of material along the foreshore under wave and tidal action is southwards, leading to the development of the spit. It is a small spit, composed of sand and a little shingle and has developed relatively recently (since 1922). It is the latest in a series of spits, each of which has been built seaward of its predecessor. Within the Wash there is no significant drift, fine sands and silts being brought in predominantly by tidal action. The coast between Gibraltar Point and Frampton is particularly at risk from extreme high tides due to the low-lying nature of the undeveloped land, reclaimed from the sea. Saltmarshes are found in particular on the west and south margins of the Wash, fronting much of the reclaimed land, with tidal currents distributing fine sediments and providing impetus for the saltmarsh development. Siltation by current borne sediments is enhanced by alluvial deposits discharged by rivers. Approximately 270km^2 of the Wash constitutes inter-tidal sand and mud flats and 44km^2 of salt marsh. The unreclaimed marshlands on the Norfolk side of the Wash are in the main like those of Lincolnshire.

Key geological/geomorphological features:

- Well known Cretaceous locality at Hunstanton with brown Carstone, Red Chalk and White Chalk.
- The Wash with its diverse habitats: extensive mudlflats, sand flats and salt marshes.
- Gibraltar Point demonstrates such features as tidal sand bars offshore, a well-developed ridged and runnel foreshore, a spit, sand dunes and saltmarshes in various stages of evolution.

Number of GCR sites:

Aptian-Albian: 1 Cenomanian-Maastrichtian: 1 Coastal Geomorphology of England: 1

Geological/geomorphological SSSI coverage: There are 2 coastal (P)SSSIs in this MNA containing 3 GCR SILs representing 3 different GCR networks.The SSSI coverage represents the Cretaceous sequence at Hunstanton Cliffs SSSI, where the brown Carstone, Red Chalk and White Chalk are all well-exposed. Gibraltar Point SSSI is a key site for studies of coastal geomorphology. The site is particularly important for the dynamism of the coastal environment and also the relationship that can be studied over different time scales between landforms and the processes responsible for their evolution.

Key geological/geomorphologicsl management issues:

- Maintain natural processes
- Promote the educational value of the resource
- Restrict offshore dredging proposals

Key geological/geomorphological objectives:

- **Maintain natural processes** through a) Coastal defence works, particularly north of Gibraltar Point being considered carefully within a Shoreline Mangement Plan, regarding longshore sediment movement, as this will have implications for geomorphological landforms and siltation within the Wash. (Given that much of this MNA is designated National Nature Reserve, the principal threat to sites comes from up-drift coast protection works) and b) Off-shore dredging proposals for nourishment schemes may effect hydrodynamics and the morphology of the area and should therefore be restricted..

- **Monitoring Programmes:** Proposed beach nourishment schemes between Skegness and Mablethorpe will use sediment dredged from some distance off-shore; a suitable monitoring scheme must be encouraged to study any changes to the wave climate and changes to the Gibraltar shoreline morpholgy as a result of off-shore dredging, eg. a reduction in sand getting through to Gibraltar Point as a result of a smothering effect of the shingle.

- **Promotion of Geomorphological/Geological resource** through on-site interpretation eg. sign boarding, trail guides, leaflets etc.

Useful guides/references:

CHATWIN, C.P. 1961: British Regional Geology, East Anglia and adjoining areas. Institute of Geological Sciences. London. HMSO.

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Gibralter Point
- Hunstanton Cliffs

Maritime Natural Area: M6. Old Hunstanton to Sheringham	**Geological Significance:** Outstanding **(provisional)**

General geological /geomorphological character: This stretch of the North Norfolk coastline extends from Hunstanton in the west to Sheringham in the east and is some 50 km in length.

Geological History: The solid geology of the Natural Area is dominated by Cretaceous Upper Chalk. This deposit was laid down on the floor of a tropical sea between 88-74 million years ago. The chalk is a very pure calcareous limestone composed of the skeletons of microscopic coccoliths which inhabited these tropical seas. Although the chalk forms substantial cliffs in the extreme west of the Natural Area and in the adjacent M5 Maritime Natural Area, it is largely obscured by Quaternary deposits along the remainder of the North Norfolk coast.

Quaternary History: The Quaternary history of the Natural Area is dominated by the advance of at least 2 major ice sheets into East Anglia during this time. The two known ice advances are the Anglian (around 300,000 to 250,000 years BP) and the Devensian (around 25,000 to 15,000 years BP). The dating and sequence of these events is, however, still the source of current research and these dates are subject to revision. The ice sheets left a considerable imprint on Norfolk by eroding, transporting and depositing large amounts of material across the area. The deposits are mainly sands, gravels and clays. The glacial tills of the area are high in locally derived chalk and are characteristically calcareous in composition. They are well exposed in the coastal cliffs at places such as Weybourne. In the periods of time between glacial events sea levels were relatively high and relative changes in the height of the land (due to isostatic adjustment following deglaciation) resulted in the formation of raised beaches such as that at Morston. Elsewhere, the coast is low lying and characterised by saltmarsh.

Geomorphological Evolution and Processes: The North Norfolk coast is characterised by former cliff lines separated from sand and shingle beaches by extensive saltmarshes and intertidal flats. However, at both the east and west extremes of the Natural Area, these beaches rest against retreating chalk and glacial till cliffs. The Natural Area includes a major barrier island, Scolt Head, and the large shingle spit at Blakeney Point. Although the coastline is predominantly low lying marshland, it does conatin areas of sand dunes, for example between Hunstanton and Holme and at Brancaster and Wells. The sand dunes here suffer seasonal erosion between Hunstanton and Holme and there is some evidence of landward retreat of shingle ridges. This is particularly the case in the area from Cley to Weybourne. The glacial till (mainly sand and clay) cliffs east of Weybourne experience continuous erosion. The coastline is generally accretionary between Hunstanton and Blakeney with extensive salt marsh developing in the lee of shingle spits. Natural shingle banks, sand dunes and spits form the front line of defence against the sea from Hunstanton to Weybourne Gap. There is a moderate westward drift from Sheringham to Hunstanton, (although a new theory has emerged which takes the view that under certain circumstances the drift is in an easterly direction). This is a predominantly accretionary coastline, with an offshore supply of sand and silt, together with a supply of pebbles from the east. Waves dominate coastal processes east of Blakeney. The coastline is currently responding more or less naturally to a rise in relative sea level. This is manifesting itself in a westerly movement of the landform, as drift rates are increased by greater wave and tidal penetration. Over the next 100 years it is estimated this could result in a movement of the main features, Scolt Head and Blakeney to a position several kilometres further west than at present.

Key geological/geomorphological features:

- Coastal exposures of Quaternary glacial sediments
- The major barrier island of Scolt Head Island and the large shingle spit at Blakeney Point.
- Westerly movement of coastal landforms in response to rising relative sea- level

Number of GCR sites:

Pleistocene/Quaternary of East Anglia: 6 Coastal Geomorphology of England: 3
Saltmarsh morphology: 1 Pleistocene Vertebrata: 1

Geological/geomorphological SSSI coverage: There are 6 coastal (P)SSSIs in the Maritime Natural Area containing 11 GCR SILs representing 4 GCR networks. The North Norfolk Coast SSSI, extending from Hunstanton to Sheringham, is a site of considerable importance for coastal geomorphology. It includes not only such internationally renowned locations as Blakeney Point and Scolt Head Island but also many smaller, no less significant beaches, which are essential to longshore transport of sediment. Morston Cliff SSSI is agood example of a raised beach deposit, whilst Wiverton Downs SSSI and Weybourne Cliffs SSSI show the effects of the Anglian glaciation on the natural area.

Key geological management issues:

- Maintain at least the present rates of longshore transport to SSSIs.
- Facilitate the natural landform migration in a westerly direction.
- Longshore transport rates should be enhanced
- Allow present processes to operate freely and the landform to adjust in as near-natural a manner as possible.
- Obtain a better understanding of offshore sediment dynamics.

Key geological objectives:

1. **Maintain and enhance the integrity of geomorphological/geological features** through a) wherever possible long shore drift rates should be enhanced to aid adjustment to relative sea-level rise. eg., removal of groynes and revetments where not required or where they are ineffective.

2. **Maintain Natural Processes** through a) Coast Protection works and sea defence being considered with care, particularly with regard to works immediately east of the site and reference should be made to an agreed Shoreline Management Plan and b) obtaining a better understanding of offshore sediment dynamics.

Useful guides and references

English Nature Research Report No. 74, 'Towards a strategy for the conservation of coastal habitats in North Norfolk' 1994.

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- North Norfolk Coast
- Holkham Brick Pits
- Morston Cliff
- Wiverton Down
- Weybourne Cliffs
- Weybourne Town Pit

Maritime Natural Area: M7. Sheringham to Lowestoft	**Geological Significance:** Outstanding **(provisional)**

General geological /geomorphological character: The Sheringham to Lowestoft Maritime Natural Area lies on the smooth curve of the north-eastern Norfolk coastline.

Geological History: The pre-Quaternary history of the area is dominated by the Pliocene Crag deposits and there is no true hard rock present within the area.The Crag deposits are shelly, muddy and sandy marine and estuarine sediments. The most extensive of the Crag deposits is the Early Pleistocene Red Crag Formation (deposited around 2.3 Ma). These consist of marine sediments deposited in relatively shallow water, of a cool or temperate nature. The Crag deposits are noted for their abundant marine fossils, which indicate how the relatively mild climatic conditions of preglacial times (Late Pliocene to Mid Pleistocene) degenerated through several oscillations of temperature into the cold glacial climates of the Middle and Late Pleistocene (see below). The Crag deposits are best exposed in the coastal cliffs of the area and are important because they define the Pliocene-Pleistocene boundary in Britain.

Quaternary History: The Quaternary history of the area is dominated by the effects of the Anglian glaciation at around 300,000 years BP. The erosional and depositional effects of this glaciation are shown by the existence of substantial quantities of boulder clay and chalky till, derived form the underlying Cretaceous strata (predominantly chalk) to the north and west. The Anglian ice sheet removed vast quantities of chalk and clay from the North Sea basin and deposited these on land as chalky till. The chalky till is best exposed in coastal sections along the Natural Area. Following deglaciation, climate has continued to oscillate with varying sequences of peats forming in times of climatic amelioration. These form the low-lying Norfolk Broads.

Geomorphological evolution and processes: The present coastline of north-eastern Norfolk is a smooth curve. In the past there were two or more islands, for example the coast from Winterton to Caister is the outer coast of the former island of Flegg. It is a vulnerable stretch of coastline with many towns and villages spread along a frontage of sand/clay cliffs, interspersed by lower lying land, fronted in most places by sand dunes and hard defences. Beaches are predominantly sand with areas of pebbles derived from cliff erosion. There is a high drift rate along this coast to the east, and south, to Lowestoft. Waves transport material southwards from eroding cliffs, providing a vital source of supply for down drift beaches. Residual tidal currents form a link between the movements of the nearshore system of sandbanks and beach changes.

Key geological/geomorphological features:

- Exposures of crag deposits and glacial sediments in coastal cliffs.
- Sand/clay cliffs interspersed by lower lying land, fronted in most places by sand dunes.
- The predominant littoral drift is to the east and south, transporting material from eroding cliffs in the north.

Number of GCR sites:

Pleistocene/Quaternary East Anglia: 7 Pleistocene Vertebrata: 3
Coastal Geomorphology of England: 1 Pleistocene/Quaternary of the Thames: 1.

Geological/geomorphological SSSI coverage: There are 8 coastal (P)SSS's in the Maritime Natural Area containing 12 GCR SILs representing 4 different GCR networks. Corton Cliffs SSSI is the recognised type site for the Anglian glacial period in Britain and is a coastal exposure of key importance. The coastal sites such as Beeston Cliffs, West Runton Cliffs, Overstrand Cliffs, and Sidestrand to Trimingham Cliffs all show the lengthy and important Pliocene to Pleistocene sequence. Taken together, these show both the Crag deposits and the glacial succession. In terms of coastal geomorphology, Winterton Ness SSSI constitutes a narrow cuspate foreland dominated by well-developed dunes and a sandy beach. It has been identified as an area with a sediment budget surplus with considerable sediment transfer into the offshore zone. An important aspect of this is the dynamism of the features present.

Key geological/geomorphological management issues:

- Coast protection works pose the most significant threat to the sites by (i) affecting sediment transport within the Natural Area (ii) threatening the integrity of geomorphic sites such as Winterton Ness and (iii) obscuring coastal geological sites and exposures .
- Maintain levels of exposure and integrity of all GCR sites.
- Maintain natural marine erosional processes of the sand and clay cliffs.

Key geological/geomorphological objectives:

1. **Maintain Natural processes** through a) ensure coastal defence proposals are part of an agreed shoreline management plan.

2. **Maintain Integrity and enhance natural landforms** through a) Promoting effective dune management and b) restricting access of vehicles to sensitive beach areas.

Useful guides/references:

GIBBARD, P.L. AND ZALASIEWICZ, J.A. 1988. Pliocene-Middle Pleistocene of East Anglia. Quaternary Research Field Guide. QRA, Cambridge.

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Beeston Cliffs
- West Runton Cliffs
- Overstrand Cliffs
- Sidestrand to Trimingham Cliffs
- Mundesley Cliffs
- Happisburgh Cliffs
- Winterton - Hornsey Dunes
- Corton Cliffs

Maritime Natural Area: M8. Lowestoft to Languard Point	**Geological Significance:** Considerable **(provisional)**

General geological /geomorphological character: The Lowestoft to Languard Point Maritime Natural Area is a vulnerable stretch of coastline consisting of glacial till cliffs or low-lying land.

Geological History: The pre-Quaternary history of the area is dominated by the Pliocene Crag deposits in the north and Tertiary London Clay in the extreme south. There is no true hard rock present within the area.The London Clay is a thick marine clay deposited in warm seas at a time when global sea level was much higher than present. It was deposited around 50 million years befor present in the Paleogene. Plant remains and fossils in the London Clay show that the sea at this time was surrounded by a tropical rain forest and that the climate was relatively warm with high levels of precipitation.In contrast, the later Pliocene Crag deposits are shelly, muddy and sandy marine and estuarine sediments. The most extensive of the Crag deposits is the Early Pleistocene Red Crag Formation (deposited around 2.3 Ma). These consist of marine sediments deposited in relatively shallow water, of a cool or temperate nature. The Crag deposits are noted for their abundant marine fossils, which indicate how the relatively mild climatic conditions of preglacial times (Late Pliocene to Mid Pleistocene) degenerated through several oscillations of temperature into the cold glacial climates of the Middle and Late Pleistocene (see below). The Crag deposits are best exposed in the coastal cliffs of the area and are important because they define the Pliocene-Pleistocene boundary in Britain. Further inland, the Crag deposits are exposed only in man-made excavations such as pits and quarries.

Quaternary History: Other than the Crag deposits which are known to be Pleistocene in age, the Quaternary history of the area is dominated by the effects of the Anglian glaciation at around 300,000 years before present. The erosional and depositional effects of this glaciation are shown by the existence of substantial quantities of boulder clay and chalky till. These were derived form the underlying Cretaceous strata (predominantly chalk) to the north and west. The Anglian ice sheet removed vast quantities of chalk and clay from the North Sea basin and deposited these on land as chalky till. The till is best exposed in coastal sections along the Natural Area, for example around Easton Bavents and Covehithe to the south of Lowestoft. Following deglaciation, climate has continued to oscillate with sea level varying particularly in times of climatic amelioration. In low-lying areas these form coastal Broads such as that at Benacre Broad

Geomorphological evolution and processes: This is a vulnerable stretch of coastline with many towns and villages situated on the glacial till cliffs or on low-lying land fronted by shingle ridges. Sandy beaches are found at Lowestoft, with a mixture of sand and shingle beaches south to Languard Point. Within this natural area is found Orfordness which is one of three large shingle structures located on the English coast, the other two being Dungeness and Chesil Beach. The predominant littoral drift is southward with a high level of sand transport and a moderate level of shingle transport. Dominant waves transport material southwards from the eroding soft cliffs in the north of the area, providing an important supply for the down-drift beaches. Areas of direct cliff erosion include those at Covehithe, Easton Bavents and Dunwich, whilst slope instability from Bawdsey to Felixstowe and beach erosion from Felixstowe to Languard Point both contribute to down-drift supply. The soft cliffs do not generally give rise to landslides or flows but retreat through local falls of small size or through more or less continuous crumbling. Erosion is high throughout the Natural Area but is by no means uniform. For example, at present very high rates of erosion occur in the Covehithe area, and the historical rate of retreat is estimated at up to 4.25 metres per year while there is relatively low loss in nearby areas such as Dunwich. It may well be that offshore sand banks have a protective effect near Dunwich at present dissipating and absorbing oncoming wave energy. Offshore banks also mean material tends to be kept in the system longer. These offshore banks are tidally formed, but processes are complicated by tidal flows at the mouth of the Deben Estuary. Benacre Ness is characterised by accretion as is the coastline from Thorpeness to Aldeburgh. Orfordness continues to grow southwards fed by a down drift supply from the cliffs north of the area. Landward recession of the coastline has occurred throughout the length of Orfordness spit, including over in Aldeburgh town frontage. Clayton (1987) pointed out that although the point of the Ness has migrated in position over the years, the actual line of the beach between the Ness and the Point has migrated relatively little, at a maximum rate of 0.3m/yr.

Key geological/geomorphological features:

- Exposures of Pliocene and Pleistocene Crag deposits and glacial sediments in coastal sections
- The complex shingle formation of Orfordness extending from Aldeburgh in the north to Bawdsey in the south (one of only three similar structures located on the English coast).
- Rapidly retreating cliffs in areas such as Covehithe

Number of GCR sites:

Pleistocene/Quaternary East Anglia: 4 Pilocene: 3 Pleistocene Vertebrata: 1
Coastal Geomorphology of England: 1

Geological/geomorphological SSSI coverage: There are 7 coastal (P)SSSIs in the MNA containing 9 GCR SILs representing 4 different GCR networks. The sediments and fossils of the Crag seas are exposed in coastal exposures at places such as Bawdsey Cliff SSSI, on the Deben Estuary SSSI and at Ramsholt Cliff SSSI. Benacre to Easton Bavents SSSI includes the spectacular coastal exposures of the Pleistocene succession in Suffolk and is recognised as the type site for the early Pleistocene Baventian glacial episode. At the Alde-Ore Estuary SSSI a large GCR site shows the presence of a complex shingle system, Orfordness, having some characteristics of a cuspate foreland and including both relic shingle formations and an actively developing spit. This area is subject to rapid geomorphological change. The complex shingle formation extends for a distance of 19.7 km and a close relationship exists between the shingle and the estuary of the River Alde.

Key geological management issues:

- Maintain natural marine and littoral coastal processes. (For example the groyne system at Aldeburgh has induced geomorphological change).
- Maintain levels of exposure and integrity of all GCR sites.
- Sensitivity of coastal geological exposures to coast protection.
- Need for management programmes which include managed retreat feasibility studies.
- Sensitivity of coastal features such as Orfordness to increased visitor pressures associated with improved access.

Key geological objectives:

1. **Future sea defences** must recognise the pervasive influence of active geomorphological processes and must be included within a Shoreline Management Plan.

2. **Dredging** in relation to offshore sand banks needs to be considered with care.

3. **Protection of Coastal Features** eg. by ensuring damage caused by pedestrians trampling by people disembarking for recreational purposes from boats, is kept to a minimum through a) limited slipways, pontoons etc. and b) boardwalks or c) restricted pathways.

Useful guides/references:

GREEN C. P. & McGREGOR D. F., 1988: Orfordness: a geomorphological assessment, Report to Nature Conservancy Council.

GRONE A. T., 1953: The sea flood on the coasts of Norfolk and Suffolk, Geography 38, 164 - 170.

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Benacre to Easton Bavents
- Crag Pit, Aldeburgh
- Alde-Ore Estuary
- Buckanay Farm Pit
- Bawdsey Cliff
- Deben Estuary
- Ramsholt Cliff

Maritime Natural Area: M9 Languard Point to Whitstable	**Geological Significance:** Considerable **(provisional)**

General geological character: The Languard Point to Whitstable Maritime Natural Area is predominantly a low-lying coast indented by several major estuaries: The Thames, Blackwater and The Stour.

Geological History: Exposures of the pre-Quaternary geology along this stretch of coastline show the Tertiary sediments of the London Basin. These are predominantly sands and clays deposited during the Paleogene (between 65 and 23 Ma). The most extensive of the London Basin sediments is the London Clay, a thick marine clay which was deposited in a warm sea at a time when global sea level was much higher than present. The London Clay is notable for its fossils, including the remains of subtropical fish, sharks teeth and birds.

Quaternary History: During the Quaternary Ice Ages (the last 2 Ma) the climate has been relatively cold in this area. Approximately 300,000 years BP, the Anglian ice sheet advanced from the north to cover the northern parts of the London Basin, leaving behind varying thicknesses of glacial sands, gravels and clays. Also during this time, the River Thames migrated southwards across the basin in response to climatic and topographic controls. The course of the Thames was altered dramatically by the Anglian ice sheet, which diverted its course southwards. As the course of the river changed it deposited large spreads of fluvial sands and gravels along its former courses as river terraces. These sands and gravels now obscure the London Clay in most places, especially where recent changes in sea level have left the deposits submerged by low lying coastal marsh. Many of the estuaries of the area (for example the Blackwater) were formed within previous channels of the Thames and therefore their morphology is primarily controlled by these geological structures and Pleistocene history rather than tidal dynamics.

Geomorphological Evolution and Processes: This is a predominantly low lying 'soft' coastline indented by several major estuaries such as The Thames, Blackwater and The Stour. The Maritime Natural Area is also scattered with several islands such as The Isle of Sheppey and Foulness Island. There is a moderate southward drift from the Naze to Colne Point, weakening southwards to the Thames. Erosion of the soft coast produces little beach building material, since tidal currents appear to be dispersing silts and muds seawards after erosive events. A decline of beaches south-east of Harwich down to Jaywick can be attributed to the lack of supply from the north. Wave induced erosion is widespread along the north facing coastline between Whitstable and The Thames. There is a moderate, but strong unidirectional westward drift which rapidly diminishes in strength west of Whitstable. The natural demand for shingle exceeds supply and shingle nourishment is used to make up the deficit. The Thames is one of the major estuaries of the Eastern English Coast, draining an area of 9,873 km^2. The estuary occupies part of the London tectonic basin, a synclinal stucture with its axis dipping towards the north-east. It appears to be one which has reached a dynamic equilibrium with tidal and wave forces (ie. the estuary has become a relatively stable feature), over the Holocene (the last 10,000 years). This is probably due to the availability of suspended sediment from the North Sea, as well as to fluvial sources. The sediments presence allows inter-tidal mudflats to accrete and build up in response to long-term changes in sea-level. The Blackwater provides a unique example on the East coast of England of a relatively undeveloped, small scale semi-natural estuarine landform. Erosion of the inter-tidal zone appears to be balanced by accretion in the sub-tidal channels ie: there appears to be a redistribution of sediments to give a new morpho-dynamic equilibrium, tentatively related to sea-level rise. The estuaries of the Orwell and Stour have suffered major interference to their natural systems, particularly the Orwell which has been altered by dredging and recent shipwash.

Key geological/geomorphological features:

- Coastal exposures of Tertiary sedimentary rocks and fossils.
- Coastal exposures of Thames gravels with archaeological artefacts and mammal remains.
- The low-lying 'soft' coastline indented by major estuaries and scattered with islands.
- The area contains two of the eleven GCR Saltmarsh Morphology sites in Great Britain.
- The coastline of the Isle of Sheppey provides some of the best examples of modern mass movement in Britain.

Number of GCR sites:

Tertiary Paleobotany: 3 Tertiary Fish/Amphibia: 3 Aves: 3 Pleistocene/ Quaternary of the Thames: 3 Saltmarsh Morphology: 2 Mass Movement: 1 Tertiary Reptilia: 1 Pleistocene/Quaternary of East Anglia: 1 Pleistocene Vertebrata: 1

Geological/geomorphological SSSI coverage: There are 10 coastal (P)SSSIs in the Maritime Natural Area containing 18 GCR SILs representing 9 different GCR networks. Warden Point SSSI provides excellent examples of modern mass movement in the form of coastal landslips, where average annual lossses are known to reach 3 metres. It is also an important site for its rich fossil fauna (with the remains of subtropical fish, sharks teeth and plants), as well as for Palaeogene stratigraphy. The mass movement here is important not only for the study of rotational slips but also for its sediment contribution to the coastal budget. Holland-on-Sea Cliff SSSI shows the composition of the terraces deposited by the Thames during the Quaternary. Dengie Marsh and St. Osyth Marsh, Colne Point are both important sites for their saltmarsh morphology.

Key geological /geomorphological management issues:

- Need to maintain and enhance existing coastal geological exposures
- Ensuring responsible fossil collecting from sensitive or vulnerable coastal sites
- Maintain and enhance the natural processes within estuaries in order to reach or maintain a dynamic equilibrium
- Maintain natural marine and littoral processes along the coast. A threat exists to coastal geological/geomorphological sites from coastal defence works in such places as Warden Point where the sediment contribution from erosion is fundamental to the integrity of neighbouring sites.

Key geological/geomorphological objectives:

1. **Maintain and enhance existing coastal geological exposures** by a) protecting sites from coast protection schemes and b) encouraging responsible fossil collecting from sensitive or vulnerable sites.

2. **Maintain the natural erosional processes occurring along the coast** to enable any sediment contributions within the maritime natural area to continue by a) Ensuring any coast protection schemes are part of an agreed Shoreline Management Plan.

3. **Maintain and Encourage natural processes within estuary** by using Estuary Mangement Plans.

Useful guides/references:

BRIDGLAND, D.R., 1994: Quaternary of the Thames. Geological Conservation Review Series 7, Chapman and Hall, London.

COLLINSON, M.E., 1983: Fossil Plants of the London Clay. Palaeontological Association Field Guide, 1.

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Stour Estuary
- Harwich Foreshore
- The Naze
- Holland-on-Sea-Cliff
- Clacton Cliffs
- Colne Estuary
- Blackwater Estuary
- Dengie
- The Cliff, Burnham-on-Crouch
- Warden Point