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Development of Estuary Morphological Models

Annex H: Morphological change and estuary management

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Development of Estuary Morphological Models

Morphological change and estuary management

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Summary

Development of Estuary Morphological Models

Morphological change and estuary management

Report TR 163
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The study of how and why changes to estuary morphology occur is of tremendous interest to those seeking to maximise the potential of estuaries for development while preserving, or even improving the quality of habitat and biodiversity in these systems. Two of the key drivers to the Estuaries Research Programme, funded by Defra, are improvement in knowledge regarding how morphological change affects flooding issues and how morphological change affects habitat. The influences of estuary morphology on these issues has therefore been a significant driver for this research.

This report discusses the influence that estuary morphological change can have on flooding based on examples from around the UK and beyond. This report is not definitive but is intended to highlight how different modes of morphological change can induce a range of flooding risks. In addition this report highlights how measures to address flood defence and coastal protection adversely affect estuary habitat and how this impact is being addressed.

This report has considered how morphological change will affect estuary management both in terms of flooding risk and the requirement to preserve estuary habitat. A number of different examples of how morphological change effects flood risk in estuaries, ranging from estuary wide to the local scale, have been considered. In addition it has been explained how the impact of the existing flood and coastal protection measures in combination with sea level rise is impacting on the extent of estuarine habitat and that the UK Biodiversity Action Plan is a key driver in targeting the replacement of this habitat.

The evidence suggests that large scale change resulting from extensive capital dredging in the UK has not been found to cause extensive or significant changes in flood risk, and indeed in situations where natural siltation rates are very rapid, such as in the Parrett Estuary, dredging can alleviate flood risk rather than increase it.

The flood risks associated with estuaries with natural flood and coastal protection features are commonly concerned with the preservation of these features for the future as the consequences of breaching in these spits/bars could be extensive to the valuable habitat and shorelines which currently enjoy protection. The preservation of these protective features often takes a localised form as extra protection is given to vulnerable or degrading parts of the feature.

Often flood and coastal management issues in estuaries take the form of local situations where degraded walls are made more vulnerable to wave attack because of eroding foreshores. The causes of these eroding foreshores vary but sea level rise, loss of saltmarsh and development are typically involved.

Many of the underlying issues governing flooding and coastal protection are the legacy of land reclamation that has taken place over centuries. However, the historical and contemporary flood and coastal protection measures have prevented the transgression of estuary habitat with sea level rise and led to a net loss of habitat through coastal squeeze.

Summary continued

The management of flooding and coastal protection issues and estuary habitat is dealt with through the CHaMPs process which is used to define how much habitat replacement is required and how this habitat replacement might best be achieved. The main tool utilised to replace the historical and also ongoing loss of habitat is termed managed realignment and consists of actively breaching a seawall (or passively letting nature take its course) to allow tidal waters to enter the land behind the breach, providing scope for future habitat to develop. The scope for managed realignments is often limited by land availability and there is a requirement for careful consideration of the design issues in order that the realignment will fulfil its function.

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1. Introduction

1.1 BACKGROUND

The study of how and why changes to estuary morphology occur is of tremendous interest to those seeking to maximise the potential of estuaries for development while preserving, or even improving the quality of habitat and biodiversity in these systems. Two of the key drivers to the Estuaries Research Programme, funded by Defra, are improvement in knowledge regarding how morphological change affects flooding issues and how morphological change affects habitat. The influences of estuary morphology on these issues has therefore been a significant driver for this research.

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1.2 REPORT STRUCTURE

The remainder of this report comprises a further five chapters. Chapter 2 places flood risk in the context of the often extensive historic reclamation of mudflat and saltmarsh. Chapter 3 considers the effect of large-scale dredging on flood risk. The issues arising from changes to natural flood defence features are discussed in Chapter 4 and the subject of flood risk and localised changes in morphology is considered in Chapter 5. The issues concerned with morphological change and habitat are considered in Chapter 6. The conclusions of this report are presented in Chapter 7.

2. The effect of large-scale estuary reclamation and flood protection

One of the main reasons that flooding problems exist is that for centuries the mud flat and saltmarsh in many estuaries have been reclaimed, originally for agricultural land and more recently for urban housing and industry. The sea wall/dyke structures enabling this reclamation to occur often now protect an extensive floodplain hinterland. Moreover they require continuous maintenance because failure often results in widespread flooding. It is near possible (and largely pointless) to investigate whether water levels before and after reclamation have been adversely affected as many of these reclamations have been in place for so long they are now part of (what we think of as) the natural estuary system. However, these seawalls have changed the morphology of many estuaries dramatically and the act of building behind this coastal protection has created the flood risk.

3. The effect of large scale capital dredging and development

Another cause of large-scale morphological change in estuaries is capital dredging. The need to deepen channels in order to allow larger ships to progress upstream has been and still is a large influence on the estuarine environment. In this section we discuss the effect of large-scale capital dredging on flood risk by considering the example of the Thames Estuary.

3.1 THAMES ESTUARY

3.1.1 Introduction

As part of the TE2100 studies the effect of changes in morphology on Tidal Propagation over the last 100 years in The Thames Estuary has been investigated (Siggers et al, 2006). The Thames Estuary TELEMAC-2D flow model was used together with detailed historical bathymetric data to simulate the flow conditions present in the 1910’s, 1920’s, and 1970’s and these were compared with results for the present day scenario. For all of these historical scenarios the flow model was used to reproduce mean spring tide conditions during summer flow conditions, an extreme event with reasonably high tidal conditions (HW at 4.55mOD) and a large freshwater flow (800 cumecs) and an extreme event with low freshwater flow (11 cumecs) but a large tidal surge (HW at 5.03mOD). Initially, no allowance for historical climate change was included in the boundary conditions to isolate changes in the tidal propagation arising due only to changes in morphology (including bridges). Subsequently, the effect of historical climate change was considered.

Figure 1 Thames Estuary at Westminster

3.1.2 Effect of morphological change on typical tidal conditions

The historical changes in spring tide water levels from changes in morphology alone (ie without sea level rise) are summarised in Table 2 and Figures 2 and 3 which present the maximum water level (HW), minimum water level (LW) and tidal range predicted in the simulations at locations along the river from Southend to Richmond. The figure shows that the predicted tide range has progressively increased throughout the 20th century. The predicted increase is small up to Charlton (a maximum of 0.15m, or 1.5%), but then rises to an increase of 0.6m at Tower (9%), to 0.75m at Westminster (13%), and 1.1m at Richmond for low river flows (27%).

Table 2 Modelled changes in spring tide water levels arising as a result of morphological changes over the last century

Year		Richmond	Westminster	Tower Bridge	Charlton	Erith	Tilbury	Coryton
1910 – 1915	High Water (m OD)	4.01	3.70	4.01	4.08	3.88	3.65	3.43
	Low Water (m OD)	-0.15	-2.23	-2.55	-3.00	-2.99	-2.92	-2.80
	Range (m)	4.16	5.93	6.56	7.08	6.87	6.57	6.23
1920 – 1925	High Water (m OD)	4.01	3.71	3.98	4.03	3.85	3.63	3.41
	Low Water (m OD)	-0.15	-2.26	-2.84	-3.06	-3.01	-2.92	-2.80
	Range (m)	4.16	5.97	6.82	7.09	6.86	6.55	6.21
1970 – 1975	High Water (m OD)	4.33	3.90	4.04	4.10	3.88	3.67	3.41
	Low Water (m OD)	-0.78	-2.73	-3.07	-3.13	-3.04*	-2.95	-2.79
	Range (m)	5.11	6.63	7.11	7.23	6.92	6.62	6.20
2000	High Water (m OD)	4.46	3.94	4.06	4.06	3.88	3.66	3.40
	Low Water (m OD)	-0.82	-2.78	-3.07	-3.11	-3.05*	-2.94	-2.80
	Range (m)	5.28	6.72	7.13	7.17	6.93	6.60	6.20

* *The tide gauge dries out at LW (these levels were extracted from a nearby wet location in the model)*

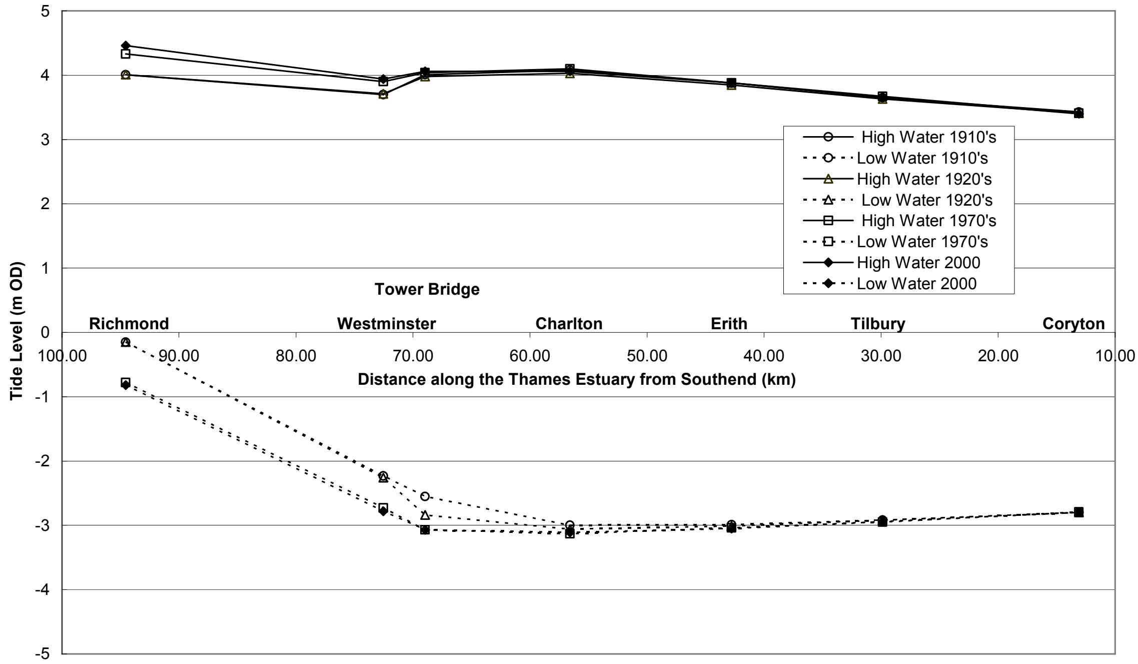

Figure 2 Modelled changes in spring tide water levels arising as a result of morphological changes over the last century

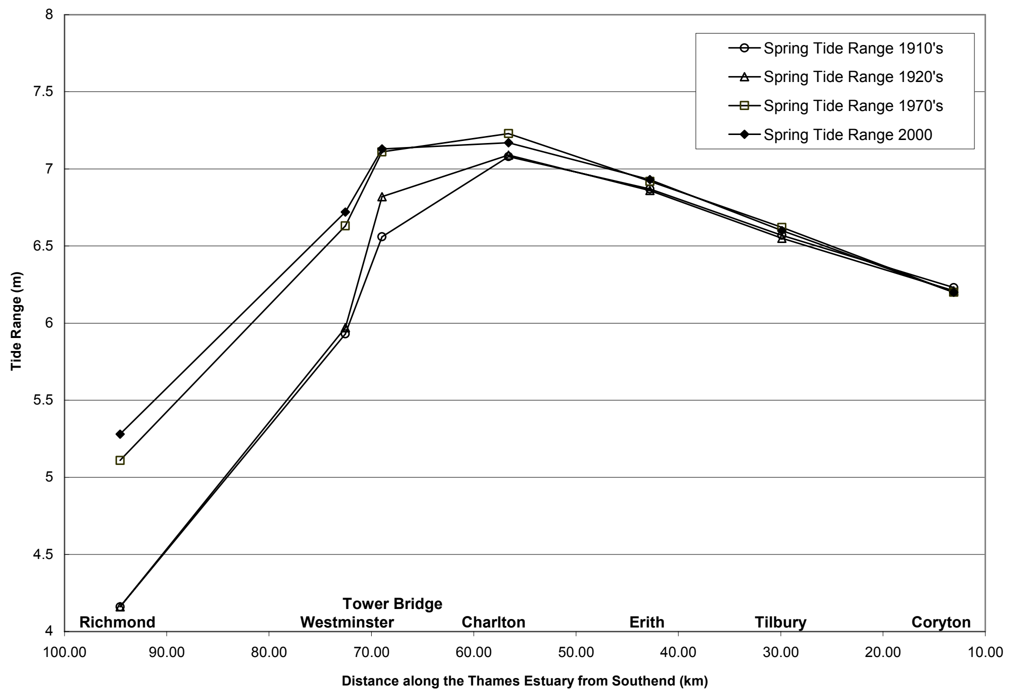

Figure 3 Modelled changes to spring tide range in response to morphological changes over the last century

When historic (relative) sea level rise was included (approximately 16cm over the 100 year period), it was found to increase the predicted differences in MHWS by 18cm at Richmond and 17cm at Westminster indicating that sea level rise appears to be super-imposed on top of the effect of morphological change.

In conclusion, historic changes in morphology at Tower Bridge and seawards of this point lead to changes in MHWS less than a few centimetres and changes in MHWS arising from sea level rise are very similar to those at Southend. MHWS at Westminster is predicted to have increased by 0.24m due to changes in morphology and 0.17m due to historical sea level rise. MHWS at Richmond during periods of low fluvial flow, is predicted to have increased by 0.45m due to changes in morphology and a further 0.18m due to historical sea level rise. These combinations may also be expressed as rates of increase in MHWS of 7-8 mm/year at Richmond, and approximately 5mm/year at Westminster.

Inglis and Allen (1957) reported that as a result of the capital dredging carried out between 1909 and 1928 the low water level was lowered by 6 inches (150 mm) and the level of high water raised by 2 inches (50 mm) at London Bridge. In the same paper the authors also reported that, over the period of 1951 to 1952, the mean spring tidal range at Richmond was "about" 15.1 feet (or 4.6m). This figure falls comfortably in the middle of the model predictions for 1920 and 1970 (See Table 3 above). This result lends confidence to the model predictions but it should be remembered that the water level in this part of the Thames may be significantly affected by fluvial flow.

3.1.3 *Effect of morphological change on extreme events and flood risk*

The effect of 100 years of morphological change on predicted extreme levels was assessed in a similar manner. The boundary conditions for these simulations were defined by combining a mean spring tide with a tidal surge profile and fluvial flow to achieve two different combined events with a 0.1% likelihood of exceedence in a given year. One event represents an extreme high water (tide and surge) at Southend in combination with a low fluvial flow at Teddington, and the other event represents a (lower) extreme high water at Southend in combination with an extreme fluvial flow at Teddington. In both cases the results were derived in the absence of Thames Barrier operation and sea level rise.

The results are summarised in Table 4. Firstly, it is seen that the historical changes in morphology have little effect on predicted peak water levels for the extreme event with high freshwater flow and a smaller tidal surge. Secondly, it is seen that the historical changes in morphology have very little effect on predicted peak water levels up to Tower Pier (<5 cm change) for both the events tested. However, it is seen that the predicted high water from the same tide dominated event has risen by 0.18m at Westminster and 0.25m at Richmond due to changes in morphology only.

Table 3 The predicted effect of historical changes in morphology on extreme levels in the Thames Estuary, assuming no operation of the Thames Barrier

	Scenario		Difference in Water Level (m)						
	Southend High Water (m OD)	Kingston Flow (cumecs)	Richmond	Westminster	Tower Pier	Charlton	Erith	Tilbury	Coryton
Present minus 1970s	5.03	11	-0.01	0.01	0.01	-0.04	-0.02	-0.03	-0.03
Present minus 1970s	4.55	800	0	-0.01	0.01	-0.01	-0.02	-0.03	-0.02
Present minus 1920s	5.03	11	0.24	0.15	0.04	-0.05	-0.04	-0.04	-0.03
Present minus 1920s	4.55	800	-0.02	-0.01	0.05	-0.02	-0.02	-0.03	-0.02
Present minus 1910s	5.03	11	0.25	0.18	0.05	-0.05	-0.05	-0.02	-0.02
Present minus 1910s	4.55	800	-0.05	-0.03	0.02	-0.03	0	0	-0.02

3.2 CASE STUDY: LOIRE

Over the 20th century the Loire experienced capital dredging on a large scale. The dredging extended from St.Nazaire to Ancenis (some 90km) and lowered the sea bed substantially. Figure 4 shows the change in MHWS and MLWS that occurred between 1903 and 2000 (Loire Estuaire Cellule de Mesures et de Bilans, 2002). The figure shows that while MLWS dropped by up to 2.65m over this period the rise in MHWS was less than 0.3m. This result mirrors that of the Thames – that large scale dredging can result in large changes in tidal range but only in small rises in levels of High Water. As a result there are large changes in tidal propagation under normal conditions but only small increases in flooding risk.

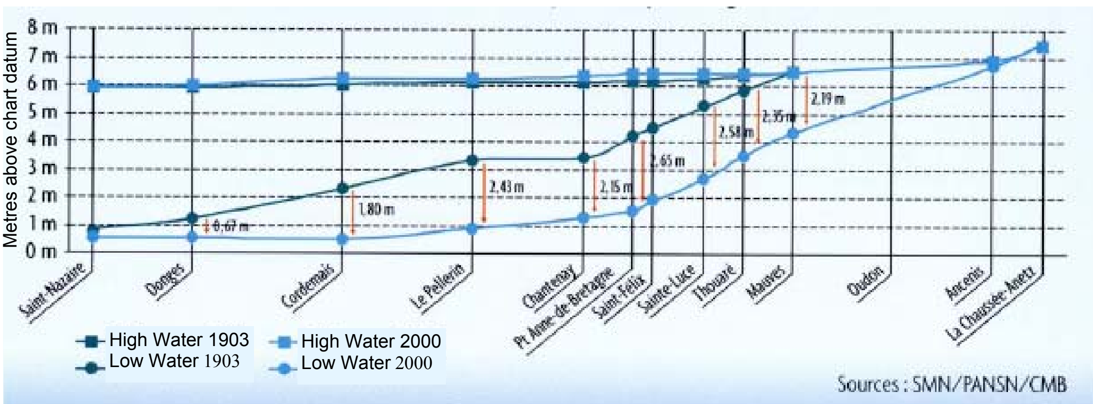

Figure 4 Changes in spring tide water levels in the Loire estuary 1903-2000

3.3 CASE STUDY: HARWICH HARBOUR

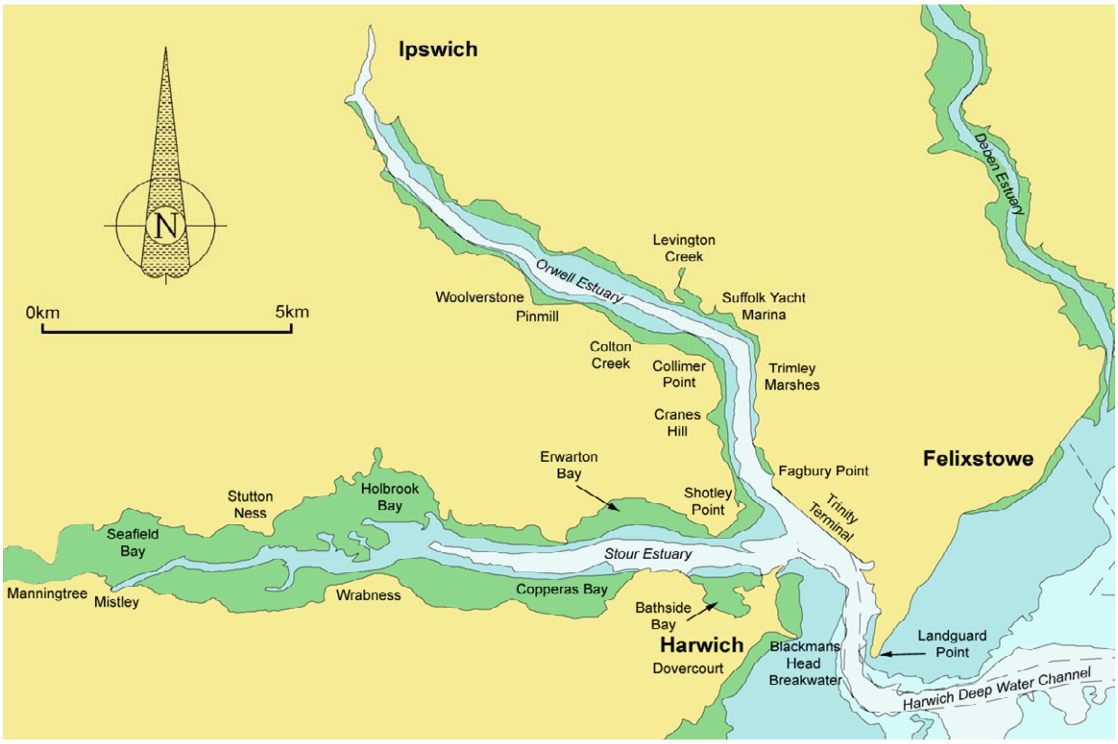

Figure 5 Harwich Harbour and the Stour and Orwell Estuaries

Harwich Harbour (Figure 5), which is the name given to the confluence of the mouths of the Stour and Orwell Estuaries as they flow into the Southern North Sea, has been progressively deepened over the last forty years to allow the progress of ships of greater draft to the Port of Felixstowe. The channel depth has increased from around -7mCD in 1970 to -14.5mCD at the present date. Studies for the proposed container terminal at Bathside Bay (HR Wallingford, 2001) showed that the deepening associated with the Harbour and the other historical changes over this period has caused tiny changes to the tidal propagation in the estuaries. However the deepening, and the reflection off the quay walls of the Port of Felixstowe, has led to a 30% increase in wave heights in the Lower Stour arising from southerly and south-westerly waves propagating into the harbour from offshore. This is illustrated in Figure 6.

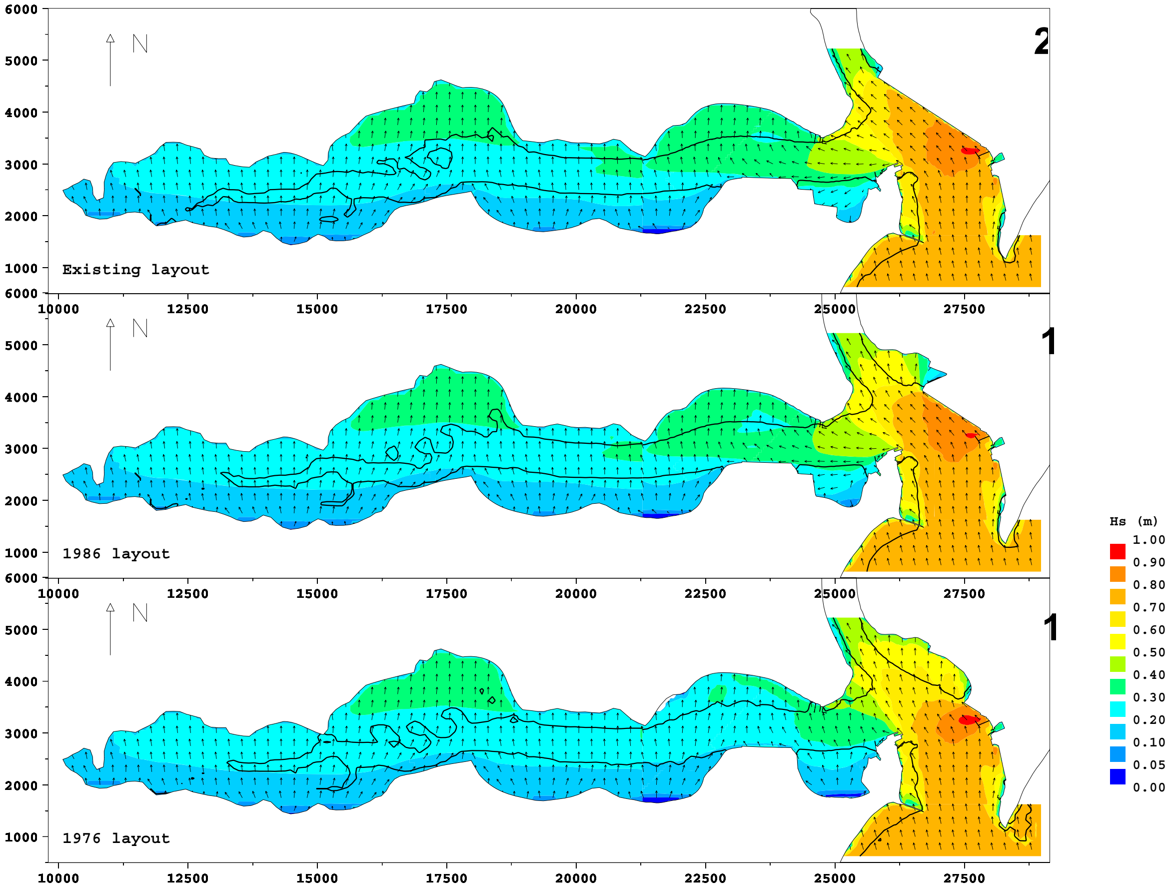

Figure 6 Predicted wave heights results for frequently experienced waves for 1976 (bottom), 1986 (middle) and existing (top) scenarios (wind dir. = 180°N, speed = 10.6m/s, offshore wave dir. = 166°N, H_s = 0.7m, T_z = 2.7s, MHWS)

However, even with this increase in wave activity, there is no evidence that the main flood risk, which is dependent on a combination of high tides and tidal surges has been affected by changes in the harbour The increase in wave activity has, however, increased the risk of erosion locally around the spit at Shotley Point which is of concern (HR Wallingford, 2001).

This example illustrates how flooding issues arising from large scale morphological change are still often concerned with a localised sensitive area. This subject is discussed further in Section 5.

3.4 CASE STUDY: PARRETT ESTUARY

Much of this section is taken from The Parrett Catchment Water Management Strategy Action Plan (Environment Agency, 2002).

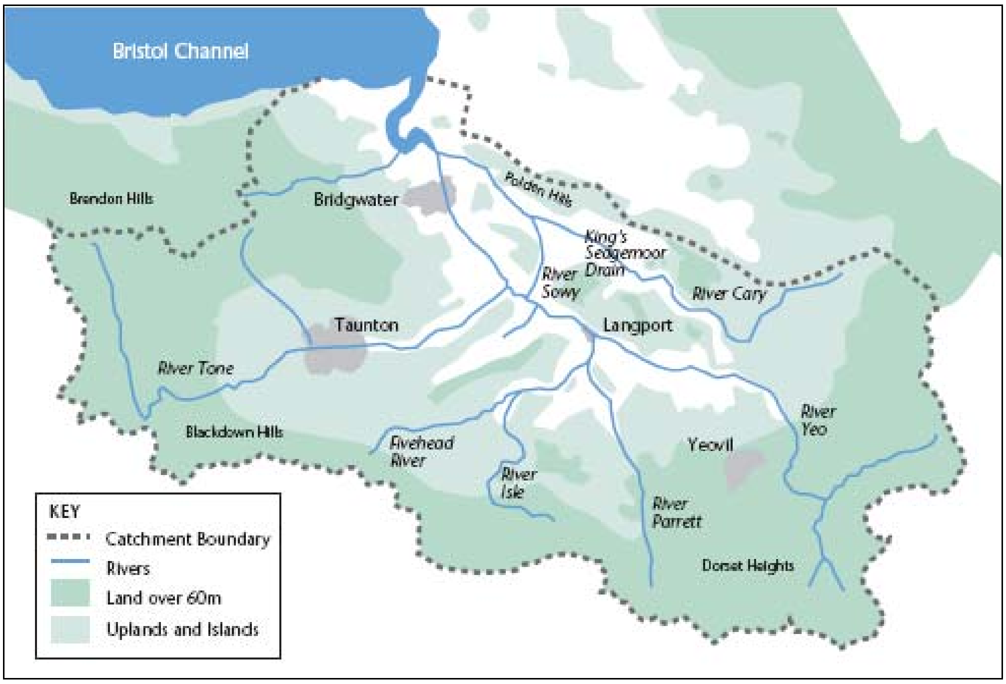

Figure 7 The Parrett Catchment

The characteristic landscape of the Levels and Moors of the Parrett system has been shaped over the last thousand years by the development of the drainage and flood defence system. Over this time there have been concentrated periods of activity related to the agricultural aspirations of the communities. The first reclamations started in 1235 and continued until the 18th century. In the 19th century the first pumping stations were built and major pumping stations were built throughout the 20th century. Before these interventions, rivers flowed to the sea through shallow heavily silted channels, particularly in the lower reaches of the Parrett. The river's flow would have exceeded the capacity of the channel for a large proportion of the time and even an average winter's rain would have put most of the low lying basin under water until the following summer. The spring tides would have reached far inland, giving saltmarsh conditions over large areas.

One of the contributing causes of flooding is the influence of the tide from the Bristol Channel. The tidal range is the second highest in the world, and each incoming tide brings with it tonnes of silt in suspension. The rate of siltation is sufficient to cause changes in bed level of a few metres which reduces the channel cross-section area and thus the conveyance of fluvial flow during the higher fluvial discharges of the winter. This normally makes it necessary to re-profile the channels every 2 years (Parrett Catchment project, 2005). Thus the effects of dredging in this case are to alleviate flood risk.

4. The effect on flood risk of morphological change around specific features

4.1 INTRODUCTION

In bar-built estuaries or those with spits or a breakwater at the mouth these features can be an important control on waves and tides within the estuary. If there are morphological changes in this controlling geomorphological feature then this can have important consequences for flood risk in the surrounding area.

4.2 CASE STUDY: EXE ESTUARY

The sediment transport regime and flood risk associated with Dawlish Warren and the Exe Estuary in general are well documented in the SCOPAC (2003) and EEMP (2007) documents. This section represents a brief summary of the work represented in these resources.

Figure 7 Dawlish warren and the Exe Estuary (courtesy of the Exe Estuary Management Partnership)

The Exe Estuary is fronted by Dawlish Warren, a major spit structure substantially composed of sand, with superimposed dunes and a series of sandbanks, of which Pole Sand, seaward of the spit, and Bull Hill Bank, landward of the spit, are the most significant (Figure 7). These features combine to provide both the Estuary and the Exmouth frontage with significant protection from wave attack, coastal surges and other coast-induced processes.

As well as being a valuable habitat in its own right Dawlish Warren provides protection to some 66 ha of saltmarsh, 1200 ha of intertidal flats and up to 500 ha of grazing marshes. Due to extensive 18th and 19th century reclamation, defences protect much of the low-lying estuary perimeter.

Dawlish Warren has a long and complex history of fluctuating erosion and accretion but has suffered net loss of sediment over recent decades. Its landward attachment and neck have been protected since the 1920s by a variety of methods including groynes, gabions and dune management. Erosion and damage within a series of severe storms during the winter of 1989/90 prompted installation of a seawall and rock armour protection of southern parts. During storm events large quantities of sediment can be removed from Pole Sand, Dawlish Warren and the Exmouth frontage and deposited in the channels.

Clearly Dawlish Warren, and the accompanying sand bank features are of tremendous importance to flood risk in the Exe Estuary. Whilst the current scale of changes in morphology, such as those experienced in recent years, have not yet materially changed the function of the Warren, constant vigilance is required to maintain the integrity of this feature so that it is preserved for future years and performs its role in protecting the Exe Estuary from wave attack and coastal surges.

Figure 8 Dawlish Warren Spit, 1997 (Courtesy of the Environment Agency)

4.3 CASE STUDY: ALDE/ORE/BUTLEY/ ESTUARY

JNCC (2007) describes this estuary system as the only bar-built estuary in the UK with a shingle bar. This bar has been extending rapidly along the coast since 1530, pushing the mouth of the estuary progressively south-westwards. The eastwards-running Alde River originally entered the sea at Aldeburgh, but now turns south along the inner side of the Orfordness shingle spit. It is relatively wide and shallow, with extensive intertidal mudflats on both sides of the channel in its upper reaches and saltmarsh accreting along its fringes. The Alde subsequently becomes the south-west flowing River Ore, which is narrower and deeper with stronger currents. The smaller Butley River, which has extensive areas of saltmarsh and a reedbed community bordering intertidal mudflats, flows into the Ore shortly after the latter divides around Havergate Island. There has been reclamation of the mudflats and salt-marsh in the estuary system over several centuries right up to the mid 19th century. This has effectively meant that the river has lost its natural form and been canalised over much of its length by the building of defensive walls to protect reclaimed land behind them (JNCC 2007).

Figure 9 Ore/Alde/Butley Estuary

Pye (2005) notes the most obvious flood risk as the outside of the meander bend at Slaughden, where the deep water channel is constricted between the quay and the old ferry point. He concludes that:

"Under natural conditions, if existing river and sea defences are not maintained and improved, the outside bend of the meander would wish to move eastwards, cutting into the landward side of the shingle bank at Slaughden. In time this would inevitably result in a breach, even without any further sea level rise. If such a breach were to occur, tidal energy in the inner part of the Alde-Ore estuary would be greatly increased, resulting in increased high water levels, and therefore risk of flooding, between Slaughden and Snape. "

In its way the flood risk in the Alde-Ore is similar to that resulting from at Dawlish Warren, except that the morphology of the Ore/Alde/Butley is such that the vulnerable part of the bar is more localised and the consequences of breaching more immediate.

5. Localised changes in morphology and flood risk

5.1 INTRODUCTION

As we have already seen in the previous sections, although morphological change may occur on a large scale it is often the case that flood risk issues resulting from these changes manifest themselves at the local scale. Additionally, as with natural flood protection features such as bars and spits, the need to preserve these features for the future may take the form of works on a local scale which give extra protection to the more vulnerable parts.

It is common for flood risk problems to take the form of localised disrepair of sea walls, sometimes in combination with lowering of the foreshore in front of the sea wall as a result of a natural (sea level rise, a change in wave climate, saltmarsh die-off) or man-made change (development, ship-wash, etc.). The following example represents a combination of a vulnerable sea wall, which has historically been accompanied by a lowering foreshore, and increased risk of erosion arising from the effects of development.

5.2 CASE STUDY: HARWICH HARBOUR

Figure 10 Location of Trinity III(2) Extension and mitigation measures

The Environmental Impact Studies for the TRINITY III(2) Port extension at the Port of Felixstowe (PDE, 2000) identified that the proposed extension (now completed) would result in increased tidal currents and wave attack on the foreshores at Trimley and Shotley and that this would result in an increased rate of erosion on the foreshore (see Figure 10). The prospective loss of foreshore was seen to have an adverse effect on flood risk because a lowering of the foreshore would increase the wave attack on the seawalls in these locations. It was further considered that these seawalls, which can be described as degraded, might not be of a sufficient height and condition to withstand the projected increase in wave attack.

Figure 11 Photograph of bunds used to alleviate flood risk and enhance habitat

The mitigation for this effect took the form of raising the level of the intertidal in front of the degraded seawall. The beneficial use of clay arising from the capital dredging was used to beneficially construct of bunds on the Shotley and Trimley foreshores at around the mean low water mark (see Figure 11). The bunds were backfilled with muds arising from either the capital dredging for the Trinity III project or from ongoing maintenance. The bunds were able to address the twin goal of enhancing habitat and alleviating flood risk issues. It was considered that the scheme proposed provides a sustainable solution for the medium term (15-25 years) and would not limit future options for managing the flood defences in this part of the estuary (Dearnaley, 2002).

6. The link between changes in morphology and management of estuary habitat

6.1 INTRODUCTION

As well as the consideration of flood risk and coastal protection issues estuary management must also take account of important estuarine habitats and the effects of sea level rise and the implemented flooding and coastal protection measures and other development on this habitat.

Many of the UK estuaries contain areas of habitat which are designated as especially worthy of protection. In estuaries these tend to be areas of mudflat and saltmarsh which are usually designated because they provide important habitat for bird populations but also may be designated because they contain important individual species of flora or fauna.

6.2 UK BIODIVERSITY ACTION PLAN

6.2.1 Introduction

The UK Biodiversity Action Plan (UKBAP) is the UK Government's response to the Convention on Biological Diversity signed by the UK Government in 1992. It describes the UK's biological resources and commits a detailed plan for the protection of these resources. The UKBAP is divided into Species Action Plans, Habitat Action Plans and Local Biodiversity Action Plans with targeted actions.

In the context of estuary management the habitats of most concern tend to be mudflat and saltmarsh and so the Action Plans for these priority habitats often feature prominently. However, there are also Action Plans for the priority habitats relating to sheltered muddy gravels, seagrass and other sublittoral habitats.

The sections below describe the UKBAP as set out in the Joint Nature Conservation Committee website (http://www.ukbap.org.uk).

6.2.2 Current status

Mudflats are sedimentary intertidal habitats created by deposition in low energy coastal environments, particularly estuaries and other sheltered areas.
The total UK estuarine resource has been estimated as *c*588,000 ha of which 55% is intertidal area, mostly mud and sandflats with a lesser amount of saltmarsh. Intertidal flats cover about 270,000 ha. The UK has approximately 15% of the north-west European estuarine habitat.

One of the major impacts of sea level rise on a shoreline defended by flood defences is a reduction in intertidal area because the rise in low water levels means that the tide in future would not go as far out as at present, but the high tide cannot flood further inland because of the presence of the flood defences. This reduction in intertidal area is known as coastal squeeze. It has been estimated (JNCC, www.ukbap.org.uk) that relative sea level rise will result in a loss of 8000 to 10,000 ha of intertidal flats in England between 1993 and 2013. Additional losses have historically arisen from Land claim (e.g. for urban and transport infrastructure and for industry), barrage schemes, pollution and other sources.

Coastal saltmarshes in the UK comprise the upper, vegetated portions of intertidal mudflats, lying approximately between mean high water neap tides and mean high water spring tides. The most recent saltmarsh surveys of the UK estimate the total extent of saltmarsh (including transitional communities) to be approximately 45,500 ha (England 32,500 ha, Scotland 6747 ha, Wales 6089 ha, and Northern Ireland 215 ha). The best available information suggests that saltmarshes in the UK are being lost to erosion at a rate of 100 ha/yr. In addition anthropogenic effects have led to deterioration of saltmarsh communities. Although large scale saltmarsh land claim schemes for agriculture are now rare, piecemeal smaller scale land claim for industry, port facilities, transport infrastructure and waste disposal is still comparatively common. Further deterioration has been caused by introduction of alien saltmarsh species, grazing and pollution.

6.2.3 Protection

Protection for mudflats is provided by various international and EU agreements and is implemented by the relevant UK enabling legislation. In addition the UK has its own domestic measures which can protect mudflats. Some of this legislation provides direct protection for the habitat whilst other measures provide indirect protection by controlling water quality. International designations of major significance to mudflats are the Ramsar Convention protecting wetlands of international importance, the Bonn Convention to protect migratory species of wild animals, and the Bern Convention to conserve European wildlife and habitats. Sites designated under EU law form part of the Natura 2000 series of protected habitats, ie Special Protection Areas (SPA) under the 1979 EC Birds Directive or Special Areas of Conservation (SAC) under the 1992 EC Habitats Directive. Under the Wildlife and Countryside Act 1981, over 300 SSSIs which include mudflats have been designated on estuaries. In addition there are 22 (November 1998) coastal ASSIs in Northern Ireland, 10 of which contain significant areas of mudflats.

Approximately 80% of the area of saltmarsh in Great Britain has been notified as SSSI, except in north-west Scotland where only about 50% has been notified. In Northern Ireland, five of the seven estuaries containing saltmarsh have been declared as ASSI. Atlantic Salt Meadows is listed as habitat type in Annex I of the EC Habitats Directive. Ten areas in Great Britain have been proposed as SACs for their saltmarsh features. In addition, 27 major saltmarsh sites and many smaller ones are included in SPAs under the EC Birds Directive and in Ramsar sites.

6.2.4 Action plan objectives and targets

The action plan objectives for mudflats include the following targets:

- Maintain at least the present extent and regional distribution of the UK's mudflats.
- Create and restore enough intertidal area over the next 50 years to offset predicted losses to rising sea level in the same period. Predicted losses in the next 15 years should be offset in the next 10 years. The target for offsetting historical and predicted loss of mudflat is 700ha/yr.

The action plan objectives for saltmarsh includes the following targets:

- There should be no further net loss (currently estimated at 100 ha/year) of coastal saltmarsh. This will involve the creation of 100 ha/year during the period of this plan.

- Create a further 40 ha of saltmarsh in each year of the plan to replace the 600 ha lost between 1992 and 1998, based on current estimates.

6.3 COASTAL HABITAT MANAGEMENT PLANS

CHaMPs are intended to provide a high level framework to advise the management decisions that may affect designated habitats and to implement the targets set by the UKBAP. CHaMPs are considered necessary where such sites are located on, or adjacent to, dynamic coastlines and where other activities, such as flood and coastal defence, may significantly affect the management of the (semi-) natural system. In general CHaMPs have two primary functions (Frost et al, 2007):

- to act as an accounting system to record and predict losses and/or gains to habitat; and,
- to set, at a high level, the direction for habitat conservation measures to address net losses. This will inform decisions on proposed flood and coastal erosion risk management activities to provide a strategic picture of habitat replacement requirements.

The need for a CHaMP arises due to:

- The concern that there may be a net loss of certain habitat types within this designated area of nature conservation value.
- The requirement for a strategic approach to the management of extensive areas of designated nature conservation value in order to pro-actively inform management planning of both flood or erosion risk and nature conservation assets over medium- and long-term timescales.
- The need to satisfy the targets set by the UKBAP.
- The intent to pro-actively inform ongoing flood and erosion risk management plans, strategies or schemes.

6.4 MANAGEMENT OPTIONS FOR MITIGATING THE EFFECT OF SEA LEVEL RISE (AND ASSOCIATED IMPACTS FROM FLOOD DEFENCE MEASURES) ON HABITAT

The main instrument that is deployed to mitigate the impact of sea level rise on habitat is managed realignment. This generally involves the deliberate breaching of an existing sea wall to allow tidal waters to flow onto the land (often termed the setback field) behind the breach. Managed realignment can also be achieved (albeit over a longer time frame) by allowing sea defences to degrade over time and breach naturally (this is termed “walk away”). The land, which is often agricultural in origin, will then, if well designed, turn over a period of years into an intertidal habitat with mudflat and saltmarsh. This subject are the issues surrounding it are discussed in detail in CIRIA (2004).

Managed realignment requires careful design to ensure that the setback field behind the breach empties and fills appropriately and to ensure that the levels of the intertidal flat in the set back field are such that the required frequency of submersion will occur (thus enabling the required saltmarsh to grow). In some schemes (as at Wallasea Island) dredged sediment from capital schemes has been used to alter the setback field morphology. If the levels in the setback field are not sufficiently engineered then the scheme may act as a sediment trap and the effect of removal of sediment from the remainder of the estuary should be considered. It is also important to note that the flow of water into the set back field will cause erosion on the foreshore in front of the breach and this can have a localised adverse effect on habitat.

In some circumstances managed realignment can have a small but beneficial effect on flooding. Badly placed managed realignment schemes can potentially have the opposite effect. However, it is more common that the effect of these schemes is minimal on flooding and they act merely as generators of mudflat and saltmarsh.

The selection of locations for managed realignment will be influenced by the considerations noted above (some locations made be ruled out because they increase flood risk or because there is an important habitat in the vicinity of the breach) but in many cases the locations of managed realignment options are a function of land availability and the area required as well as the practical costs of engineering the site and maintaining the new seawalls at the back of the managed realignment site.

Table 4 Managed realignment schemes in the UK

<table>
<tr><th colspan="2">Scheme</th><th>Area (ha)</th><th>Reason</th></tr>
<tr><td>Tollesbury,</td><td rowspan="4">Blackwater Estuary</td><td>20</td><td>Trial</td></tr>
<tr><td>Orplands,</td><td>42</td><td>Trial</td></tr>
<tr><td>Abbots Hall</td><td>49</td><td>Habitat creation</td></tr>
<tr><td>Northey Island</td><td>2</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Saltram, Plym Estuary</td><td>5</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Porlock Bay, Somerset</td><td>140*</td><td>Habitat creation (“walk away”)</td></tr>
<tr><td colspan="2">Lantern Marsh, Orford Ness</td><td>37</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Havergate Island, Ore Estuary</td><td>9</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Thornham Bay, Chichester Harbour</td><td>5</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Trimley, Orwell Estuary</td><td>16</td><td>Compensation</td></tr>
<tr><td colspan="2">Freiston Shore, The Wash</td><td>66</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Brean, Axe Estuary</td><td>13</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Nigg Bay, Cromerty Forth</td><td>25</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Brancaster, Norfolk coast</td><td>11</td><td>Habitat creation</td></tr>
<tr><td>Thorngumbald</td><td rowspan="4">Humber Estuary</td><td>80</td><td>Part habitat creation, part compensation</td></tr>
<tr><td>Alkborough</td><td>440*</td><td>Habitat creation</td></tr>
<tr><td>Welwick</td><td>80</td><td>Compensation</td></tr>
<tr><td>Chowderness</td><td>14</td><td>Compensation</td></tr>
<tr><td>Wallasea Island,</td><td rowspan="2">Crouch Estuary</td><td>110</td><td>Compensation</td></tr>
<tr><td>Hullbridge, Essex</td><td>10</td><td>Compensation</td></tr>
<tr><td colspan="2">Goosemoor, Exe Estuary</td><td>6</td><td>Habitat creation</td></tr>
<tr><td colspan="2">Total area of implemented schemes</td><td>1110</td><td></td></tr>
</table>

** Correction to the figure cited by Crookes and Sharpe (2007)*

Examples of managed realignment schemes which have been implemented thus far in the UK (although most of them were not implemented as a result of the CHaMPs process) are given below in Table 4 (Cookes and Sharpe, 2007). The table indicates the size and overall purpose of the completed schemes. The Tollesbury and Orplands schemes were essentially trial schemes. The Porlock Bay scheme was the result of the breach of a shingle ridge and the decision not to restore it. Trimley, the Crouch schemes and some of the Humber schemes were implemented to offset habitat lost as a result of development. The rest were implemented to create habitat to offset the loss of habitat resulting from sea level rise.

6.5 CASE STUDY: HUMBER ESTUARY

The Humber Estuary Shoreline Management Plan (HESMP), which was published in 2000 (Environment Agency, 2000), identified a flood defence strategy for the Humber estuary. HESMP identified the importance of understanding how the estuary and adjacent coastline will behave in future, in particular how they will respond to sea level rise and what steps would be required to manage the environmental impact of these changes. HESMP Phase 2 studies were commissioned in 2001 to examine these issues in more detail. These geomorphology studies form an important input into the Humber Coastal Habitat Management Plan which reviews the likely impact on the internationally designated Humber conservation sites of the future evolution of the Humber in response to sealevel rise.

The extent of flood defence structures in the Humber Estuary means the Estuary will experience coast al squeeze (see Section X.2) and one of the main aims of the studies was to estimate the loss of intertidal habitat that would result under the action of sea level rise. The predicted loss of intertidal habitat that will occur in the Humber Estuary over the next 50 years is summarised in Table 5 (Black and Veatch, 2004).

Table 5 Recommended coastal squeeze allowance for the Humber

Sea level rise rate (mm/yr)	Recommended Coastal Squeeze Allowance (Ha)			
	Outer Humber	Middle Humber	Inner Humber	Total
1.8	50	140	10	200
6.0	180	360	60	600

As a result of the predicted coastal squeeze in the Humber the following sites for managed realignment were identified (Black and Veatch, 2004):

- Skeffling (Outer Humber N bank)
- Welwick (Outer Humber N bank)
- Keyingham (Middle Humber N bank)
- Alkborough (Inner Humber S bank)
- Whitton Ness (Inner Humber S bank)
- Goxhill (Middle Humber S bank)
- Donna Nook (Outer Humber S bank)

These managed realignment sites are shown in Figure 12 along with the site of Paull Holme Strays (also known as Thorngumbald) which is a managed realignment site partially representing compensation for loss of habitat resulting from development.

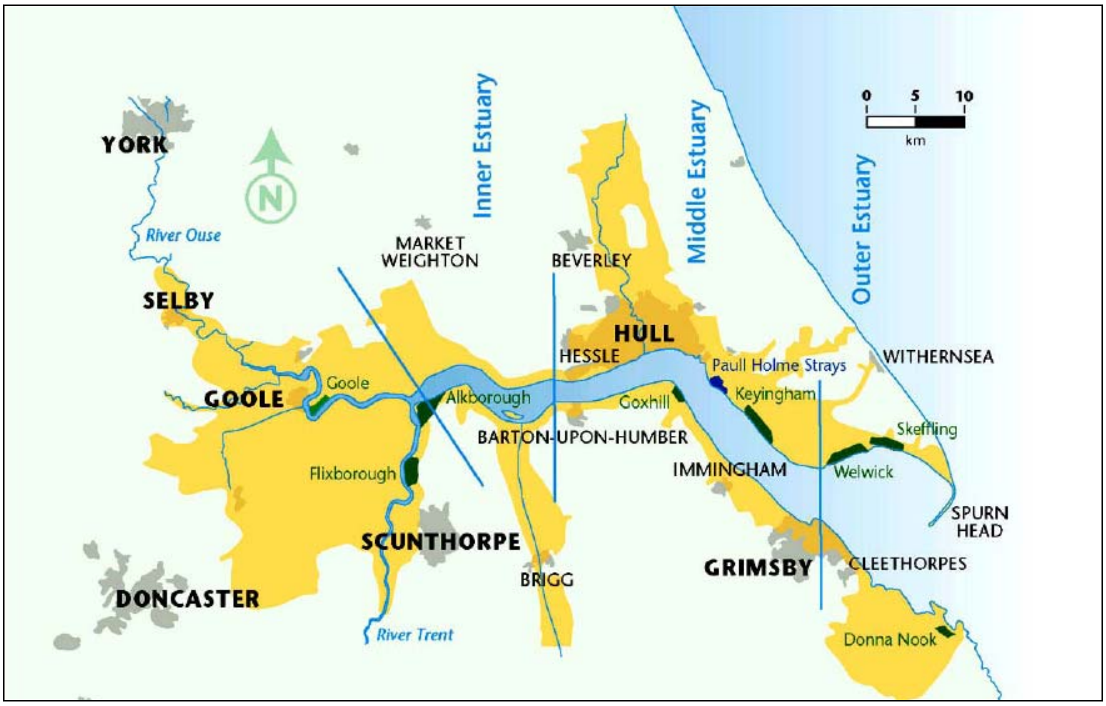

Figure 12 Humber Estuary managed realignment sites (Reproduced from Townend et al, 2004)

7. Conclusions

This report has considered how morphological change will affect estuary management both in terms of flooding risk and the requirement to preserve estuary habitat. A number of different examples of how morphological change effects flood risk in estuaries, ranging from estuary wide to the local scale, have been considered. In addition it has been explained how the impact of the existing flood and coastal protection measures in combination with sea level rise is impacting on the extent of estuarine habitat and that the UK Biodiversity Action Plan is key driver in targeting the replacement of this habitat.

The evidence suggests that large scale change resulting from extensive capital dredging has not been found to cause extensive or significant changes in flood risk, and indeed in situations where natural siltation rates are very rapid, such as in the Parrett Estuary, dredging can alleviate flood risk rather than increase it.

The flood risks associated with estuaries with natural flood and coastal protection features are commonly concerned with the preservation of these features for the future as the consequences of breaching in these spits/bars could be extensive to the valuable habitat and shorelines which currently enjoy protection. The preservation of these protective features often takes a localised form as extra protection is given to vulnerable or degrading parts of the feature.

Often flood and coastal management issues in estuaries take the form of local situations where degraded walls are made more vulnerable to wave attack because of eroding foreshores. The causes of these eroding foreshores vary but sea level rise, loss of saltmarsh and development are typically involved.

Many of the underlying issues governing flooding and coastal protection are the legacy of land reclamation that has taken place over centuries. However, the historical and contemporary flood and coastal protection measures have prevented the transgression of estuary habitat with sea level rise and led to a net loss of habitat through coastal squeeze.

The management of flooding and coastal protection issues and estuary habitat is dealt with through the CHaMPs process which is used to define how much habitat replacement is required and how this habitat replacement might best be achieved. The main tool utilised to replace the historical and also ongoing loss of habitat is termed managed realignment and consists of actively breaching a seawall (or passively letting nature take its course) to allow tidal waters to enter the land behind the breach, providing scope for future habitat to develop. The scope for managed realignments is often limited by land availability and there is a requirement for careful consideration of the design issues in order that the realignment will fulfil its function.

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