3. Coastal Processes Assessment

3.1 INTRODUCTION

This chapter is part of a series that examines how best to manage the frontage at Eastoke Point, at the eastern end of Hayling Island. This particular chapter is concerned with the coastal processes that influence the evolution of the Eastoke frontage, namely the interaction of the mixed sand/shingle beach with the various hydrodynamic "loadings" (waves, currents etc). The principal aim of this study is to understand how the beach has developed in the past, with a view to later quantifying the future evolution of the beach, in response to both natural forces and to possible changes in the coastal defences. The following simplified flow chart sets out the main littoral processes and their interrelationship.

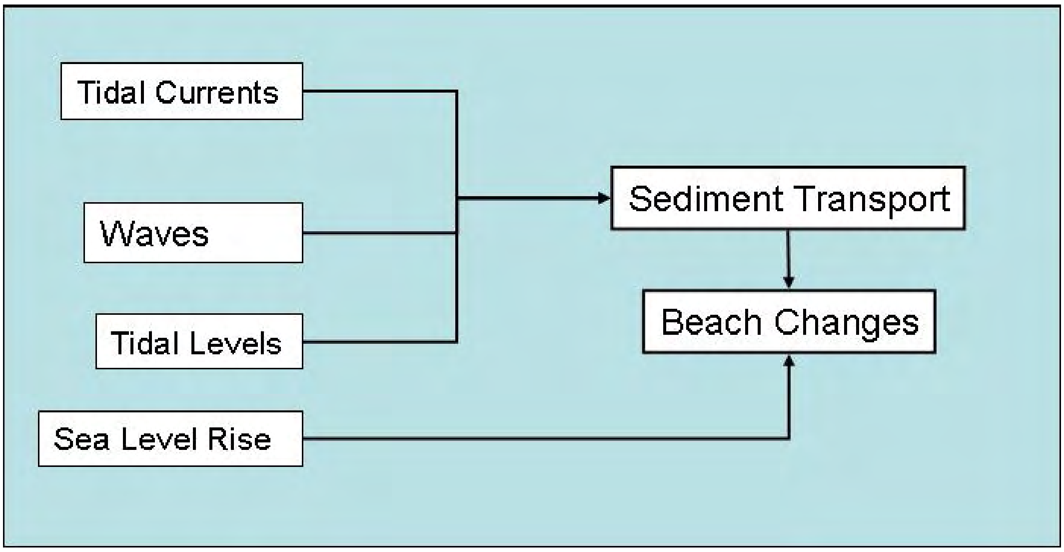


Figure 3.1 Simplified flowchart of littoral processes

In order to understand the present day morphodynamic regime at Eastoke, it is necessary to consider a range of factors, including geological evolution, hydrodynamics, historic coastline evolution and sediment transport processes, both now and prior to the 1985 beach replenishment. The chapter will also consider any interrelationships between Eastoke/Black Point and East Head and make a preliminary assessment of the impacts of coastal squeeze.

3.2 GEOLOGICAL SETTING

The Solent region has undergone a complex geomorphological evolution and it is important to appreciate this geological history, as many of the present day features and controlling influences are inherited from earlier periods. Past behaviour therefore provides a valuable insight into the types of change that might be anticipated in the future under the changing climatic conditions associated with global warming.

3.2.1 Solid geology

The underlying bedrock of the Solent region comprises chalk beds, which were lain down in a shallow sea during the Upper Cretaceous period 83-74 million years ago (mya). The chalk is overlain by Tertiary deposits of soft clay, sand and silt. Approximately 54-51 mya, an initial fall in sea level instigated the deposition of the Reading Beds, in an area of freshwater marsh with ponds and dunes. These beds contain a highly diverse fossil fauna.

Some 51-47 mya, a rise in sea level led to the deposition of the London Clay sequence, which comprises dark marine clays that are rich in fossil plants typical of a sub tropical rainforest. The overlying Bracklesham Beds were deposited in alternating inter-tidal and offshore environments some 47-44 mya. The solid geology of the eastern Solent region is presented schematically in Figure 3.2.

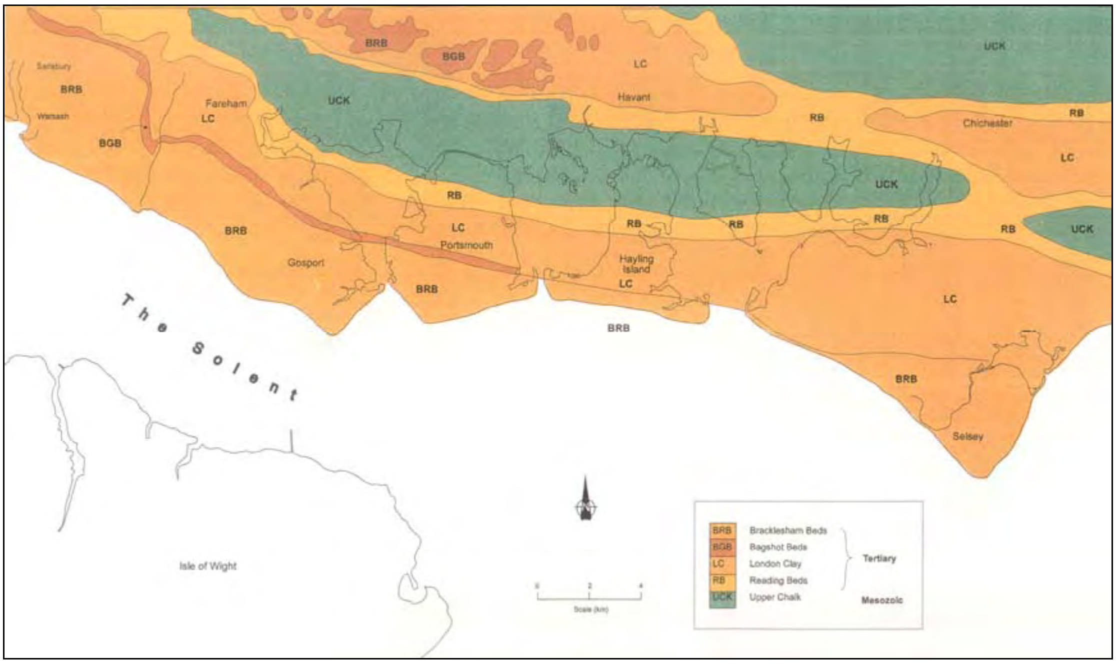


Figure 3.2 Solid geology of the east Solent Region

Earth movements associated with the Alpine mountain building era (approximately 15 mya) folded this sequence of rocks and produced two parallel ridges – the Littlehampton chalk ridge and one to the south, which now forms the Isle of Wight chalk downs.

The eastern Solent itself represents the drowned valley and floodplains of the ancient Solent River that flowed across Dorset and Southern Hampshire before joining the larger 'English Channel River'. The Solent River developed during the late Devensian Glaciation, when sea levels were as much as 120m below the present day level and originally flowed from west to east between the two chalk ridges described previously.

During the Holocene Transgression which occurred between 15,000 and 5,000 years before present (BP), rising sea levels breached the southern chalk ridge and separated the Isle of Wight from the mainland. During this period, the Solent river valley was inundated and eventually infilled with fluvial deposits. Over time, vast quantities of sand and gravel were deposited throughout the region and these now form the major sources of beach material along the modern Solent coastline.

3.2.2 Sedimentary deposits

As a result of continued sea level rise, vast quantities of sand and shingle were forced landwards by wave action, forming a series of massive shingle spits, barrier beaches and offshore shoals located several kilometres seawards of the present shoreline. Relict beach terraces have been identified on the seabed in both Hayling and Bracklesham Bays. There is evidence of tidal channels through the barriers and the inundation of the chalk ridge between the Isle of Wight and the mainland probably instigated the complex tidal regime that characterises the modern Solent.

The onshore movement of sediment at Hayling Island is not readily identifiable, not least because the beaches have been nourished with material won from seabed deposits. However, in certain other areas the seabed sediments continue to be actively reworked by wave action, a process that is evident at Selsey Bill, for example. Here, the onshore migration of shingle, in the form of large spits migrating landwards, is commonly seen. Such onshore migration represents an important source of supply to the beaches. For example, shingle that is carried westwards along the Medmerry frontage, has the possibility (at least) of reaching Eastoke Point, in due course.

3.2.3 Historical development of barrier beaches and other accretion structures

Parts of the open coastline of the Solent are characterised by substantial accumulations of gravel and mixed gravel and sand, some of which extend several hundreds of metres inland from the backshores of modern shingle beaches. The other major accretion structures are sand and shingle spits that have developed across the entrances to harbours and estuaries. Most of these occur in pairs, and appear to have grown in opposite directions, resulting in the narrowing and deflection of estuary mouths. Although some such features are known to have formed during the early to mid Holocene, most of the smaller examples are likely to be much more recent in their origins. Historical evidence shows that these features in particular have been subject to fluctuations in their shape, volume and stability in recent times (Tubbs, 1999). For example, East Head at the mouth of Chichester Harbour has experienced cyclical growth, decay and even temporary extinction during the past 500 years. It is thought that the present spit at East Head dates from the mid eighteenth century.

These spits are the product of the storage of sediments that have been supplied by littoral drift, although several authors have postulated that some inputs from offshore to onshore movement may also occur. More problematic in origin are the several examples of double or paired spits at estuary mouths. In some cases, there are significant contrasts in size, morphology and sediment composition between each structure. In most examples convergent and – usually – apposition spit growth has been interpreted as evidence of convergent littoral transport pathways. This involves short distance reversal of the net longshore transport direction on one side of the inlet, which may occur along a morphologically uniform length of beach where there is no evidence of a drift divide other than a zone of erosion. A good example of this is the apparently quasi-stationary drift divergence boundary some 600m westwards of the entrance to Chichester Harbour. Eastwards movement away from this point, located in the vicinity of the Creek Road car park, close to the site of the old Beach Club, feeds the Black Point spit at the end of the Eastoke peninsula. The strongly recurved form of this spit, together with the progressive curvature of East Head, indicates the role of wave refraction and complex wave current interaction with the large, partially emergent sandbanks adjacent to each channel that are formed by a combination of sustained longshore and onshore sediment transport. As these banks are highly mobile features, it is unsurprising that the wave regime over them is also extremely variable in time. This means that wave conditions, and the resulting patterns of longshore transport along the eastern Hayling frontage are also variable with time, making good beach management a challenge.

Evidence for transgressive barrier beach development within recent centuries is available from numerous locations and the destruction of earlier barriers may have contributed to more recent barrier creation and breakdown throughout the late Holocene. However, it has become apparent that large quantities of shingle were moved onshore very quickly as a result of so called ‘super storms’ that are known to have occurred between the 11th and 15th Centuries.

Wallace, (1990) stated that the open coastline of Hayling Island was set back several hundred metres compared to its current position until at least the mid fifteenth century. He proposes that an ancestral barrier beach extended from Malt Owers to Southsea and was progressively breached between the eighth and fourteenth centuries perhaps in response to the super storms that took place between 1014 and 1490. It is thought that the existing barrier beach at Eastoke was created between the mid fifteenth and early eighteenth century.

Such “super storms” should by no means be considered to be a thing of the past. If anything, future climatic changes may well increase the incidence of such storms. Even the higher than average incidence of “normal storms” can have dramatic impacts that are difficult to forecast. The high incidence of south-westerly gales during the last few years appears to have provoked an increase in the rate of onshore transport between Selsey Bill and Pagham Harbour, for example.

3.3 BATHYMETRY

The Hayling Island coastline, like adjacent coasts, is fronted by a shallowly sloping seabed that enables seabed transport to be very active. The coastal inlets in this area are also shallow, whilst the sediments within them are highly mobile because of the rapid tidal currents, especially near the entrances of the inlets.

The bathymetry around Langstone, Portsmouth and Chichester harbours is less than 10m below Chart Datum (approximately lowest astronomical tide). The entrances to both Langstone and Chichester harbours are flanked by sandbanks. The West Pole Sands extends southwards from Eastoke Point whilst the larger East Pole Sands juts out from East Head, forming the western extremity of Bracklesham Bay. The outer part of Chichester harbour is bifurcated by the Chichester Bar, which dries to around +0.3m CD.

Hayling Bay lies to the west of East Head and the seabed bathymetry shelves gently towards the -10m CD contour.

3.4 SEABED SEDIMENTS

Large quantities of sand and gravel are found in the east Solent due to deposition from the ancient Solent River. These are Quaternary sediments that are typically 2-3m thick, although much thicker deposits exist in the infilled channels (Whitcombe, 1995). Large scale sediment distribution maps compiled by BGS show the east Solent as a large region of sand with areas of medium sand south of the Langstone and Chichester harbour entrances (ABP, 2001). Further seawards, the seabed sediments comprise sand and sandy gravel. Sediment mobility studies carried out by HR Wallingford (1993), classified the sediments in Hayling Bay as gravels with pockets of sand at the entrance to Chichester Harbour. Gravelly, muddy sands are found in the offshore submarine canyons. A more detailed assessment by Whitcombe (1995), classified the sediments in Hayling Bay as predominantly sandy gravel with sand deposits either side of the main channels. The entrance to Chichester harbour is classified as gravel, whilst a large deposit of sand is found in the centre of Bracklesham Bay. The distribution of seabed sediments is presented in Figure 3.3.

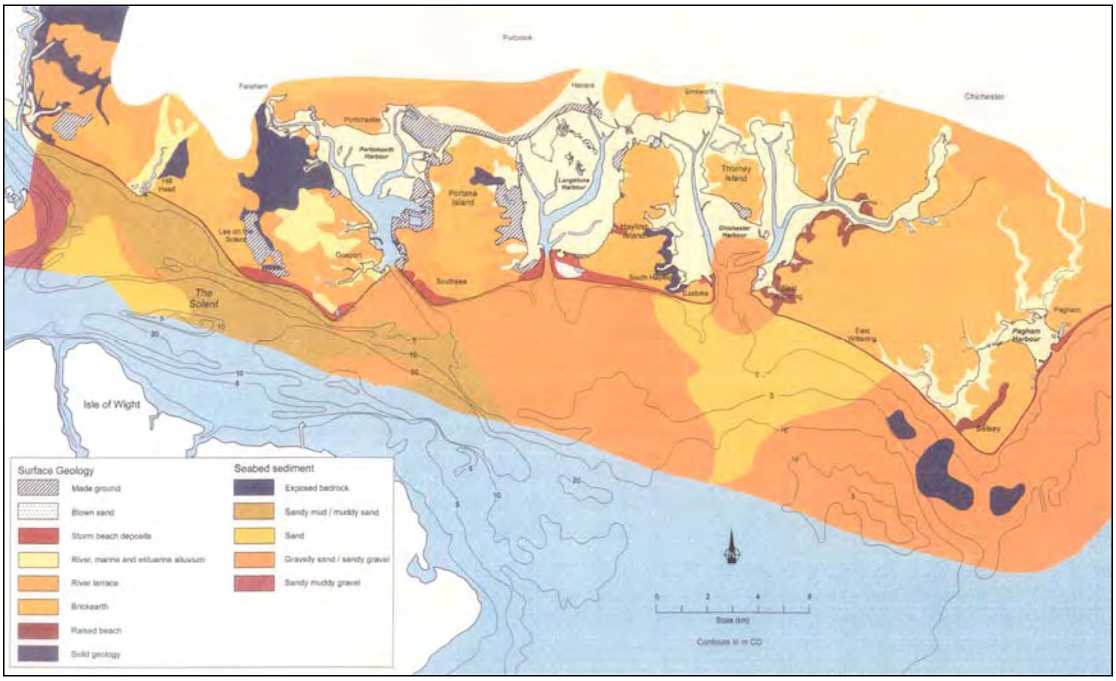


Figure 3.3 Distribution of surficial sediments

3.4.1 *Beach sediment distribution*

The beaches of the east Solent open coast are mainly shingle upper and sand lower as a result of their geological formation. Construction of seawalls and groynes along with beach recharge schemes have influenced the natural plan shape of the beach, resulting in the narrowing of the shingle ridge in some areas. Thus, before the nourishment scheme was carried out in 1985, parts of the Eastoke frontage, for example in front of the old Beach Club (Creek Road car park), had become denuded of shingle cover and were at that time predominantly sandy, albeit at a low level compared to today’s beach at that location.

3.5 HISTORIC EVOLUTION OF THE STUDY FRONTAGE

Hayling Island is low lying and has suffered from both rapid erosion and flooding. Residential and commercial development on the open coast of the island began in the 1930s with the construction of beach huts and bungalows on the backshore of the wide shingle beach at East Hayling. By the 1930s, coastal defences including a wall, revetment and groynes had been built to protect the new properties. These defences were extended both west and east in stages until 1974 when they covered 2.6 km of the frontage west from Eastoke Point. In 1985, a major shingle recharge was carried out and further works including rock revetments and groynes have been undertaken at Eastoke to prevent breaching of the shingle bank. This land is, however, still vulnerable to flooding during surge conditions in combination with severe wave action. Protection from wave and tidal action is provided by a narrow shingle beach, which is vulnerable to both wave overtopping and erosion, as the crest of the beach is only as high as the last most severe event would have created (Plate 3.1).

East Hayling has been particularly difficult to defend as the nearshore and beach sediment transport processes are subject to significant seasonal and annual variability. Inshore wave transformations are influenced by strong tidal currents and shifting nearshore banks and channels. Minor changes in offshore wave directions can cause beach drift directions to reverse with severe consequences for both beach erosion and wave overtopping.

Plate 3.1 Aerial view of Eastoke Point

Until sea defences were constructed the beaches of Hayling Island were retreating northwards, while also tending to build out at the ends. Unlike continuous frontages that have a predominant drift in one direction, Hayling Island experiences a westward and eastward transport, with the drift divide being at Eastoke. As a result of the divergence of littoral drift beach material tends to be transported away from the Eastoke frontage, towards Gunner Point in the west, and Eastoke Point in the east. Because of the rapid accretion at the western end of the island, the western part of the island has tended to be more stable than the eastern half. This makes the eastern part all the more vulnerable, and Eastoke Point, in particular, is historically an area of instability, with major changes in size and orientation having taken place during the past 160 years. The scale of changes in coastline position and orientation in this area is shown in Figure 3.4, where three recorded positions of the high water mark are compared. Overall, if taken at face value, the whole of this end of Hayling Island has retreated northwards substantially over the c150 year separating the first high water line from the more recent ones. But even against this backdrop of a gradual recession, the scale of changes observed between 1986 and 2005 is large.

These coastal realignments are believed to have been caused by climatic variations, with changes to the bathymetry within Chichester Harbour entrance also having an effect. The proximity of the deep-water channel at the entrance to Chichester Harbour, with its rapid ebb and flood flows and the intermittent onshore transport of material from the ebb delta, result in a highly complex system that is subject to rapid short term variability. For example, in the late 1980s, the input of material to the system following the 1985 beach recharge led to massive accretion at Eastoke Point. This created a ‘ness’, which protruded seawards until the rapid ebb flows in the vicinity of the Eastoke Beacon, moved material into deep water and transported it offshore, leading to losses in the overall beach sediment “budget”. This event coincided with a period of instability in the area and also coincided with an unusually high number of storms, which caused the recharge material to disperse quite rapidly. Between 24th March 1986 and 6th January 1988 wave heights in excess of 1.5m were observed on 9 occasions, and on two of these, the wave height was as large as 2.5m. On four occasions the wave period exceeded 12s, and on one occasion, the mean wave period was 17s. Sea defences are particularly vulnerable to overtopping by long period waves; on any of these occasions serious overtopping of the seawall would have occurred had the beach nourishment scheme not been in place (Clare, 1988). Despite the increased volume of sediment from the recharge, the period of accretion was shortly followed by extremely rapid erosion, during which, part of the Sandy Point LNR was lost. In spite of emergency works (including a rock revetment and rock groynes) and even with the long term influx of material from offshore via West Pole Sands, erosion of the beaches at Eastoke Point continued, thereby increasing the risk of overtopping and flooding.

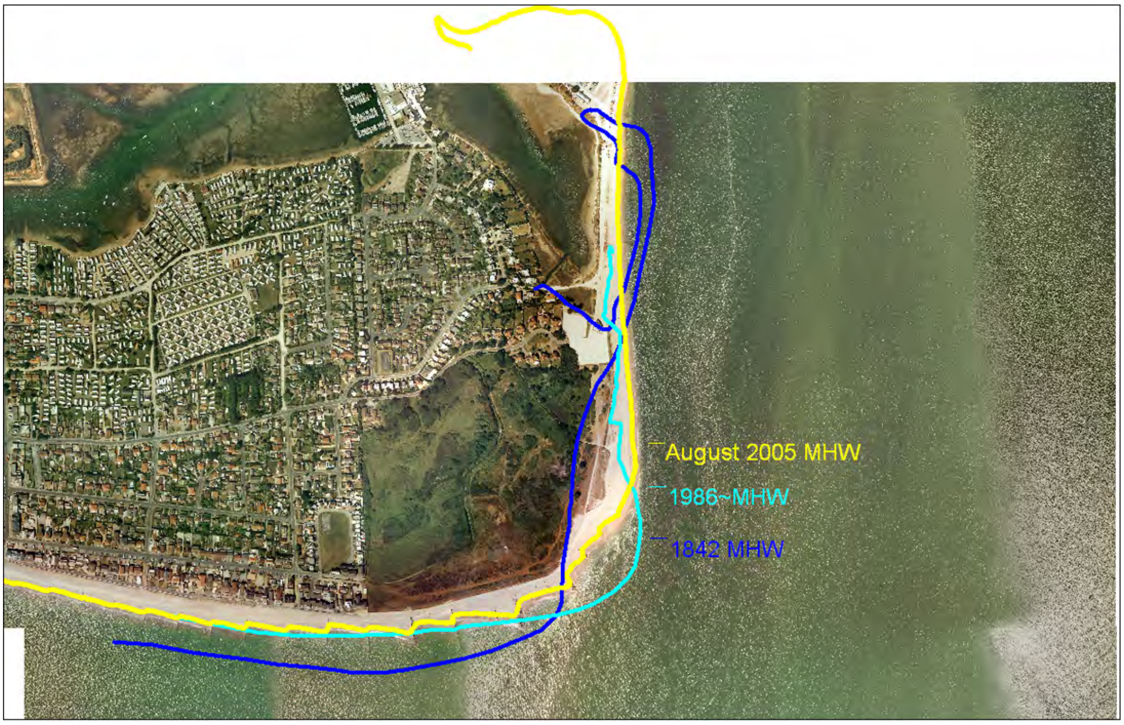


Figure 3.4 Net changes in position of mean high water mark

The evolution of the Eastoke frontage since 1979 is shown in Figure 3.5. The large fluctuations in shoreline position have made it difficult to manage this frontage effectively. The 1980s photographs clearly show the growth of a “ness” east of the easternmost groyne, which can be attributed to the enhanced longshore transport in the first few years after nourishment. The 1990s photographs show how this ness has tended to migrate northwards towards Black Point (although much of the sediment from this accumulation was actually lost into the entrance channel itself).

Note also the changes in the size and orientation of the West Pole, a feature that has a considerable impact on wave conditions at Eastoke Point, as well as on the transport of sediments over the lower foreshore.

The rate of shoreline recession over the Eastoke frontage is relevant to the present study in that it gives an indication of when beaches at Eastoke will be deprived of shingle and longshore transport to Eastoke Point seriously reduced. Profile analysis has shown that recession of the upper foreshore at Eastoke averaged 0.6m per annum up to 1976. Thereafter, there has been a mean accretion of nearly 30m as a result of the 1985 beach recharge. Between 1976 and 1992, the frontage increased in volume by almost 260,000m^3. The remainder of the 530,000m^3 nourishment volume has been lost, both, eastwards and westwards as well as by the migration of sand beyond the low water mark. Recent estimates on the basis of profile analysis (see section 3.9) indicate that the shoreline has retreated slightly, despite the ongoing recycling operations that have been used to maintain beach width.

3.6 HYDRODYNAMIC REGIME

3.6.1 Wave modelling

The prediction of wave climate along the south-east coast of Hayling Island in the present study was based on the methods and models used in a previous HR Wallingford study (1995a, report EX 3121). The wave models were driven by twenty years of time series wind data (1971-1991) taking account of the shape of the coast, depth refraction, and current refraction at eight states of the tide. The HINDWAVE component model was used both for waves generated in the English Channel and separately for waves generated in the lee of the Isle of Wight. The TELURAY component model was used for wave transformation from the English Channel to the coast. The TELEMAC component model was used to derive current field data for use in wave transformation.

The intention here was to retain the value of the previous wave modelling (HR Wallingford, 1995a), but to take some account of new wind data available since 1991 and also to extend the model to include Chichester Harbour Entrance. Three wave prediction points, i.e. Points 11, 12 and 13 along Hayling Island, as shown in Figure 3.6, were thus re-commissioned from the previous study. New Points 11a and 11b were also added on the Hayling Island side of Chichester Harbour Entrance.

For each of the prediction Points 11, 12 and 13, the original wave model was run for both the original period of wind data (1971-1991) and for an extended period of wind data (1971-2006) but for only one of the original eight states of the tide, namely MHWS. This is the critical tidal level at which wave overtopping etc. are likely to take place.

In each case, and throughout the whole range of wave heights, the wave heights for the longer period of data were found to be fractionally lower than in the shorter original period of data. For significant wave heights above about one metre, the wave height (for any given percentage exceedence level) in the longer period of data is about 5, 10 and 10 cm below that in the original period of data, for Points 11, 12 and 13, respectively. These modifications (with a progressively reduced adjustment for significant wave heights below 0.8m) were applied to the original wave climates and extremes in HR Wallingford (1995) to update them for the longer period of wind data now available.

A similar approach was adopted for new Points 11a and 11b (see next section for the location of these points). The longer period of wind data (1971-2006) was run for MHWS for Points 11, 11a and 11b. For significant wave heights above about one metre, the wave heights (for any given percentage exceedence level) at Point 11a were between 73% (larger waves) and 100% (at 1m) of those at Point 11. For Point 11b the wave heights (for any given percentage exceedence level) are approximately 50% of those at Point 11. These modifications were applied to the updated wave climate and extremes for Point 11. An additional adjustment to wave direction was made to take account of the restricted range of directions that could exist at Points 11a and 11b.

Results showing the probability of occurrence of significant wave height against wave direction are presented in Tables 1.1A to 1.1E in Appendix 1. Derived extreme wave conditions are presented in Table 3.1 below for return periods ranging from 1 to 200 years at each location.

Table 3.1 Extreme wave heights along the coast of Hayling Island

Point	**Significant wave heights (metres) for given return periods**				
	1 year	**10 year**	**50 year**	**100 year**	**200 year**
11	2.77	3.37	3.79	3.96	4.14
12	3.51	4.24	4.73	4.94	5.14
13	5.09	6.35	7.21	7.58	7.95
11a	2.02	2.46	2.77	2.89	3.02
11b	1.30	1.58	1.78	1.86	1.95
The corresponding mean wave period (in seconds) will be three to four times the square root of significant wave height (in metres).					

3.6.2 Tidal currents

Tidal currents have also been examined in this study, the current simulation along the south-east coast of Hayling Island being re-commissioned from a previous HR Wallingford study for Chichester Harbour in 1994 (EX 3094). Tidal flows in Chichester Harbour were simulated using the depth-averaged finite-element tidal flow model, TELEMAC-2D. Currents were simulated for the whole of Chichester Harbour east of Langstone Bridge, and for an area of coastal waters seaward of the harbour mouth, extending 6 km offshore and 12 km parallel to the shore. The model boundaries seaward of the harbour were positioned sufficiently far from the harbour mouth for sediment transport in and out of the harbour to be correctly simulated. The flow model results were validated using some of the results of the field exercise, and other published data.

The model was previously run for the high spring tide on 1 March 1994 and for a mean neap tide. The resulting current speeds and directions, together with locations of the prediction points, were extracted from the existing model runs and are plotted in Figures 7 and 8.

The exact locations of the nearshore points 11a and 11b have been chosen bearing in mind the representation of the seabed levels in the narrow and constantly changing entrance channel to Chichester Harbour. They are at approximately the following National Grid co-ordinates, and the bed levels at these locations, as represented in the model, are as follows:

Location	Easting (m)	Northing (m)	Bed Level (below CD)
Point 11a	475200	98800	4.5m
Point 11b	475250	98360	4.7m

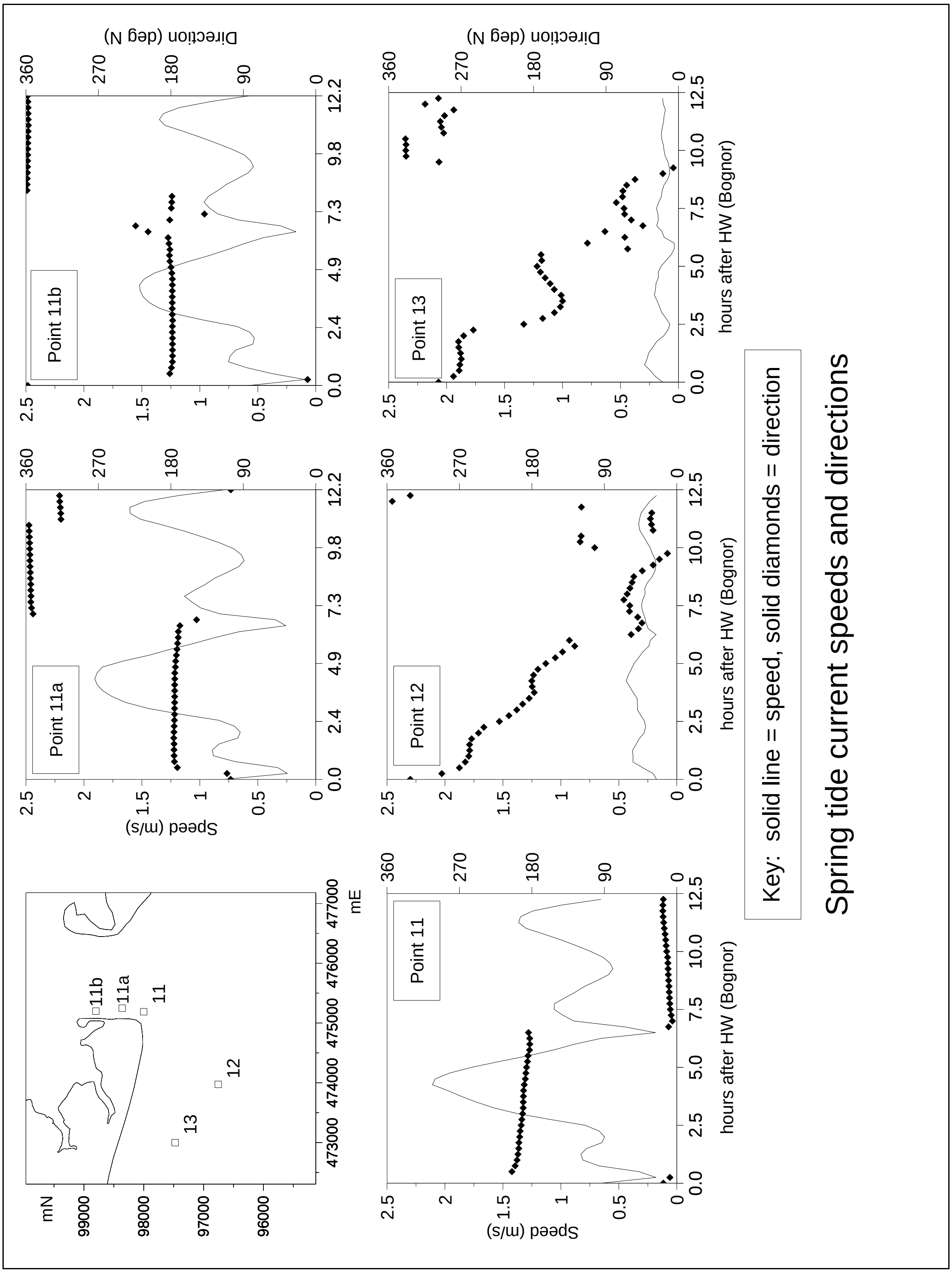


Figure 3.7 Spring tidal currents

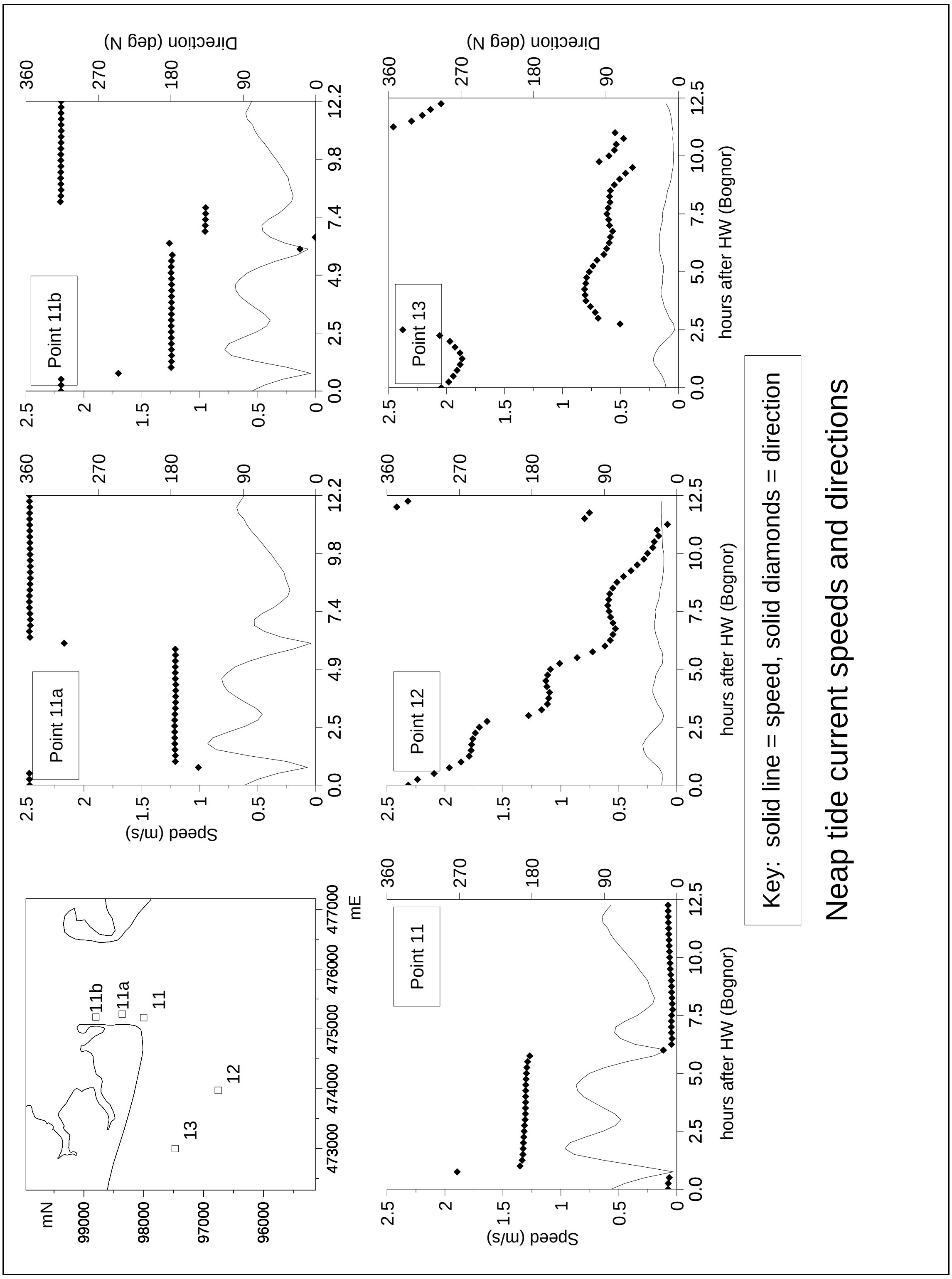


Figure 3.8 Neap tidal currents

3.6.3 Tidal range and sea level

Tidal Range

Astronomical tidal levels near to Eastoke, taken from UK Admiralty Tide Tables for 2006, both to Chart Datum and converted to Ordnance Datum, are reproduced in Table 3.2.

Typically, a sea level equal to HAT occurs about three times per annum (0.33 year return period) and a level equal to MHWS about sixty times a year (0.017 year return period).

Table 3.2 Present-day (2006) astronomical tidal levels (mOD)

Tidal level parameter	Portsmouth		Chichester Harbour Entrance	
	mCD	mOD	mCD	mOD
HAT	5.1	2.37	5.3	2.56
MHWS	4.7	1.97	4.9	2.16
MHWN	3.8	1.07	4.0	1.26
MWL	2.9	0.17	2.9	0.16
MLWN	1.9	-0.83	1.9	-0.84
MLWS	0.8	-1.93	0.9	-1.94
LAT	0.2	-2.53	0.2	-2.54

Values for Chichester Harbour Entrance, in bold in Table 3.2, are taken as being the same at those likely to occur along the coastline of Eastoke Point.

Sea Level Variation through the Tidal Cycle

Sea levels for the five prediction Points 11, 12, 13, 11a and 11b were extracted from tidal model runs undertaken during a previous HR Wallingford study undertaken in 1994 (report EX 3094) that was also referred to in the earlier section on currents. The results for a high spring tide and for a mean neap tide, together with the locations of the prediction points, are presented in Figures 9 and 10.

The tidal levels predicted for the mean neap tide case correspond to the MHWN and MLWN values listed in Table 3.2. A similar comparison for the high spring tide suggests that the event was closer to a highest astronomical tide than to a mean spring tide. There is little variation in tidal level between the five prediction points except for the low tide level at Point 11a which may be influenced by being close to drying at low water.

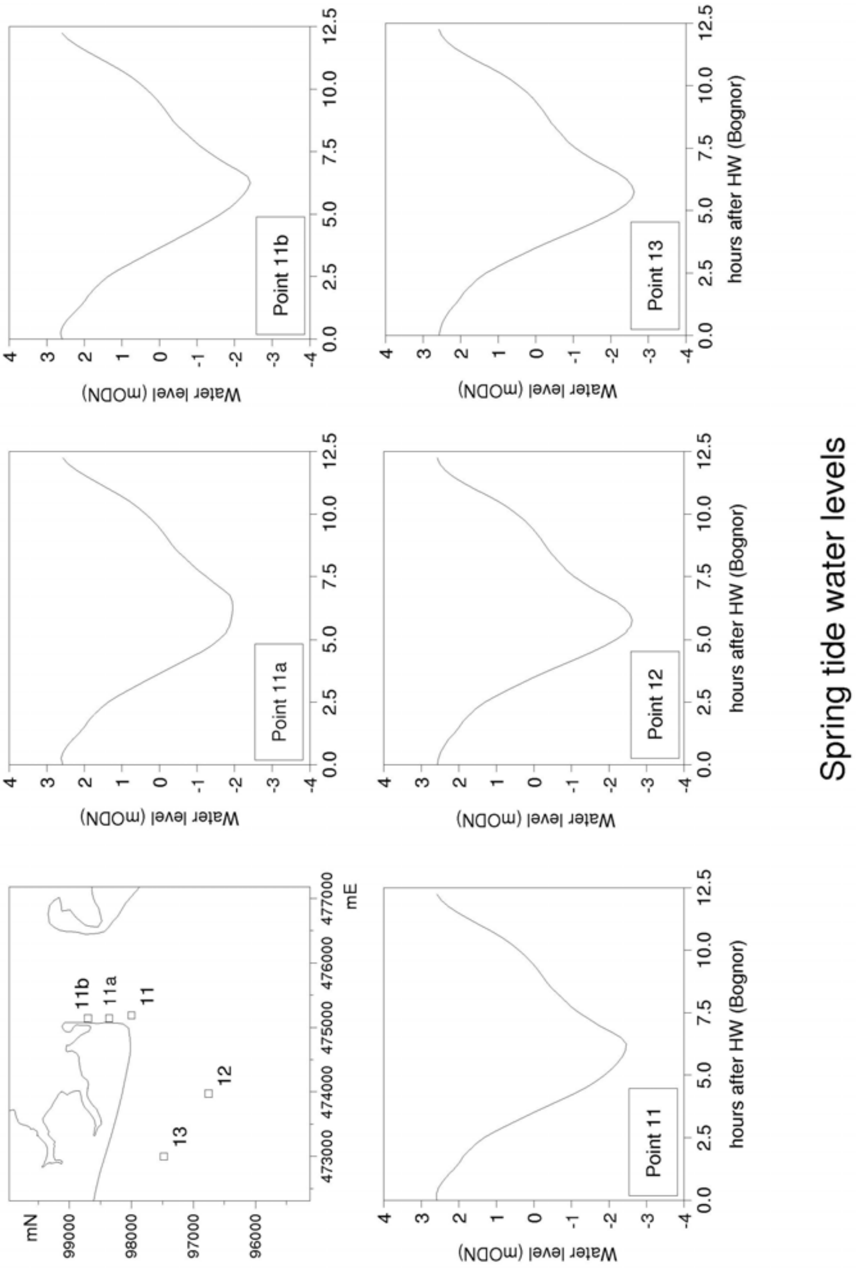


Figure 3.9 Spring tide water levels

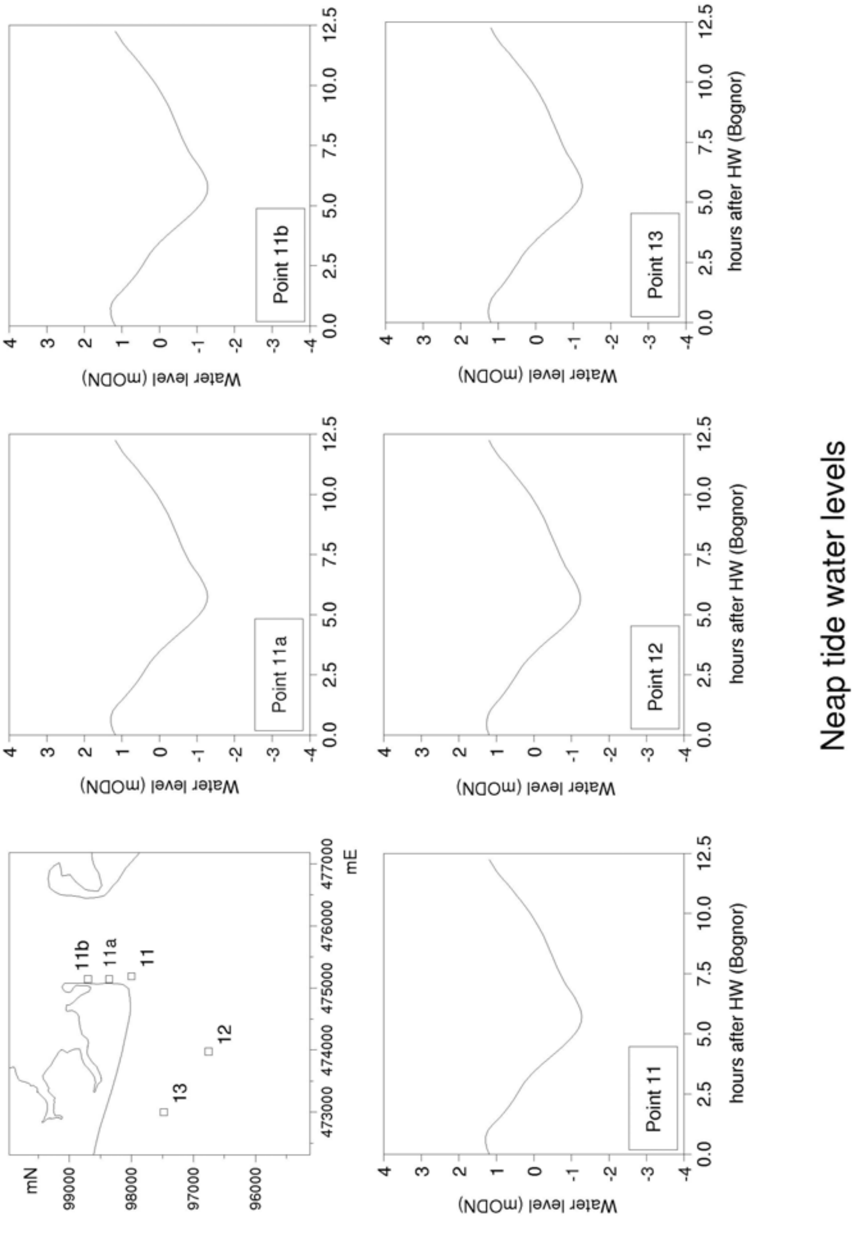


Figure 3.10 Neap tide water levels

Extreme Sea Levels

At the outset of this study, there were four published sources of extreme still (i.e. without waves) water level predictions that were reviewed, converted to Ordnance Datum and brought forward to present-day (2006) levels by adding 1.2mm/year, and presented in Table 3.3a below. These values were used in early calculations of the joint probability of waves and tidal levels and of shingle beach response and overtopping rates under those conditions.

Table 3.3a Present-day (2006) extreme still water levels (mOD, from literature review)

Return Period (years)	**1**	**2**	**5**	**10**	**25**	**50**	**100**	**250**
Portsmouth, POL (1995)				2.71	2.82	2.88	2.98	3.08
Portsmouth, Coles and Tawn (1990)				2.84			3.11	
Portsmouth, JBA (2004)	2.51	2.61	2.71	2.81	2.91	3.01	3.11	3.21
near **Eastoke**, POL (1997)	2.52			2.82	3.01	3.13	3.34	3.56
Chichester Harbour, JBA (2004)	2.81	2.91	3.01	3.11	3.21	3.31	3.31	3.41

In January 2008, however, new Environment Agency guidance on present-day and future extreme tidal levels along the Hampshire coastline was received from Havant Borough Council.

Table 3.3b reproduces the information provided by the Environment Agency for the Hayling Island section of the Hampshire coastline, and shows the values for both the 200 and 1000 year return period events that were recommended for use in the present study. These values were used to modify those taken from the report produce by JBA (2004) to provide updated "present day" extreme tidal level predictions. This new information was then used to amend the joint wave/ tidal level input conditions used for the subsequent modelling of wave overtopping and breaching, and these results in turn used to calculate the food risks for properties in Eastoke (see Chapter 7).

Future Sea Level Rise

Mean sea level around the UK has been rising at a rate of 1-2mm/year for about the last century. However, land level changes mean that sea level increases relative to the land tends to be slightly lower in the north of the country and slightly higher in the south. POL (1997) and JBA (2004) estimate rates of sea level rise relative to the land near Eastoke in the recent past of 1.2 and 1.3mm/year respectively.

The average rate of rise around the British Isles is predicted to increase more rapidly in future. At the commencement of this study, the appropriate precautionary allowance for future mean sea level rise recommended by Defra (2003) for the south coast of England was 6mm/year. As there is no strong indication to the contrary, it is assumed that extreme sea level will rise in line with mean sea level. A numerical allowance for future sea level rise could be determined as follows. If a structure has a design life of 50 years and is to be designed for a specified probability of failure *at the end of that period*, then add the sea level rise expected to occur over the next 50 years (300mm) to all present-day values. The new Defra guidance, also presented in Policy Planning Statement 25 during the course of this study, now recommends allowing for a relative increase in sea level of 4.0mm per annum from 1990 to 2025. From this date until 2055, a rate of 8.5mm / year should be assumed, increasing to 12.5mm/ year until 2085 and then to 15mm/year until 2115 (see http://www.communities.gov.uk/documents/planningandbuilding/pdf/planningpolicystatement25.pdf).

Table 3.3b Present and future extreme tidal levels for Hayling Island

Extreme Still Water Level Estimates	1990	2010	2025	2055	2085	2115
1:200 year return SWL (m ODN)	3.3	3.4	3.4	3.7	4.1	4.5
1:1000 year return SWL (m ODN)	3.5	3.6	3.6	3.9	4.3	4.7

These tidal levels, at least for the present-day return period of 200 years, are very similar to those presented in Table 3a. However, it should be noted that the tidal level in Table 3a with an expected return period of 200 years is higher than the value for 2004 that would be deduced from the values given in Table 3b. We have therefore combined the information on present-day extreme tidal level estimates from Table 3a for return periods less than 200 years with that provided in Table 3b for higher return periods.

For the estimation of flood risks later in the project, we have then adjusted the estimates of present-day extreme tidal values, for all return periods, to account for the latest guidance on expected sea level rise. This leads to the expected extreme tidal levels being 0.34m higher than present day values in 2055, 0.7m higher by 2085 and 1.03m higher buy 2107, i.e. a hundred years from now. These estimates of extreme tidal levels have then been combined with information on extreme wave conditions, as explained in the following section, to produce suitable input conditions for assessing the present-day and likely future performance of the coastal defences at Eastoke Point.

3.6.4 *Joint probability of large waves and high sea levels*

The highest threat to sea defences tends to occur when large waves coincide with a high sea level (i.e. when both affect the coast *in the same two or three hour period*). To estimate the probability of occurrence of such conditions, it is necessary to have information, not only on waves and sea levels, but also on the dependence between them. Surges on the south coast of Britain tend to be associated with strong westerly or south-westerly winds. Some of the largest waves at Eastoke will be associated with high winds, or swell, from these directions, but some will also occur on strong southerly or south-easterly winds. There will therefore be some dependence in the study area between large waves and the highest sea levels.

Defra / Environment Agency (2005) includes information on the dependence between large waves and high sea levels around Britain, based on analysis of tide gauge measurements and wave predictions from a Met Office forecasting model for the same locations and periods of time. Results based on Weymouth, Portsmouth and Newhaven tide gauges indicate a significant dependence, about the average level for the UK, whether waves approach from the south-west, south or south-east. On a scale of independent, modestly correlated, well correlated or strongly correlated, covering the range occurring around Britain, large waves and high sea levels near Eastoke would fall approximately on the border of the ‘modestly correlated’ and ‘well correlated’ categories. To be on the conservative side, they are assumed to be ‘well correlated’.

Appendix 2 summarises the combinations of wave heights and tidal levels used in the initial assessment of the likely performance of coastal defences at Eastoke Point. These figures take into account the guidance issued by the Environment Agency in January 2008 on the estimates of extreme tidal levels along the Hampshire coastline, which for Hayling Island are summarised in Table 3b above. These joint probability wide / tidal level values were calculated for present day, 2055, 2085 and present-day plus 100 years (i.e. 2107) and used to produce estimates of flooding risks for each of those four dates (see report TNCBR3873-06).

In the present study, the combinations of tidal levels and wave conditions listed in Appendix 2 were used to calculate the expected flood risks at Eastoke assuming that the defences remain in their present configuration. It is a matter of some conjecture whether the effects of global warming will lead to more frequent and severe storms. In order to allow for this possibility, the most recent Defra / EA guidance, issued in October 2006, indicates that at the time of designing coastal defences, a sensitivity analysis should be undertaken in which the effects of larger extreme wave heights, and longer wave periods, should be undertaken. However, to include such allowances in the present study would potentially over-estimate the flood risks. In the light of the need to derive a robust estimate for the benefit: cost ratio for any coastal defence scheme proposed, we have not therefore modelled the effects of any increase in storms or wave heights in the next 100 years.

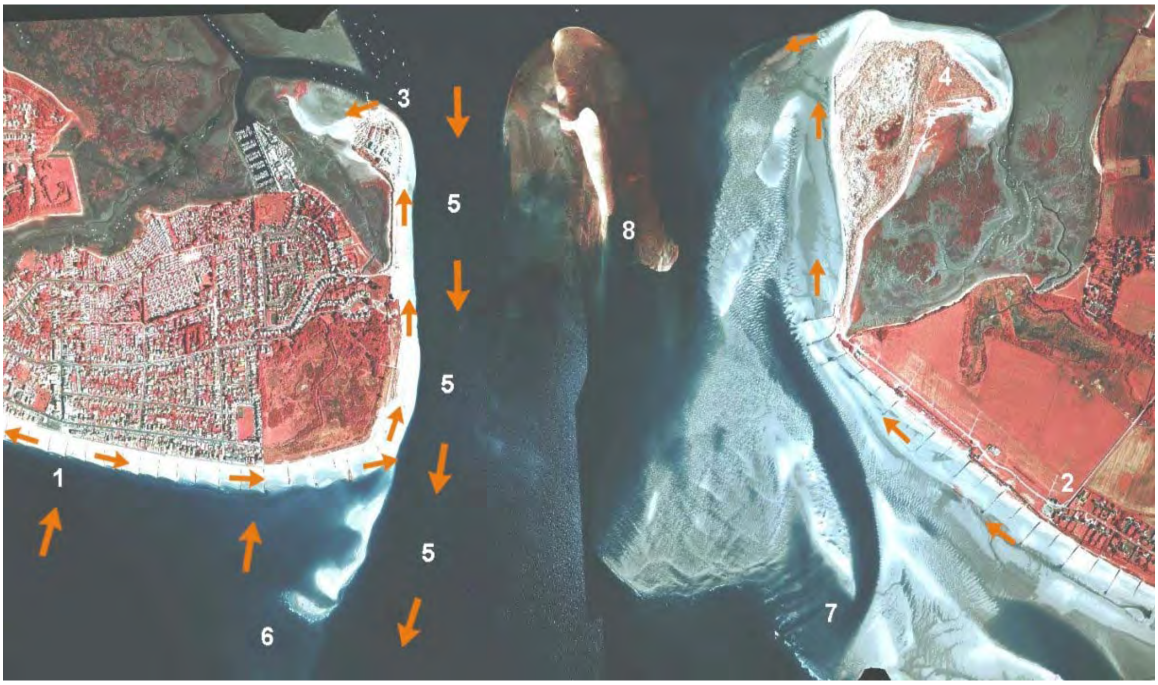
3.7 SEDIMENT TRANSPORT

Wave energy on the east Solent frontage decreases progressively from east to west, largely due to the protective effect of the Isle of Wight, so that modified swell waves do not contribute to the wave climate west of Easter, but do have some effect at Hayling Island itself.

Complex local refraction effects are accentuated by the East Winner and East and West Pole Sands and wind waves are also diminished by interaction with tidal streams at the entrance to Chichester Harbour. The main sediment transport pathways affecting the study frontage are presented in Figure 3.11.

Defra / Environment Agency (2005) includes information on the dependence between large waves and high sea levels around Britain, based on analysis of tide gauge measurements and wave predictions from a Met Office forecasting model for the same locations and periods of time. Results based on Weymouth, Portsmouth and Newhaven tide gauges indicate a significant dependence, about the average level for the UK, whether waves approach from the south-west, south or south-east. On a scale of independent, modestly correlated, well correlated or strongly correlated, covering the range occurring around Britain, large waves and high sea levels near Eastoke would fall approximately on the border of the ‘modestly correlated’ and ‘well correlated’ categories. To be on the conservative side, they are assumed to be ‘well correlated’.

Appendix 2 summarises the combinations of wave heights and tidal levels used in the initial assessment of the likely performance of coastal defences at Eastoke Point. These figures were later revised to take into account the guidance issued by the Environment Agency in January 2008 on the estimates of extreme tidal levels along the Hampshire coastline, which for Hayling Island are summarised in Table 3.3b above. The revised joint probability wide / tidal level values were then calculated for present day, 2055, 2085 and present-day plus 100 years (i.e. 2107) and used to produce estimates of flooding risks for each of those four dates (see Chapter 7).



1 = Drift divide – onshore sediment transport
2 = Westerly littoral drift towards East Head
3 and 4 = Growth of Black Point and East Head spit
5 = Offshore transport of sediment on ebb current
6 = Accumulation of sediment at West Pole Sands onshore sediment transport
7 = Accumulation of sediment at East Pole Sands
8 = Winner Bank

Figure 3.11 Sediment transport pathways at Eastoke

3.7.1 Sources of beach sediment

Most of the Hayling backshore is at or below sea level and coastal erosion/flooding has been prevented by the construction of extensive coastal protection structures over the past 100 to 150 years. The maintenance of beaches relies upon supply from adjacent sediment transport systems, but significant longshore supply by littoral drift is prevented by deepwater channels scoured by rapid tidal currents at the mouth of Chichester Harbour. Consequently, the most effective potential sediment supplies to the beaches of Hayling Island are via onshore feed, mostly from sediment stores that are associated with the harbour entrance. Supply directly from the seabed of the Eastern Solent is thought to be negligible and will not operate except under high wave conditions. Sediment supply to this frontage has been historically maintained by the progressive erosion and recession of the coastline (i.e. erosion at Selsey Bill). As a result of sub-aqua investigations of submerged relict barrier beaches and archaeological sites, Wallace (1990) indicates that this recession is in the order of kilometres since the 13th Century.

Gravel Feed from the Chichester Harbour ebb tide delta

At Chichester Harbour entrance, the ebb tidal current is of shorter duration than the flood but is typically of significantly higher velocity. Therefore, the net transport direction of sediment that moves into this channel is offshore. Over time, this has created a major accumulation of sediment that extends 3 to 4 kilometres offshore (Harlow, 1980, Wallace, 1988) and has an estimated volume of 25 million m^3 (Webber, 1979). Significant sediment transport occurs on the delta by the combined action of waves and tidal currents. Sedimentological analysis of the delta deposits indicates that there is a net westwards movement of gravel that results in an accumulation off West Pole (Whitcombe, 1995). Conversely, sand is more widely distributed in both an eastward and westward direction (Webber, 1979). A potential onshore sand transport pathway was identified by HR Wallingford (1980) but conclusive evidence to support this theory is lacking.

Analysis of beach volumes by Harlow (1980) and Whitcombe (1995) identified a zone of drift divergence in the vicinity of the old Beach Club on Hayling Island, just to the west of the study frontage. Despite loss of sediment to the east and west, beach levels in this area did not fall as dramatically as anticipated and led to the theory that sediment volumes in the region of $13,000m^3$ per annum were supplied through onshore feed (Harlow, 1980). However, during the period between 1976 and 1985 beach levels declined significantly and it appears that onshore feed declined during this time. Following the 1985 beach replenishment at Eastoke, it is difficult to determine the present status of the onshore gravel feed. However, the initial depletion of the nourished beach in the area of the Creek Road car park indicates that the volume of sediment transported onshore was considerably less than that lost through littoral drift, particularly as net drift rates were found to increase following the nourishment (HR Wallingford, 1988).

Onshore Feed from West Pole Sands

Onshore movement of gravel to the beach takes place during the periodic migration of offshore bars during storm conditions. Historic maps and charts show episodic development of ‘islands’ developing on the West Pole Sands as gravel was driven onshore from the Inner Chichester bar. HR Wallingford (1988) found that as the onshore feed to the Eastoke frontage declined after 1976, the onshore transport of sand and gravel over West Pole intensified. Evidence for this was recorded as net accretion of a stretch of frontage, 150m to the west of the Eastoke Beacon. It could thus be argued that onshore feed from West Pole Sands, and that from the Chichester Harbour delta, are actually transports from the same source, though arriving at different locations

Diffuse Onshore Feed

Diffuse wave driven gravel feed from Hayling Bay is regarded as insignificant following tracer experiments and sampling. However, Whitcombe (1995) identified potentially mobile gravel in the nearshore zone under high energy incident waves with a possible onshore feed. Based on his calculations of the sediment budget for the post replenished beach at Eastoke, he produced a maximum onshore component of $12,000m^3$ per annum. It is, of course, impossible to differentiate the input of sediments from the differing sources. Neither is it possible to be certain that such feed will continue in the future.

3.7.2 Littoral transport

Sediment transport in the inter-tidal zone is considered to be largely wave driven. This refers specifically to longshore transport along the open coast frontage, as well as on the spits that flank the harbour entrances.

Tidal currents in this area are insufficiently strong to transport much sediment along the open coast, but can transport material in the harbour mouths and offshore. They may also contribute to the sediment accumulation at Sandy Point, for example. Although the rectilinear tidal currents at the mouth of Chichester Harbour are much stronger, their contribution to littoral transport along the study frontage is unlikely and it is not thought that littoral transport can move material across the harbour entrance directly towards East Head.

Eastward drift to Eastoke Point

Prior to the beach nourishment scheme in 1985, long term drift rates were determined by measuring beach volume changes between 1842 and 1972 from Ordnance Survey 1:2500 plans. As stated previously, a transient drift divide was located approximately 100m to the west of the old Beach Club, i.e. close to the Creek Road car park. The precise location of this feature at a given time is determined by variations in incident waves, and on net drift rates to the east and west. Net potential eastward drift was found to vary between 2,000m^3 per annum and 12,000m^3 per annum with a long term average of 5,000m^3 per annum (Harlow, 1980). Due to the change in orientation of the beach at Eastoke Point, a mean littoral drift of ~10,000m3 per annum was suggested for the study frontage (HR Wallingford, 1980). The natural westward drift has been estimated as about 20,000 cubic metres per annum, This leaves a net deficit of some 30,000 cubic metres per annum, leading to problems in maintaining a Hold the Line defence policy not just for Eastoke Point, but also for the frontage extending westwards to Eastoke Corner and beyond.

This widespread problem of gradually depleting beach reserves in this region is graphically illustrated by the changes on the east side of Chichester Harbour in the last two centuries, or so. Old Ordnance Survey maps and navigation charts show that in the 19th century the long spit to East Head extended westwards from the Selsey peninsula to almost the full width of the tidal inlet into Chichester Harbour. At that time, there was deduced to have been a considerable feed of material from East Head to Hayling Island, across the narrow harbour entrance. It is at this time that the main channel into the harbour became attached to the east side of Hayling Island and that has stayed on that alignment since.

A reducing supply of shingle reaching the mouth of Chichester Harbour, due to coast protection works between East Head and Selsey Bill, was the probable cause of this spit dwindling and to rotating clockwise, and the entrance to Chichester Harbour becoming much wider. This all reduced the availability of material for transport across the harbour entrance itself, and then, onshore to Hayling Island. In addition, what sediment might be transported across the entrance is probably now carried into Chichester Harbour itself, because of its openness to wave action. Some of the littoral drift from the direction of Selsey is therefore now widely spread over the Winner, the large drying area just inside the harbour entrance.

Following the replenishment, the rate of longshore transport along the Eastoke frontage increased by several magnitudes as a result of the following:

- Large volumes of gravel became available for transport from an area that was previously severely depleted;
- Some groynes were completely buried during nourishment;
- The scheme caused a slight change in beach orientation, particularly at the eastern end of the frontage; and
- The recharge material was poorly sorted and the initial profile was somewhat steeper than the natural equilibrium profile. This promoted enhanced sediment mobility due to both increased wave reflection and the ‘washing out’ of fine particles from the beach face.

The replenished beach has been routinely monitored and a comprehensive post-nourishment profile analysis was carried out by HR Wallingford in 1987 and 1988. Littoral drift was calculated assuming that all beach volume changes occur solely as a result of longshore transport. However this approach may yield erroneous results in areas that receive sediment from offshore sources (Whitcombe, 1995). The drift divide was shown to have remained in the same location but the eastwards drift was found to have increased to 53,000m^3 between February 1986 and February 1987 (HR Wallingford, 1987 and 1988). Short term deployment of aluminium pebbles revealed that the mean eastward drift over the period 1986-1990 was around 30,000m^3 per annum (Havant Borough Council, 1992) and approximately 11,500m^3 between 1990 and 1991 (Whitcombe, 1995). Therefore, longshore transport was initially very rapid following the beach replenishment but decreased as the beach adjusted towards an equilibrium profile. Analysis of wave refraction patterns indicate that net eastward movement of sediment is driven primarily by modified swell waves approaching from the south west. These waves reach the Hayling Island frontage at a very small angle of incidence, with small shifts in wave angle producing large changes in the transport rate, as well as direction. This is why it is possible to have a drift divide at Eastoke.

South easterly waves, which are much less common, set up a net westward movement but it is thought that during these short episodes, the drift divide becomes inactive (i.e. longshore transport is then westwards along the whole of the Hayling Island frontage).

Groynes were constructed between 1987 and 1991 in order to restrict the eastwards movement of sediment and consequently beach erosion (HR Wallingford, 1988; Whitcombe, 1995) and following this, Havant Borough Council calculated that the prevailing drift was in the region of 13,300m^3 per annum whilst W S Atkins proposed a slightly lower rate of 11,300m^3 per annum. Therefore, as expected, net eastward drift rates have declined as the beach morphology becomes more stable.

Based on previous beach replenishment experience initial losses from the nourished beach were predicted to be significantly greater than long term trends. This was confirmed by HR Wallingford (1995b) and Whitcombe (1995), who concluded that by 1994 about 55% of the post replenishment beach volume had been lost, i.e. an annual loss of around 30-40,000m^3 per annum. Data from W S Atkins (1998) and Havant Borough Council, (1999) indicate a mean loss of 27,100m^3 per annum between 1991 and 1998, declining from 46,000m^3 per annum from 1991-1994 to 25,000m^3 per annum from 1996-1998. This latter information was based on regular topographic surveys and post 1992 data on recycling inputs. There is circumstantial evidence to indicate that some losses do still occur, but the quantities involved are unknown.

As stated previously, rapid increases in eastward drift, following the replenishment scheme, led to significant accretion at Eastoke Point. Material has been artificially recycled from this accumulation area and replaced over the replenished beach. As the ness at Eastoke Point grew, so it tended to impinge upon and affect the deep water channel into Chichester Harbour. The rapid ebb flows off the end of this ness removed material into the channel from whence it was transported offshore and effectively lost from the system. A terminal groyne was constructed in 1990 to prevent further losses into the channel. However, erosion then occurred to the east (down drift) of this structure, threatening to create a breach in the shingle ridge immediately to the north. A rock revetment was constructed at Eastoke Point in 1992 in order to help stabilise the beach and reduce the likelihood of breaching. Despite providing considerable protection to the frontage, the beach in this area remains highly volatile and is particularly sensitive to changes in sediment supply from the west and, changes in wave conditions.

Since 1991, recycling has been carried out annual in order to maintain an adequate standard of flood and coastal defence. However, the overall beach volume at the eastern end of Hayling Island continues to diminish as material is transported eastwards and lost into the harbour entrance channel. Atkins (2006) has tabulated the annual recycling rates, which over the period 1993 to 2004, have averaged at:

- 14,500m^3 from west to east (i.e. from west Hayling to Eastoke); and
- 7,500m^3 from east to west (i.e. from Eastoke Point to Eastoke).

The net deficit of sediment due to the drift divide is therefore around 22,000m^3 per annum despite the groyne system along the frontage, which must substantially reduce the potential longshore transport rates.

As shingle has been transported alongshore by wave action and subsequently recycled by mechanical means, so the character of the beach sediments has altered. Some 20 years after the initial beach nourishment, it is now evident that the material available for recycling is becoming finer. Ultimately, the material on the beach will become too small to provide an effective buffer against wave action. At this stage, it may become necessary to top up the beach with coarser material. Such measures are normal for beach recharge schemes, and it is unusual to find a scheme that remains effective for as long as that at Eastoke.

From the above it is evident that longshore transport along the Hayling Island frontage is not constant, and this would perhaps explain the discrepancy between the various estimates that have been made along the Hayling Island frontage. Clearly, any management at Eastoke Point, as elsewhere on the Hayling Island frontage, should allow for this variability.

Eastoke Point to Black Point

Site observations and surveys indicate a northward drift from Eastoke Point to Black Point (Harlow, 1980) but the volumes of sediment involved are typically small, because wave action in the harbour entrance is relatively weak and the net drift is interrupted by groynes. Beach volume analysis showed that prior to the recharge at Eastoke, losses from this frontage were in the region of 8,000m^3 per annum (Hydraulics Research, 1980) but littoral drift was probably less significant, for some of this material was diverted into the tidal channel. Analysis of historic charts shows that between 1842 and 1932 Black Point spit accreted by around 1000-5000m^3 per annum, whilst erosion of 1000-2000m^3 per annum occurred between 1932 and 1967 (Harlow, 1980). It is unlikely that the beach recharge scheme had a significant effect on this frontage, as the effects were most evident at Eastoke Point itself, whilst material was also lost into the harbour entrance. Further downdrift transport is likely to move eastwards into the harbour entrance channel rather than along the north-south orientated frontage. Furthermore, sediment supply has been further restricted since the completion of the terminal rock groyne and rock revetment at Eastoke Point (1990-1992). A mixture of coast protection structures between Black Point and the western limit of the Sandy Point Nature Reserve currently maintain beach levels, but these remain vulnerable to extreme wave conditions. Sediment stored here might rapidly increase littoral drift in the event of any significant morphodynamic changes and increased erosion, providing that there is free passage from Eastoke Point, unhindered by groynes.

Chichester Harbour Entrance

Sediment supply to the main tidal channel is possible by either eastward or westward littoral drift at the harbour entrance. Sediment has been supplied in the past at rates of up to 70,000m^3 per annum from East Head via the Winner gravel bank or directly from the distal end of the spit (Webber, 1979). Supply from this source has reduced significantly with the progressive and comprehensive protection of the shoreline of Bracklesham Bay since 1974 (Harlow, 1980) and has now virtually ceased following extension of the groynes at West Wittering during the 1980s. Eastward littoral drift at Eastoke Point supplies sediment to the tidal channel at a minimum rate of 5000m^3 per annum. Beach replenishment at Hayling Island initially increased littoral drift to 45-50,000m^3 per annum (Hydraulics Research, 1988) and later reduced to a mean 11,000-15,000m^3 per annum (Whitcombe, 1995). Although some material accumulated at Eastoke Point, significant quantities migrated into the deep water channel, and were then transported offshore by the strong ebb currents onto the tidal delta. The construction of the terminal rock groyne at Eastoke Point reduced these losses.

The entrance channel to Chichester Harbour is deeper and has higher tidal currents compared to other harbours of similar formation. Sediments entering the tidal channel are flushed offshore and deposited at varying distances from the entrance depending on grain size, wave conditions and water depth. Gravel can be transported a maximum of 1 to 2 km offshore and sand, a maximum of 3.5km offshore (Webber, 1979). Dynamic change of the plan-shape of West Pole Sand since the 1960s is a result of variations in the balance between erosion and deposition (Whitcombe, 1995). Sediment sampling by Harlow (1980) revealed a series of sedimentary zones related to current velocity and suggested that wave action could mobilise surficial sediments. The volume of sediment transported offshore by tidal currents was not calculated, but fresh supply could be estimated from littoral drift volumes at the entrance, as bedload transport by tidal currents from within the harbour is negligible. Contemporary supply to the tidal channel consists almost entirely of eastward drift of mostly fine gravel and sand from Eastoke Point. Virtually no fresh material is now introduced into the offshore transport pathway in the tidal channel although sediments transported will be those periodically pushed onshore from the tidal delta by storms from the south. The tidal delta is therefore a finite resource and any outputs – particularly dredging – are likely to represent a net permanent loss from the local sediment budget. It is significant that the Winner lowered by 0.50-1.0m between 1926 and the present time, contributing to an increase in the pivotal movement and erosion of East Head, and thus expansion of the cross sectional area of the harbour mouth (ABP Research and Consultancy, 2000). It is presumed that the progressive increase in the width and depth of the Chichester Harbour entrance channel reflects its adjustment towards morphodynamic equilibrium. It is not clear if this has been fully attained.

It can be concluded that any future defences at Eastoke Point (or Eastoke itself) cannot rely on any natural supply of fresh beach sediment being available from the Chichester Harbour delta. If the deficit in the budget is not made good (by artificial recharge, for example), then the shoreline at the eastern end of Hayling will continue to experience erosion and will retreat if allowed to do so. Further, without recharge, any hard defences will eventually become undermined, because of falling beach levels. Historic changes at Eastoke suggest that this will happen in several decades at the very latest.

3.8 SHORELINE RECESSION RATES

As stated above, the average rate of shoreline recession at Eastoke, until 1976, was around 0.6m per annum. Following the 1985 beach recharge, the shoreline recession increased to around 1.6m per annum (HR Wallingford, 1995b) although there are wide confidence limits on this figure. (Note that this represents the initial readjustment as the nourishment material was sorted by wave action).

When considering the erosion rate as a means to assess the inherent risk to the adjacent coastal assets, it is important to bear in mind that the proposed recession rate refers only to erosion of the beach face itself. Where the foreshore is backed by a seawall, the recession will not continue at the same rate once the wall is exposed. As erosion continues, more and more energy will be dissipated on the wall itself, rather than producing transport. Following the collapse of the wall, the shoreline will continue to migrate landwards but this in itself will have an impact on erosion and hence adds further uncertainty to the predicted recession rate. At Eastoke Point, where there is no sea wall, the beach is backed by the Nature Reserve, which contains primarily sandy soil. Once the beach and associated defences (including the rock revetment) have been lost, a breach will occur and the erosion rate is liable to increase as the finer sediments within the LNR become exposed to wave action.

It is also reasonable to assume that hydrodynamic conditions may become more severe as a result of climate change and that this too will influence the rate of shoreline recession. Assessments carried out for the Eastoke Sectoral Strategy Study (Atkins, 2006) assumed that, given the variation in erosion rate and the overall performance of the beach, an erosion rate of 2.3m per annum leading to failure of the defence was appropriate. This value is higher than that from an assessment by Havant Borough Council, who concluded that the average recession rate prior to 1992, when recycling commenced was 1.8m per annum (Atkins, 2006). However, for the purposes of this study, an average rate of 2.3m per annum has been taken for the likely recession at Eastoke, to allow for the acceleration in sea level rise. However, it should be noted that severe, episodic erosion has taken place at Eastoke Point in the past. During such periods in the future, the shoreline recession rate will far exceed this average rate.

3.9 BEACH PROFILE ANALYSIS

An analysis of beach profiles has been carried out in order to establish the recent changes in the shoreline at and near Eastoke Point. The beach profile data supplied by Havant Borough Council has been analysed using the BDAS software designed by HR Wallingford, a description of which is presented in Appendix 3. The locations of the beach profiles used in the BDAS analysis are presented in Figure 3.12. As can be seen the analysis includes the frontage from Eastoke Point northwards towards Black Point and westwards onto the Eastoke frontage

Based on this beach profile analysis, an assessment of changes in the position of MHW between 2003 and 2005 has been carried out. The mean rate of retreat or advance of this contour is presented in Figure 3.13. The plot shows that the beach sections at the end of the promenade (profile 273) and just north of the apex of Eastoke Point (profile 264) are the areas where the beach has retreated landwards most during this period. Both locations are where the shoreline is convex, making it vulnerable to increased littoral drift at both. The retreat just north of the apex of Eastoke Point contrasts with that just to the west of it, which shows a tendency for a seawards advance over the same period.

The frontage from Eastoke Point to Black Point generally shows little trend for change, although with a modest advance in the mean high water line in the vicinity of the lifeboat station.

An analysis of variability on the beach cross-sectional areas has also been carried out for the same period and this is presented in Figure 3.14. The trends in cross-sectional area over that period are presented as changes in volume per metre run of frontage, and are presented in this manner in Figure 3.14.

Where beaches are eroding or accreting strongly, it can be expected that both the change in the position of the contours and the beach volumes will show the same trend, i.e. both will decrease or increase together. Where the changes are less clear cut, there can be a difference between these two measures of change. For example, a decrease in the beach profile gradient could result in the high water contour retreating landward despite the beach cross-sectional area increasing.

Comparing Figures 3.13 and 3.14 show that there are few parts of the frontage where there is good agreement between the trends in the Mean High Water position and beach volume. At two profiles, 273 and 264, both figures show a strong trend for erosion.

Thus, the volumetric analysis confirms that the most vulnerable areas are just north of Eastoke Point itself and at the end of the promenade. The tendency force both beach retreat and loss of volume also occurs, but less strongly, just east of the promenade seawall at section 270. This analysis is confirmed by visual inspections of beached and anecdotal evidence from Havant Borough Council.

The volumetric analysis indicates a tendency for beach accretion along the frontage from the north-western corner of Sandy Point Nature Reserve extending past the Lifeboat station. This is in accord with the increase in the area of vegetated shingle along this section of beach, and the routine collection of shingle from here as part of the routine recycling operations. This accretion is the result of the reducing longshore transport along this frontage, as wave heights decrease in the narrowing entrance of the harbour, together with the effects of the rock groynes interrupting the northward transport of beach material.

Between the westerly limit of the study frontage and the end of the promenade, i.e. at section 279 and 276, the changes are less clear cut, presumably as a result of the opposing effects of the natural tendency for erosion and the positive effects of the recycling operations that result in an increase in beach volumes here.

It is also noticeable that the beach trends shown differ significantly at adjacent profiles, and this is due the effects of the groynes along this frontage as well as the effects of the recycling operations. In places, for example at the eastern end of the promenade (profiles 273 and 276), opposing trends in volumetric change are shown, indicating that at some point between these profiles the trend will be zero, i.e. significantly different from the trends at either of these profile locations.

The rather inconsistent pattern of beach changes shown in Figures 3.13 and 3.14 makes it impracticable to attempt to produce an accurate “budget” for the beach sediments along the southern and eastern sides of the Eastoke peninsula.

This task is made more difficult by, the unquantifiable losses of sediment offshore from near the apex of Eastoke Point and the implication of further losses along the beach to the north of the Lifeboat station, together with the effects of beach recycling.

This type of analysis would require, if it were to be seriously attempted, more detailed surveys of beach levels and hence volumes in each groyne compartment and the quantification of the volumes of material removes from or placed into each compartment during the recycling operations. The latter could be usefully achieved by a combination of surveys before and after recycling and by noting the collection points and deposition areas for each truck load of sediment moved. This would also serve to provide information on the effects of such recycling on beach volumes. Even if no sediment was lost from the beach as a result of these operations, it is not certain that the *in situ* density of beach sediments would be the same before and after they are recycled.

3.10 INTERACTIONS BETWEEN EASTOKE AND EAST HEAD

East Head has undergone a major change over the past 100 years. Early maps show a substantial shingle spit extending north-west across the Chichester Harbour entrance. In the late 19th century, the spit apparently rotated by 90° towards its present north-eastern orientation and altered in character from a shingle bank to sand dunes. This change occurred primarily before any significant coastal defences were built and was therefore judged to be a result of natural changes to the coastal environment. The present sand spit is considered to be reasonably stable apart from the area at the neck, which is known as 'The Hinge'. Since the turn of the 20th century, work has been carried out to prevent breaching at this point. This has included the construction of groynes and gabions. The dunes on the main spit have been actively managed since the 1970s.

The large change in alignment at the Hinge means that longshore sediment transport is interrupted at this point. Shingle arriving at the Hinge tends to accumulate on the eastern side of the westernmost groyne, then being drawn down during storms to be scattered over the foreshore. Some of the shingle pushed into the harbour itself tends to form banks. Whether further movement from such banks is likely, or not, is a matter for further investigation. Some shingle will also find its way into the deep water channel from whence it is more likely to be flushed seaward by the rapid ebb currents, than transported into the harbour itself.

Longshore sand transport is less affected by the groynes and a feed into Chichester Harbour mouth will continue, irrespective of what changes in the updrift defences may occur in the future. This transport is likely to continue to feed the lower foreshore of the beaches, and the seabed in Hayling Bay. The effect it has on the budget of "sandy sediments" is unclear, since most computations of beach sediments that have been made to date refer to changes in the volumes of the upper foreshores, where the sediments are predominantly shingle.

The widening of the entrance to Chichester Harbour, and the maintenance of the deep navigational channel, now mean that there is no likelihood of any direct effect of coastal management at Eastoke Point affecting the coastline at East Head or vice versa. These two parts of the Hampshire coastline are both affected by, and in turn affect, the changes in the large ebb shoal delta outside the harbour entrance, i.e. the ever-changing banks of sand and shingle on both sides of the deep entrance channel. In that context, changes in the amounts of beach sediment lost offshore from the beaches at Eastoke Point and East Head would alter the evolution of this ebb shoal delta and hence, at least hypothetically, might alter the coastline on the other side of the harbour entrance. Any changes to Eastoke Point and its defences considered in this study, however, could only have an immeasurably small and insignificant effect on the coastline at East Head through this mechanism.

3.11 COASTAL SQUEEZE

Eastoke Point is presently able to adjust to hydrodynamic changes and coastal squeeze would, at first sight, not be an issue. However, as the Eastoke frontage is backed by a seawall, then it is likely to be affected by coastal squeeze, as it was in the past (when beach levels at Beach Club fell to the point of shingle being lost entirely). If this happens longshore transport of shingle to Eastoke Point will decline and it will erode rapidly. Thus, coastal squeeze on the main frontage of Eastoke will have (an indirect) impact on Eastoke Point, as well as on the beaches to the west of Eastoke.

Similarly, when developing and assessing potential coastal defence schemes for the Eastoke Point frontage, it will be necessary to ensure that the chosen option will not be affected by coastal squeeze under future rising sea level, as might be the case if a seawall option was chosen, for example. If this is not possible it will be necessary to provide compensation for the loss of inter-tidal habitat.

3.12 SUMMARY

This chapter identifies the coastal processes that govern the past and present evolution of Eastoke Point. From this assessment it is clear that Eastoke Point represents a highly dynamic stretch of coastline, which is subject to complex hydrodynamic and geomorphological forcing mechanisms.

In addition to the complexity of the natural processes, man-made interventions away from the area to be managed also have an impact. Conditions at Eastoke Point are strongly affected by the management operations at Eastoke itself. Eastoke Point is also to some degree dependant on the processes taking place on the Selsey peninsula. The movement of sediment across the harbour entrance forces flows towards the west, potentially increasing erosion on the east face of Eastoke Point. However, sediment from the Selsey peninsula that is transported onto the ebb-delta does provide a feed to Hayling Island, although this feed has reduced in recent years.

Consequently, defining an appropriate management strategy for the Eastoke Point frontage, which will provide protection to human and environmental assets, whilst not disrupting the natural equilibrium, is a difficult task. This is especially so, given that, despite the existing beach management methods that are employed, beach levels continue to fall, whilst the risk of overtopping and flooding during storm conditions increases.

The information derived from this assessment of coastal processes is now used to carry out a flood risk assessment for the frontage and to develop a range of suitable coastal protection options.

4. *Physical Survey of Defence Structures*

4.1 INTRODUCTION AND METHODOLOGY

Condition grading of coastal defence structures is required for three main purposes:

- To inform immediate management interventions with regard to those defences;
- To help define the fragility of defences against breaching for risk analysis and prioritising intervention at national, regional (catchment or shoreline) and local level; and
- To help decide whether the existing structures can be incorporated into any improved coastal defence scheme, perhaps after modification, or will need to be removed.

Condition grading has sometimes been linked to a kind of risk assessment of the defences, taking some account of intensity of loading and the consequences of failure, but this is now regarded as misleading. Such aspects are better considered elsewhere in a systems risk analysis.

To meet these demands, an improved performance-based method for visual inspection of flood risk management assets (such as embankments and vertical walls) and of assessing of asset condition has recently been developed by University of Nottingham within the FRMRC (Flood Risk Management Research Consortium) and trialled under the PAMS (Performance-based Asset Management System) R&D and TE2100 projects.