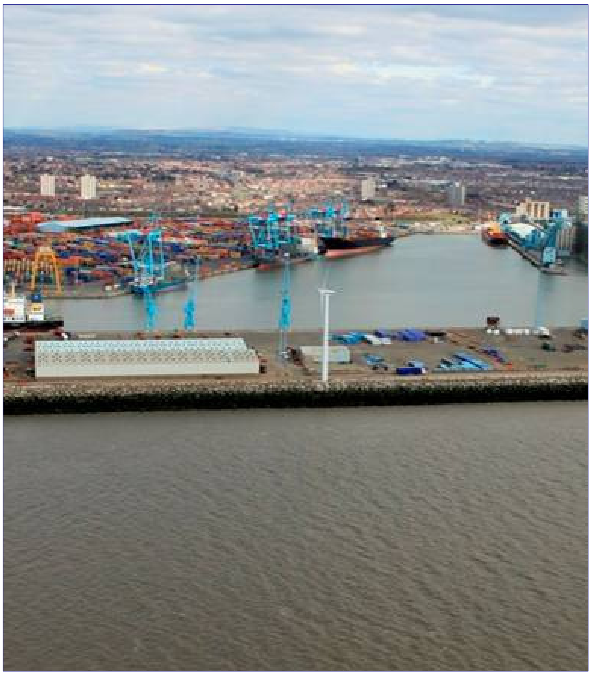
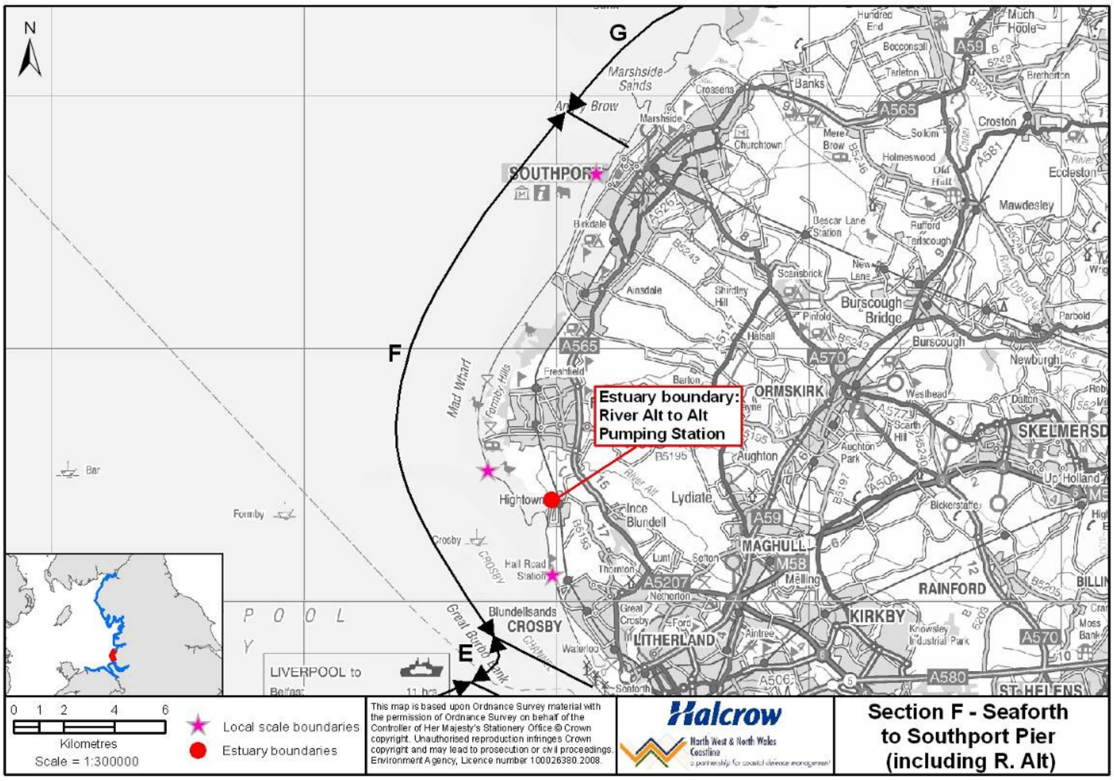
F - Sefton Coast (Seaforth to Crossens)




This statement includes the following:

1. Location map showing local-scale boundaries
2. Report on existing defences
3. Baseline understanding of shoreline dynamics and behaviour
4. Baseline scenario assessments ('no active intervention' and 'with present management')
5. Supporting information and references

1 Location Map



2 Report on existing defences

Location	Defence History	Present Defences	Residual Life (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Crosby Marine Lake South adjoining Royal Seaforth Dock National Grid: (331200E 397310N) to (331180E 397520N)	Constructed in 1972	Linear rock armour revetment.	>20	Fine to medium sand beach with ridge/runnel formations.	Sefton Annual Defence Inspection 2006. Residual life reviewed as part of Crosby to Formby Strategy.
Crosby Marine Lake to Mariners Road National Grid: (331180E 397520N) to (330600E 398880N)	Constructed in 1972	Stepped concrete revetment topped by wave return wall and supported by buried sheet pile toe. Promenade backed by dwarf wall to landward.	<20	Fine to medium sand beach with ridge/runnel formations.	Sefton Annual Defence Inspection 2006. Residual life from Baseline Report 2002.
Mariners Road to the Serpentine National Grid: (330600E 398880N) to (330160E 399680N)	Unknown	Stepped concrete revetment topped by wave return wall and supported by buried sheet pile toe. Promenade backed by dwarf wall to landward. Some concrete maintenance work needed.	<20	Fine to medium sand beach with ridge/runnel formations.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life reviewed as part of Crosby to Formby Strategy.
Serpentine to Hall Road West National Grid: (330160E 399680N) to (329910E 400280N)	Vertical timber breastwork was built in 1960, and rebuilt in 1975 with stepped revetment at toe and recycling suitable timber. Some repairs made following	Stepped concrete revetment topped by vertical timber breastwork with concrete coping and supported by buried sheet pile toe. Promenade backed by dwarf wall to landward .	<5	Fine to medium sand beach with ridge/runnel formations.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life reviewed as part of Crosby to Formby Strategy.

Location	Defence History	Present Defences	Residual Life (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
	storm damage in 1990, and subsequent small repairs in 2003.				
Serpentine to Hall Road West (2) National Grid: (329910E 400280N) to (329860E 400500N)	Vertical timber breastwork was built in 1960. The defences were rebuilt in 1975 with stepped revetment and a wave return wall.	Stepped concrete revetment topped by wave return wall and supported by buried sheet pile toe. Promenade backed by dwarf wall to landward.	<20	Fine to medium sand beach with ridge/runnel formations.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life reviewed as part of Crosby to Formby Strategy.
Hall Road West to Coastguard Station National Grid: (329860E 400500N) to (329841E 400653N)	Timber revetment was built in 1975 and reinforced by rock armour before 2003. The beach was reinforced with rubble following WWII.	Timber breastwork, partly reinforced with armourstone. Beach reinforced with rubble. Shoreline is vulnerable to erosion under extreme conditions.	<5	Cobble and rubble upper beach with sand lower beach.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life reviewed as part of Crosby to Formby Strategy
Coastguard Station to Alt Training Bank National Grid: (329841E 400653N) to (329580E 401580N)	Rubble added to the shoreline between 1950 and 1974. The training wall was built in 1936 and has since been refurbished intermittently.	Rubble-reinforced beach which forms artificial promontory at the northern end. It is linked to a low level training bank which extends to MLW and ins constructed of rubble fill, concrete and rock.	N/A	Sand/rubble upper beach and sand lower beach.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Alt Training Bank to North of Far Moss Outfall National Grid: (329580E 401580N) to (329500E 402460N)	Rubble added to the shoreline between 1950 and 1974. Date of outfall construction pre 1980s.	Rubble/hardcore reinforced beach which forms 2m high cliff at crest. Far Moss outfall at the northern end is supported by timber pile and trellis structure. Outfall acts as a groyne and fixes position of Alt Channel at this point.	N/A	Steep upper sand and rubble beach, with muddy River Alt channel and salt mud flats. Formby bank to seaward of Alt channel.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.

Location	Defence History	Present Defences	Residual Life (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
South of Blundellsands Sailing Club National Grid: (329500E 402460N) to (329620E 402855N)	Rubble added to the shoreline over southern part between 1950 and 1974.	Continuation of rubble hardcore cliff at southern end which merges into natural dunes. Rubble drift northwards reinforcing beach. Broseley outfall protected by concrete casing - acting as groyne although now largely buried.	N/A	Natural sand dunes fronted by sand beach with some cobbles. River Alt channel meanders across the frontage. Formby Bank to seaward of Alt channel.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Blundellsands Sailing Club National Grid: (329620E 402855N) to (329650E 402950N)	Date wall constructed unknown. Toe protection added 2002/3.	Concrete and rubble vertical defences to protect Sailing Club which forms an artificial promontory. Also protected by small timber groynes. The wall is being undermined at the northern end and is vulnerable to storm damage.	<5	Natural sand dunes fronted by sand beach with some cobbles. River Alt channel meanders across the frontage. Formby bank to seaward of Alt channel.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life reviewed as part of Crosby to Formby Strategy.
Hightown Dunes - South of River Alt National Grid: (329650E 402950N) to (329600E 403550N)	N/A	Natural sand dunes. Hightown outfall acts as groyne and influences local beach behaviour. Dunes recessing.	N/A	Sand upper foreshore which turns to mud by River Alt channel. Some marsh and reed bed growth. Formby bank to seaward of Alt channel.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.

Location	Defence History	Present Defences	Residual Life (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Altcar Firing Range - River Alt Defences National Grid: (329534E 404361N) to (329590E 403554N)	Unknown	Stone river bank protection and a length of steel sheet pile retaining wall.	>20	Mud edges to channel, saltmarsh and reed beds. Sand dunes to west side.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life from NFCDD.
Altcar Firing Range National Grid: (329550E 403554N) to (328160E 404670N)	N/A	Natural sand dunes	N/A	Sand foreshore backed by sand dunes.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Nature Reserve to Formby Point National Grid: (328160E 404670N) to (327000E 406975N)	N/A	None at shoreline, secondary earth flood embankment approximately 500m inland.	N/A	Sand foreshore with ridge/runnel formations backed by sand dunes.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Blundell Avenue to South of Dale Slack Gutter National Grid: (326940E 407400N) to (327460E 409240N)	N/A	Natural sand dunes	N/A	Sand foreshore backed by sand dunes.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.

Location	Defence History	Present Defences	Residual Life (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Dale Slack Gutter to Massams Slack National Grid: (327460E 409240N) to (328460E 411020N)	N/A	Natural sand dunes	N/A	Sand foreshore backed by sand dunes.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Ainsdale Sands National Grid: (328460E 411020N) to (329720E 412460N)	N/A	Natural sand dunes.	N/A	Sand foreshore backed by sand dunes with ridge/runnel formations. Car parking is permitted on the beach resulting in sand compaction reducing sediment supply to the dunes.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Southport Holiday Village, Ainsdale-on-Sea National Grid: (329720E 412640N) to (329720E 412960N)	Unknown	Natural sand dunes with some timber breastwork holding back the dunes by the access point.	>20	Sand foreshore with ridge/runnel formations backed by sand dunes. Car parking is permitted on the beach resulting in sand compaction reducing sediment supply to the dunes.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life from NFCDD.

Location	Defence History	Present Defences	Residual Life (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Birkdale Dunes 1 National Grid: (329720E 412960N) to (331365E 415682N)	N/A	Natural sand dunes.	N/A	Sand foreshore with ridge/runnel formations backed by sand dunes with some colonisation of upper beach by vegetation. Car parking is permitted on southern part of the frontage, resulting in sand compaction reducing sediment supply to the dunes.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Birkdale Dunes 2 National Grid: (331365E 415862N) to (332120E 416455N)	N/A	Natural sand dunes.	N/A	Sand foreshore backed by sand dunes with some colonisation of upper beach by vegetation.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002.
Weld Road - Victoria Park South National Grid: (332120E 416455N) to (332183E 416740N)	Revetment was built when the frontage was reclaimed from the foreshore in 1975 and maintained. Previously the dunes provided defence.	Sloping concrete revetment, although growth of dunes to seaward has reduced role of revetment to secondary defence.	>10	Vegetated beach with sand foreshore to seaward.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life estimated from condition inspection.

Location	Defence History	Present Defences	Residual Life (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Weld Road to Esplanade National Grid: (332183E 416740N) to (332421E 417207N)	Revetment was built when the frontage was reclaimed from the foreshore in 1975 and refurbished in 2001. Previously the dunes provided defence.	Sloping concrete revetment with concrete toe beam topped by a recurved wave return wall.	>20	Marsh grasses on upper beach, sand lower beach. Car parking is allowed on a narrow strip at top of beach, and immediately seaward of this area is used as a runway for light aircraft in the summer.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life from NFCDD.
Pleasureland / Marine Parade National Grid: (332421E 417207N) to (333214E 418108N)	First defences were built in 1883 when the land was reclaimed for the promenade. Road behind flooded on spring tides until present defences built in 1997/8.	Sloping concrete revetment with concrete toe beam topped by a promenade and recurved wave return wall.	>20	Sand foreshore with car parking allowed on a narrow strip at the top of the beach.	Sefton Council Annual Defence Inspection 2006 & Baseline report 2002. Residual life from NFCDD.

3 Baseline understanding of shoreline dynamics and behaviour

LARGE SCALE: F - SEFTON COAST (SEAFORTH TO CROSSENS)

Interactions:

The coast is macro-tidal, with a mean spring range of around 9m at Formby Point. The eastern Irish Sea is characterised by strong tidal currents and, due to higher flood than ebb tidal current velocities, there is a near bed residual current circulation towards the coast throughout the area, turning south-east towards the Dee and Mersey estuaries and north-east towards the Ribble. The flood tidal streams flow landwards and then diverge around Formby Point and flow towards the Mersey and Ribble Estuaries. Surface current flow is eastward off the North Wales coast and northwards off the Lancashire coast.

The prevailing winds are from the south-west, but wind conditions vary spatially due to topography and coastal orientation (Pye and Blott, 2008).

In terms of wind-wave generation, Liverpool Bay can be considered as an enclosed basin, with waves being locally-generated (HR Wallingford, 2001). Wave conditions along the shoreline vary considerably as inshore wave conditions are influenced by the shallow waters in the nearshore region, much of which is characterised by wide intertidal beaches fronted by banks and shoals. This produces significant attenuation of waves before they reach the shoreline, whilst tidal streams can also be locally set up in places behind these banks. Adding to this, surge conditions create deeper water over these shallows and thus large changes in the shoreline wave conditions occur during such events. This produces a complex array of shoreline processes, which can be significant in influencing the response of the soft shorelines that characterise much of this area (Halcrow, 2002). Sand from Jordan's Spit is moved onshore to the south of Formby and at Southport there is also onshore movement of fine sediment from the offshore banks. As beach levels have increased at Southport there has been an increased deposition of fine sediments.

A littoral sediment divide exists at Formby Point, which is probably associated with the sediment circulation cells of the Ribble and Mersey Estuaries. Sand is therefore moved alongshore north and south from here.

Much of the seabed is covered by predominately fine to medium sand, with local areas of mud and gravel. These surficial deposits cover a partially eroded surface of boulder clay (till). The sandy cover is quite thin, less than 1.5m thick in places, but does represent a possible sediment source and there is evidence of onshore movement within Liverpool Bay. The Mersey and Ribble estuaries are not believed to supply sand to the coast.

Liverpool Bay, itself is believed to act as a major sink with any material leaving the shoreline between Great Ormes Head and Morecambe Bay probably accumulating here and being internally redistributed, rather than being moved to other areas offshore or alongshore beyond the limits of the bay. There has been a general trend for shoaling within Liverpool Bay over the last 150 years. Much of this material is believed to remain in the nearshore, particularly the sand-sized fraction, resulting in the growth of the intertidal and subtidal banks rather than contributing to the building of beaches and dunes. Growth of the banks in the area, and the infilling of the Formby Channel, suggests that these are presently acting as sediment sinks or stores. There has also been continual silting up within the estuaries indicating that they are also significant sediment sinks in this area.

The dune system itself represents a large store of sand, some of which has effectively been cut off as a potential supply by development. Along much of the frontage, the frontal dunes are active and as the dunes along the Formby frontage erode, sand is released to the beach system. In the short-term, this material will build up the beaches and increase wave dissipation, but is then transported alongshore. Despite sediment input from the dunes along the Formby frontage, there has been a lowering of beach levels, exposing peats and illustrating that the beach along this stretch of coast is only a veneer and not conducive to being a sediment store.

There is also sediment transport along the intertidal ridges, and from Formby fine sand is transported northwards onto the offshore banks, such as Horse Bank which lies to the south of the Ribble Estuary. The River Alt acts to curtail the southward progression of Formby Bank and redirects drift offshore.

The coastline is susceptible to storm surges because of the shallow nature of the eastern Irish Sea and large tidal ranges. Heaps and Jones (1978) demonstrated that winds over the Irish Sea and externally-generated surge disturbances passing into the Irish Sea through St George's Channel and the North Channel both significantly affect surge level sin this region. The most significant erosion occurs when storms surges coincide with significant wave activity (i.e. during periods of high winds).

The foreshore features ridges and runnels; these are 'quasi-permanent features' which lie roughly parallel to the coastline around Formby, but become detached from the shoreline south of the Point. It has been suggested that the development of ridge and runnel morphology is associated with specific conditions of tidal range, fetch, sediment size and beach slope (King and Williams, 1949).Although these features may affect the very short term shoreline dynamics, they do not have a significant impact on long-term evolution.

Movement:

Historical changes along the Sefton coast are relatively well documented, particularly over the last 150 years. Dune formation along this coast is believed to have commenced around 5,300 years ago (Neal, 1993; Pye and Neal, 1993a), and probably developed on an elongate offshore sand bank (Pye and Neal, 1993a), which would have provide a sheltered environment in which subtidal sediments accumulated. There then followed periods of stability and instability, such as during the 13th century when climatic instability coincided with higher sea levels (Neal, 1993). There is historical evidence of dunes being breached and flooding of low-lying inland areas and sixteenth century court proceedings mention the villages of Meanedale, Argameols and Ravemmeols lost to the sea and old maps show a village of Altmouth near what is now the Altcar Rifle Range (Smith, 2002).

Evolution of the dunes continued, with little human interference, until the 18th century, when the dunes started to be managed through the use of marram planting and use of brushwood fences and many of the foredunes formed during this period owe their parallel form to this management techniques (Pye, 1990). This management was probably a response to severe storms during the early 18th century, when sand was blown inland several kilometres, engulfing agricultural land.

Between 1845 and 1906, Ordnance Survey maps indicate that there was relatively rapid accretion of Formby Point, with the central section of coast accreting more that 200m. This trend then reversed around the start of the 20th century (Gresswell, 1953; Pye and Smith, 1988; Pye and Neal, 1994; Neal, 1993), possibly due to changes in the wind-wave regime (although other factors may have exacerbated this). Since this time there has been a progressive trend of erosion along the central stretch of coast. The southern limit of erosion has remained roughly stable, but the northern limit has gradually extended northwards (Pye and Neal, 1994). The most extensive dune erosion occurs when storm surges are accompanied by strong wave action. During storms tidal levels can be raised by up to 1.4m.

Recent accretion of saltmarsh southwards from the Ribble Estuary is now encroaching on the Southport beaches. As the beach levels and intertidal width increase, conditions are becoming more favourable for deposition of finer material.

Modifications:

Although there are few man-made defences along this shoreline, the whole of this coastline has been affected by reclamation works, construction of training walls, and subsequent dredging within both the Mersey and Ribble estuaries, which may have exacerbated, but probably not caused, the present trend of erosion at Formby Point. Sand winning from the Horsebank areas offshore of northern Southport commenced in 1966, but operations ceased in 2007.

Over the past two centuries material dredged from the Mersey has been dumped offshore, which, together with the training works, is believed to have contributed to silting up of the Formby Channel and the resultant reduction in sediment supply to Formby Point. The location of spoil dumping grounds has varied over the last 150 years from the south to the north of the navigation channel. However, in addition to human intervention, natural changes in forcing factors have also been proposed as a driver of this erosion trend and it is impossible to conclusively identify the relative contribution of either factor to the erosional trend.

The dunes have been modified in places and also their current morphology is a result of past and present management practices (Pye, 1990). In the early 18th century marram grass planting was implemented, and was obligatory for landowners until 1886, which led to the development of high dunes. Between 1880 and 1925, planting of brushwood fences reinforced a natural progradation trend and led to the formation of parallel dune ridges. Following the onset of erosion around Formby Point, the negative beach-dune sediment budget, coupled with continued high wind energy, led to lower beach levels, which increased the risk of storm wave damage and led to the development of transgressive sand sheets. Erosion has resulted in the truncation of the parallel dune ridges around Formby Point.

Most of this coastline relies upon the dunes as a natural protection against tidal inundation of the low-lying hinterland. The key locations for coastal defences are along the developed areas at Southport and Crosby. At Crosby, the sea wall forms a shallow bay, where sand is currently accumulating. Occasional removal of sand takes place to prevent problems of wind-blown sand and in the past this material has been used to replenish the beach at the Marine Lake. To the north, along the Southport frontage, there has been reclamation of the coast over the last century. The shoreline now lies seaward of its natural position and is protected by a seawall and promenade. This has restricted any new dune growth, but there is a natural trend for silt deposition in this area due to growth of the offshore banks.

There are also secondary defences at Cabin Hill, adjacent to Altcar. There was significant sand extraction here between 1945 and 1975, which lowered the levels of the sand. As a result, this area has become a potential flood pathway for flooding of the hinterland and in response to this flood risk an embankment was built in 1971 (Sefton Council, 2007f).

The course of the River Alt has also been modified. The River Alt previously meandered naturally across the foreshore but following erosion of the shoreline, a training wall was constructed in the 1930s to deflect the channel away from the shoreline. This has helped reduce the erosion of the dunes locally, although the channel still restricts sediment transport to the upper foreshore and therefore to the dunes.

Although there are no formal defences along much of the dunes system, they have been affected by man's activities. Large parts of the dune system have been built-on or levelled for agriculture (Pye and Blott, 2008) and for the creation of recreational facilities, such as car parks and the Holiday Camp at Ainsdale. Dumping of organic tobacco waste also took place, along the National Trust frontage at Victoria Road, between 1962 and 1973, in a former sand winning area; sand winning historically took place from both within the sand dunes and the foreshore. Sand winning from within the dunes had stopped by 1970, following concerns raised regarding coastal erosion and the risk of flooding (Crosby, 2007).

In addition to the above changes, visitor pressure is also a key factor affecting the frontal dunes. At access points, dunes have been severely damaged in the past and compaction of the beach can affect the development of embryo dunes. In the past, recreational pressures resulted in the development of blowouts and sandsheets along the frontage, due to the destruction of dunes vegetation, particularly along the eroding sections of coast. In response to this, a dune management programme was introduced in the 1970s, which used various methods to both control visitor access and restore and maintain areas of dunes that had been heavily damaged. This programme utilised brushwood fences, marram planting and use of fences and Christmas trees to reduce storm damage. Although this has reduced damage to the dunes, it has not altered the underlying trends.

Historically there has also been vehicular access to the beach; this is now more restricted, with beach access at the Esplanade and at Ainsdale. Access to the beach at Weld Road was stopped in 1993.

Wider-scale interactions:

The Sefton coast is transitional between open coast and estuarine regimes and is influenced by processes in Liverpool Bay and by the Mersey and Ribble estuaries (Pye, 1990). Historically, changes in the tidal regimes of these estuaries over the last few centuries have been significantly influenced by human interference. Their interaction with the open coast processes has also therefore changed over time. In general, both estuaries have been sinks for sediment, with material eroded from the dunes around Formby Point transported northwards towards the Ribble Estuary and southwards towards the Mersey Estuary.

Pye and Neal (1994) investigated the potential impacts of dredging and training wall construction, associated with both the Mersey and Ribble estuaries, on wave refraction and beach dynamics: their findings are reproduced below. Construction of training walls in the Ribble Estuary began in the 19840s and the net effect was to concentrate ebb flow within the trained channel and create areas of flood dominant flow on either side. This led to enhanced shoaling and intertidal flat development, which was also enhanced by saltmarsh reclamation within the estuary. Since dredging of the channel ceased in the 1970s, the estuary has attempted to revert to a more natural regime, which has enhanced the trend of shoreline accretion at Southport, by reducing ebb tidal current transport in the South Channel, located off Southport. Bog Hole Channel, at the head of the pier, is the remnant of this old South Channel. This feature has been pushed further north by feed of sediment into the Ribble and has become detached from the end of the pier (Coastal Engineering UK Ltd, 2005; Sefton Council, 2007a).

Analysis of sequential historical bathymetric charts from the Ribble Estuary (van der Wal and Pye, 2000) revealed that that there has been a significant accretional regime over the last 150 years, with infilling of the North Channel and South Channel. However, the report determined that it was not possible to define rates of sedimentation from these data sources. Accretion has been apparent in the upper intertidal zone (including saltmarshes), with little change in volume in the lower intertidal zone (Pye and van der Wal, 2001). Van der Wal *et al.* (2002) concluded that whilst infilling of the Ribble Estuary would have occurred naturally, it has been enhanced by human activities, both through land reclamation and construction of training walls. This report also concludes that the contribution of sediment from erosion around Formby Point to the estuary infilling is minor when compared to the total volume of material entering the estuary from the bed of the Irish Sea.

Dredging within the Mersey began in 1890, with construction of the Mersey training walls commencing in 1909. These works contributed to shoaling in the Formby Channel, deepening of the Queen's Channel and growth of Taylor's Bank. Dumping of dredge spoil also led to the development of Jordan's Spit. The net effect of these works appears to have been an increase in wave focussing onto Formby Point (Neal, 1993; Pye and Neal, 1993b). Significantly, the 2002 chart shows that Taylor's Bank had moved only slightly further to the east, indicating that the bank may have reached an equilibrium position with respect to its retaining training wall (Blott *et al*., 2006).

The EMPHASYS project (now part of the Estuaries Research Programme Phase 1; ERP1) also investigated changes within the Mersey Estuary, which looked at the trend of net influx of sediment into the estuary throughout most of the 20th century. This indicated that there has been a large increase in sediment within the Liverpool Bay and Mersey system as a whole over the 20th century. However, the Mersey is no longer losing capacity and is though to have either stabilised or is possibly gaining capacity at a slow rate (ERP1).

The River Mersey is believed to contribute very little sediment to the Sefton coast: it is mostly intercepted by the Ship Canal (Sefton Council, 2000). However, River Ribble is believed to carry fine silt downstream, which settles out on the northern beaches, where there are sheltered conditions (Sefton Council, 2007c)

The River Alt has an important influence on the shoreline to the south of its mouth as it effectively forms a barrier to littoral and aeolian transport of sand. The Crossens Channel to the north also has a local zone of influence, but its is more difficult to distinguish this from the impact of the Ribble Estuary.

There is large-scale realignment taking place on this coastline resulting from the redistribution of the dune system, with sand eroded from Formby Point and deposited on the frontages to the north and south. Whilst this is expected to continue in the near future, the extent of this straightening of the shoreline may reduce as it approaches a point of natural equilibrium for the present transport dynamics. The evolution of this coastline is also dependent upon any future changes in the regimes of the Ribble and Mersey estuaries and associated changes in the outer banks. Both estuaries seem to be reaching a stable state, but this would be perturbed by any further human modifications.

A further uncertainty, particularly along the dune coast is future changes in the wind-wave climate. It has been proposed (Pye and Blott, 2008; Pye, 2001) that the occurrence of extreme high tides and wave action associated with storms is of greater importance to the pattern of dune erosion and accretion along this coast than increases in the rate of mean sea level rise. However, dune systems of this size are fairly robust and beach-dune systems can cope with rates of sea level rise of several millimetres a year, as long as there is a continued supply of sediment (Pye, 2001).

For the purpose of this report, the coast has been split into four sections:

- Crosby and Blundellsands;
- Blundellsands to Altcar, including the River Alt;
- Sefton dunes (Altcar to Weld Road); and
- Southport.

Crosby and Southport are both artificially defended stretches of shoreline, which are influenced by the Mersey and Ribble estuaries, respectively. The stretch between Crosby and Altcar is very dependent upon the position of the Alt channel, which runs parallel to the shoreline at this point. Between Altcar and Southport is the main dune belt of the Sefton dune system. There are, however, strong sediment interactions along this coastline and policies in one area could have significant impacts on adjacent sections.

LOCAL SCALE: CROSBY AND BLUNDELLSANDS

Interactions:

The backshore is characterised by defences which lie in front of dunes, some of which have been significantly modified. The defences are fronted by a wide sandy foreshore, which widens to the north. At the southern end of the frontage there has been sand accumulation, which has buried the defences. Along the rest of the frontage the toe of the defences is fully exposed.

The foreshore is not covered on all tides, therefore there is potential for aeolian transport, which accumulates at the toe of the defence or is blown onto the promenade.

The net littoral sediment transport is to the south, but the protrusion of the Seaforth Terminal effectively forms a barrier to littoral drift (Shoreline Management Partnership, 1999a; HR Wallingford, 2002). The River Alt is also believed to affect the transport of sediment along the upper beach south to the beaches of Crosby and Blundellsands, however, sand transport is still able to take place along the lower foreshore (HR Wallingford, 2002).

The Mersey does not contribute any sediment to the beach system and is likely to be a sink for sands and finer sediments.

Movement:

Historically, the northern part of this shoreline was affected by the natural meandering of the Alt Channel. In the 1920s and 1930s there was significant erosion of the dunes and loss of properties at Blundellsands; this was a particularly stormy period, but the issues were exacerbated by the proximity of the river channel to the shoreline. A training wall was constructed in 1936 to direct the discharge away from the coastline, which solved the issue. There has been recovery of the beaches since construction of the training wall (HR Wallingford, 2002).

Currently the shoreline position has become partly fixed in place by defences, although sand drift along the southern end of the frontage and subsequent vegetation development has resulted in the defences becoming buried; the dunes and high beach levels now play a defence role along this southern stretch. Blown sand is a management issue in this area and attempts have been made to reduce sand blow through stabilisation the dunes. There has also been recycling of sand to the Blundellsands frontage.

Existing predictions of shoreline evolution:

Future behaviour of the shoreline will depend upon the condition of the River Alt training bank (HR Wallingford, 2002); if the present training bank is not maintained then the river could meander further south, as it has done historically, which will threaten defences along this stretch.

SMP1 (Shoreline Management Partnership, 1999a) stated that this shoreline is vulnerable to specific storm events, with erosion occurring at these time at particular points alongshore, in particular Hall Road West and North of the River Alt Training Bank. Therefore this shoreline will be vulnerable to recession if the Alt Training Bank is breached and the point of discharge is pushed further to the south. The best estimates are that the shoreline would relocate by between 50 and 100 m landward of its present position along the section south of the Crosby.

LOCAL SCALE: BLUNDELLSANDS (HALL ROAD) TO ALTCAR, INCLUDING THE RIVER ALT

Interactions:

The backshore for much of this stretch is characterised by dunes, which are fronted by a sandy intertidal zone that broadens to the north, as the Port of Liverpool navigation channel swings away from the coast. The foreshore features ridges and runnels, although these are generally less pronounced than those along the dune system to the north.

The River Alt discharges across the foreshore and the channel runs parallel to the shoreline for a couple of kilometres before turning seaward, due to a training bank. The channel effectively cuts off the upper beach and dunes from the lower foreshore. There are small areas of saltmarsh on the landward side of the channel. The soft shoreline from Hall Road to the River Alt has been reinforced by rubble and there is a short stretch of concrete defences at Blundellsands Sailing Club.

The Alt is a small estuary, which receives very limited freshwater input from the River Alt. The river is essentially self-scouring under the current flow regime enforced by the pumping station (HR Wallingford, 2002).

Inshore wave conditions along this shoreline are significantly affected by the shallow nearshore bathymetry. Waves from the west and west-north-west are refracted as they approach the shore. Added to this, surge conditions create deeper water over these shallows and thus large changes in the shoreline wave conditions occur during such events. Neal (1993) demonstrated that there was increased wave focusing on the Crosby shoreline during storm conditions. The Mersey navigation channel is believed to have little influence on contemporary shoreline behaviour (Coastal Engineering UK Ltd., 2005).

To the north of this coastline there is a littoral divide at Formby Point, which results in the southward transport of sand eroded from the beaches and dunes to this shoreline. The River Alt, however, provides an effective barrier to the upper beach littoral transport of this sediment, which has resulted in accretion of the dunes and foreshore to the north, along the Altcar Rifle Range frontage. The outfalls along the landward side of the Alt Channel are also partial barriers to local littoral drift along this frontage. There is also a possible local drift reversal in the vicinity of the Alt mouth (Coastal Engineering UK Ltd, 2005).

Sediment movement along this frontage is complex, with interactions with the offshore banks. There is a potential onshore movement of sand from the offshore, although much of this sediment is believed to remain in the nearshore, resulting in the growth of Taylor's Bank. Movement of sand from this bank either through wave or aeolian transport is hindered by the position of the River Alt, which effectively cuts off this stretch of shoreline. Inshore wave conditions are also affected by Taylor's Bank and the Crosby Channel.

The Mersey does not contribute any sediment to the beach system and has historically been a sink for sands and finer sediments, although it appears to have reached a stable stage.

Movement:

The evolution of this shoreline has been affected by changes in the Mersey Estuary and in particular the dredging and subsequent dumping of dredge spoil. Dredging within the Mersey began in 1890, with construction of the Mersey training walls commencing in 1909. These works contributed to shoaling in the Formby Channel, deepening of the Queen's Channel and growth of Taylor's Bank. Dumping of dredge spoil also led to the development of Jordan's Spit. There has been continued accretion in this nearshore area and of the dunes along the Altcar frontage to the north. This has effectively pushed the river channel further landwards at Hightown, which has increased the erosion risk here.

Between 1936 and the mid 1970s demolition waste, rubble and tin slag was placed along the shoreline as a defence. Coast protection works were undertaken in the 1970s to protect the developed land between Seaforth and Hall Road West. This structure is vulnerable to overtopping and suffered structural damage in the 1990 storm (Shoreline Management Partnership, 1999a).

The shoreline has also been affected by changes in the position of the Alt channel. The River Alt has been managed since the 13th century (Sefton Council, 2007e), but the earliest written detailed accounts of the management of the river Alt are from 1779 and in this year the Alt commissioners built new tidal gates 800 yards downstream of the existing gates to prevent flooding of the low lying areas and to control the flow of the river in the tidal reaches (Mersey and Weaver River Authority, 1971). Map evidence from the early 18th century suggests that in the past, the mouth of the River Alt was a kilometre further north than at present, but accretion to the north of the river deflected it southwards. This was associated with reclamation of the Balling Wharf area after 1797. Following this, during the early part of the 20th century, the river Alt changed its course: it originally discharged seaward from Altcar in a westward direction, it then moved to the south, resulting in coastal erosion and loss of properties along the Blundellsands frontage in the 1920s and 1930s (Smith, 1982). In response to the coastal erosion, a training bank was constructed in 1936 which directs the discharge away from the coastline (Sefton Council, 2000). This had to undergo repairs and reinforcement in 1949 and 1969. A pumping station at Altmouth was constructed in 1972, due to issues of siltation resulting in problems with the tidal gates opening and closing (Sefton Council, 2007e). This has had an impact on the tidal section of the river and the position of the river has changed over time, resulting in erosion of the coastline south of the Blundellsands Sailing Club.

The outfalls along this frontage help to fix the position of the channel (Coastal Engineering Consultancy Services, 2002) and in recent years the position of the channel has not noticeably changed (Coastal Engineering UK Ltd, 2005; Sefton Council, 2007e).

Hightown developed during the late 19th and early 20th centuries on former dune belt and is therefore on higher land. The immediate hinterland is, however, much lower and is drained by ditches that discharge to the sea via outfalls. Sections of the coast between Hall Road West and Altcar are eroding at an average rate of between 1 and 1.5 m/year (Sefton Council, 2000). Despite the defences constructed at the Blundellsands Sailing Club, the shoreline has continued to erode and the defences are at risk from becoming undermined, due to the landward movement of the river channel.

The small area of marsh at the mouth of the River Alt has reduced in size since the 1930s (Smith, 1999).

Existing predictions of shoreline evolution:

The Coastal Defence Issues and Strategy (Sefton Council, 2000) suggested that there is a risk that the sea could break through into the West Lancashire Golf Club by 2050, in the vicinity of Far Moss outfall.

Future behaviour of the shoreline will depend upon continued drift onto Formby Bank, the position of the River Alt and the condition of the River Alt training bank (Halcrow 2002; HR Wallingford, 2002). If coastal defences were not in place or failed the main areas at risk from flooding would be Formby and Hightown, and if fluvial defences were not in place, or failed, Great Altcar and Ince Blundell would be at risk from flooding (Sefton Council, 2007e).

Continued growth of Formby Bank could also result in the channel being pushed further inshore (Halcrow, 2002). Futurecoast (Halcrow, 2002) also suggested that in places the dunes form only a narrow barrier and should the dunes erode there would be a high risk of breach and therefore extensive flooding of the low-lying land behind. The River Alt would restrict new dune development because it inhibits the cross-shore transport of sediment therefore a breach could remain permanent.

LOCAL SCALE: SEFTON DUNES (ALTCAR TO WELD ROAD, SOUTHPORT)

Interactions:

This stretch of coast is dominated by the large dune system, which is one of the largest in the UK, that extends from Southport to Seaforth; for this report this section discusses the main belt of dunes between the River Alt and Weld Road, Southport.

The dune system protects a large area of low-lying hinterland from flooding and is widest and highest at Formby Point. The dunes are fronted by wide, sandy beaches, which feature well developed ridge and runnel formations. Typically the dune toe lies slightly above the level of mean high water spring tides (Pye and Blott, 2008).

Inshore wave conditions along this shoreline are significantly affected by the shallow nearshore bathymetry. Waves from the west and west-north-west are refracted as they approach the shore, with a focusing of waves onto Formby Point, resulting in an increase in breaker heights (Sly, 1966; Neal, 1993, Pye and Neal, 1994). Conversely there is a dispersion of waves and therefore reduced wave breaker heights between Birkdale and the Ribble Estuary. Added to this, surge conditions create deeper water over these shallows and thus large changes in the shoreline wave conditions occur during such events. The Mersey navigation channel is believed to have little influence on contemporary shoreline behaviour (Coastal Engineering UK Ltd., 2005).

There is strong evidence of a net landward movement of sand from the offshore, due to residual currents, which is supported by the trend of shoaling within Liverpool Bay. This is supported by the growth of Taylor's Spit and Formby Banks and the infilling of the relict Formby Channel. There is also no evidence of a general shortage of sand in the zone immediately offshore (Pye and Neal, 1994).

A littoral drift divide occurs in the vicinity of Victoria Road, Formby Point, with net movement of sand away from Formby Point to feed areas to both the north and south of the Point. SMP1 (Shoreline Management Partnership, 1999b) suggested that at Ainsdale the net volume of sediment entering the area was balanced by that leaving the frontage. Due to this drift divide, evolution of this coastline will not be significantly changed by changes in policy along the adjacent stretches of coast, it is however affected by changes in nearshore and offshore bathymetry, which is turn in affected by the estuary regimes of the Mersey and Ribble.

Movement:

Around Formby Point, there was a change from a net accretion phase to a net erosion phase around the turn of the 20^{th} century. Since then the beach and dunes have continued to erode, with erosion extending northwards towards Ainsdale. To the south of Formby Point and between Ainsdale and Southport there has been accretion (Pye and Blott, 2008). Several factors are believed to contribute to the pattern of erosion along the Sefton coast, including changes in the nearshore bathymetry (both natural and man-made) and changes in the wind-wave climate.

The current trends of shoreline change are accretion between the River Alt and Alexandra Road; erosion around Formby Point, between Alexandra Road and Ainsdale; and accretion between Ainsdale and Weld Road, Southport.

Around Formby Beach, where dunes are currently eroding, the beach is narrower and steeper, whereas to the north and south it is wider and flatter. Erosion of the dunes is primarily driven by storm events, as during normal tides the toe of the dunes is beyond wave action and the wide sandy foreshore dissipates wave energy. Pye and Blott (2008) suggest that changes in the frequency and magnitude of severe storms and tidal surges have had a detectable effect on the historical rates of frontal dune erosion and accretion. Parker (1971, 1975) concluded that the onset of erosion occurs when water levels exceed around 3.9m OD at Liverpool and the rate of dune erosion increases significantly when water levels at Liverpool exceed 5.2m OD. The most severe erosion occurs when elevated water levels, due to storm surges, coincide with strong wave action. When water levels exceed around 5.2m OD the impact of higher water levels against the toe of the dunes results in dune slumping, adding to the effects of wave impact and undercutting (Pye and Blott, 2008).

The amount of dune recession during these severe conditions is dependent upon the characteristics of the storm, but the most severe episode of erosion occurred in February 1990, when up to 14m recession was recorded (Pye, 1991). Under more 'typical' storm events, 1 to 2m dune erosion may occur. During most storms only sections of the dune system tend to be eroded; however, during the 1990 storm event all of the dune system was affected to some degree. Pye and Blott (2008) suggest that this is only likely to occur during the most severe storms (i.e., greater than 1 in 10 year events), with erosion during smaller storms tending to be focussed on parts of the frontage.

During severe storms the level of the upper beach is also planed down by wave and sand is drawn down the beach into the lower foreshore and nearshore zone (Pye and Neal, 1994). This allows the foot of the dunes to be reached more frequently. During quiescent periods, sediment can be moved back onshore and blown into the dune system, meaning that much of the dune system is able to recover. The main exception is around Formby Point, where the dominant long-term trend is one of erosion and the beaches are steeper, due to the drift divide material is moved away from this frontage. Records of beach levels indicate that there has also been a drop in beach levels around Formby Point., with increases in beach levels to the north and south, where dunes are accreting. Erosion along this central section (between Lifeboat Road and Ainsdale) averages between 1.2 and 3.7m/year (Pye and Blott, 2008).

Accretion is taking place to the south of Formby Point, although this coastline is still affected by storm events when substantial cut back of the dunes can occur. Despite, these events, there is a long term accretion trend, with dune advance averaging between 0.7 and 2.4m/year (Pye and Blott, 2008).

Accretion is also the long-term trend for the dunes and foreshore to the north of Ainsdale. Since the 1980s the average long term trend has been between -0.5 to 2.8m/year, with the rate of accretion increasing in a northward direction (Coastal Engineering UK Ltd, 2005; Pye and Blott, 2008). As to the south of Formby Point, erosion of the dunes does still occur during storm events, but dune recovery is more effective than along the Formby Point frontage.

Primarily along the eroding stretch of shoreline there is a number of blowouts and transgressive sand sheets. The blowouts are orientated in alignment to the prevailing wind direction. It is likely that these features have developed as a result of recreational pressure, with subsequent exploitation of bare sand areas by winds.

Along the Victoria Road frontage, erosion of the sand dunes has reached the tobacco waste. There is no evidence to suggest that the tobacco waste is anymore resistant to erosion than the natural sand dune, as it seems to be eroding at the same rate (Sefton Council, 2007b), although the failure mechanism differs from the adjacent dunes (Jay, 1998).

Existing predictions of shoreline evolution:

Pye and Neal (1993) concluded that there is little evidence to suggest that the erosional trend at Formby Point will reverse naturally in the near future. The authors also stated that, whilst an increase in the rate of sea level rise could lead to an acceleration in the rate of coastal retreat at Formby Point, these may be offset by more rapid progradation in the Ribble Estuary. SMP1 (Shoreline Management Partnership, 1999a, b) suggests that, although there is no data available to determine the extent to which erosion at Formby Point will continue, under a scenario of sea level rise erosion may carry on for some time. The SMP1 also identified that that recent data indicated that the rate of low water retreat has slowed down, suggesting that movement of the high water mark could also slow in the future.

For the area between Ainsdale and Southport, SMP1 (Shoreline Management Partnership, 1999b) predicted that accretion would continue whilst there is erosion of Formby Point.

Pye and Blott (2008) suggest that the present trend of accretion and erosion, which has caused the overall plan form of Formby Point to become flatter, is likely to continue, unless there are major changes in the offshore and nearshore bathymetry or wind/wave regime.

Based on historical data and assuming no major engineering works are undertaken, the Coastal Defence Issues and Strategy (Sefton Council, 2000) made the following predictions for 2050: the coastline between Lifeboat Road and Victoria Road is likely to erode by 150m, north of Victoria Road, the coastline is likely to erode by 270m, with little change likely where the erosion trend changes to accretion, both to the north and south. These changes would, not however, result in any flood risk.

HR Wallingford (2002) suggested that sea level rise and increased storminess could exacerbate the erosion of Formby Point, at least in the short term, and this would provide further accretion and reduced exposure along the shoreline to the south of the Point.

Futurecoast (Halcrow, 2002) proposed that, assuming no major changes in the estuaries, the coastline would continue to realign, with erosion of Formby Point and redistribution of the sand to the north and south, with further development of dune ridges. There could be some dune roll-back with accumulation of sand behind the dune crest and this would continue in the future but with a net loss of sediment from the dune face. Although still at a significant rate, historically the annual rate of erosion of Formby Point has slowed and therefore the system might be beginning to reach a point of dynamic equilibrium. The system would still be vulnerable to storm surges and any recovery along the central section would be restricted by the limited sediment input. Further growth in Taylor's Bank and Formby Banks would increase the protection afforded to Altcar frontage, but could, conversely increase wave focusing onto Formby Point, increasing instability. Growth of these banks is likely to slow as the Mersey adjusts to its modified hydrodynamic regime. In addition, there is no longer dumping of dredge spoil in this vicinity. Around Formby the net change over the next century was predicted to be ‘very high’ (100 to 200m), with ‘moderate’ (10 to 50m) accretion to the north and ‘high’ (50 to 100m) accretion to the south.

Sefton Council (2007c) have made further predictions of potential shoreline change, using Bruun Rule to take account of sea level rise. Their studies came up with erosion estimates for the coastline between Fisherman’s Path and Lifeboat Road, of: 49 to 88m by 2025, 109 to 278m by 2055 and 237 to 681m by 2105. An Ainsdale erosion of 13,70 and 347m was predicted for years 2105, 2025 and 2105 respectively. It is not possible to use Bruun to predict accretion rates, but the predictions by Sefton Council (2007c) suggest that, assuming accelerated sea level rise, there would be a reduction in the rate of accretion and for along the southern accreting stretch of shoreline, the report estimates a net advance of the shoreline of between 4 and 23m, 31 and 44m and 62 and 70m, by 2025, 2055 and 2105 respectively. For comparison, a simple linear projection of historical accretion rate produced an estimate of 107 to 109m by 2105.

LOCAL SCALE: SOUTHPORT

Interactions:

The coastline is heavily defended for much of its length. The southern stretch is characterised by a belt of sand dune, which is a continuation of the dune belt to the south, and wide sandy foreshore. At this southern end, the dunes are fronted by a ‘green beach’ formation. Further north the coastline protrudes landwards and the dunes disappear; here the seawall is fronted by a wide sandy foreshore, which becomes progressively more silty towards the north. North of the pier the foreshore has become colonised by saltmarsh vegetation. The hinterland behind the dunes and defences is low-lying and is therefore at risk from inundation.

The coastline is fronted by wide intertidal flats, which dissipate wave energy. Ridge and runnel features are evident along this coastline, but disappear past the pier. There is a potential feed of sediments from the offshore and from erosion of Formby Point. Long term estimates of sediment influx suggest there is an average of 1,000,000m^3/year sediment entering the system (Shoreline Management Partnership, 1999b).

There is also littoral sand transport northwards along this frontage, into the Ribble Estuary; historically, the Ribble has been a strong sink for sediments. To the north of the pier, finer sediments have settled high up the beach, encouraging saltmarsh growth.

Movement:

Southport lies on the outer limit of the Ribble Estuary. Historically there has been significant accretion along this shoreline, which has been progressively drained, reclaimed and defended since the 1800s. The shoreline position has therefore changed significantly and the coastline in the 16th century was more than a kilometre landward of the current coastline (Sefton Council, 2000). There have also been significant offshore changes due to the net infilling of this area, from both offshore and alongshore.

Over the last century, there has, however, been limited change in backshore position, as the shoreline position has become fixed by coastal defences. The first promenade and sea wall was built in 1835 to protect the developing seafront and as constructed in advance of the natural shoreline position. Southport is currently protected by two lines of defences: a second line of defence is provided by 19th century embankments, whilst the outermost defences to the north of Weld Road consists of a series of coastal revetments dating from the

1960s onwards. These include the most recent construction of Marine Drive seawall, completed in 2002, which protects the previously undefended central kilometre of shoreline between the Esplanade and Marine Parade. Previously Maine Drive was a beach causeway over which the highest tides could pass in order to fill the Marine Lake; it was therefore frequently closed to traffic.

Development of saltmarsh to the north of the pier has been significantly affected by changes within the Ribble Estuary, including dredging, which commenced during the late 1800s; the construction of training walls; and substantial land claim, both within the estuary and along the adjacent shorelines (Sefton Council, 2007d). There has been progressive accretion along the Marshside coast, which is evident from the infilling of Bog Hole Channel. There has been saltmarsh development at Marshside, just to the north of the pier, and between Birkdale and Ainsdale, known as 'Smiths Slack' (formerly known as the 'green beach'), which has been monitored since the early 1970s. The spread of pioneer vegetation was originally controlled through the use of herbicides, but this practice ceased at Weld Road in the 1990s, and a modified programme of control was introduced to the north of the pier. Herbicide treatment has now ceased. Sefton Council (2007d) reports that the saltmarsh extent is extending seawards and southwards towards Southport Pier. There has also been an increase in marsh height. There has been an associated seawards movement of the mean high water mark.

Surveys suggest that there has been general growth in the lateral extent of the Smith Slack saltmarsh, although there is uncertainty regarding different interpretations of the marsh edge location. (Coastal Engineering UK Ltd, 2007). Accretion of Smiths Slack may be attributed to car parking restrictions along the beach (Sefton Council, 2002).

Existing predictions of shoreline evolution:

There is unlikely to be further northward encroachment of the dunes from Weld Road, due to the increase in exposure along the artificially protected shoreline here (Coastal Engineering UK Ltd, 2005).

SMP1 (Shoreline Management Partnership, 1999b) suggest that under present conditions the accretion of the Ribble Estuary is likely to continue, although rates could reduce if Formby Point stopped eroding. Futurecoast (Halcrow, 2002) predicted a 'moderate' (10 to 50m) accretion over the next century.

4 Baseline Scenario Assessments

No Active Intervention Scenario Assessment Table: F - Sefton Coast (Seaforth to Crossens)

Location	Predicted Change for No Active Intervention		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
Crosby	All of the shoreline is currently defended by a stepped concrete revetment topped by a wave return wall. Landward of this is a promenade backed by a dwarf wall. Between the Boating Lake and Brighton le Sands this structure is partially buried by dunes. For much of its length the defence will remain during this period. The main areas of risk are between Serpentine and Hall Road West and in front of the Coastguard Station, where the defences could fail by early to mid period	Under this scenario, most defences along this stretch will fail during this period.	No defences.
	Historically, since training of the Alt channel, this beach has remained quite stable, with some build up of sand at the southern end. Along the southern stretch the defences are only affected during storm conditions, but towards the Serpentine wave exposure conditions increase. There is a risk that defences could start to fail, but the remains of defences would continue to have an impact of erosion rates. It is possible that failure of the Alt training wall could fail during this period and therefore there would be a risk of the channel meandering towards the shoreline, as has occurred	Failure of defences along Marine Lake would result in exposure of the thin strip of backing dunes. These would be vulnerable to breaching during storms and the Marine Lake could act as a sink for sediments, with subsequent realignment of the coastline. This would probably result in loss of the dunes currently built up in front of defences immediately to the north. This area will also be affected by the potential failure of defences at Royal Seaforth Dock, which currently acts a groyne to littoral transport. Failure of this structure would probably result in significant beach loss and increased exposure of	No defences would remain therefore the main defence would be the narrow strip of dunes and backing grass sward. This would be subject to erosion with the greatest recession likely to occur during storm events, when several metres could be at risk in a single event. Net erosion by year 100 could be between 80 and 120m. This area would be at increased risk should the Alt start to meander towards the shoreline as previously experienced.

Location	Predicted Change for No Active Intervention		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
	historically.	remaining defences. Defence failure is likely to commence along the northern stretch of this frontage, where defences are more exposed to wave action and overtopping. Once a breach occurs, failure could be fairly rapid along the rest of the stretch. Loss of defences along the remainder of the frontage would result in exposure of the narrow dune belt. Erosion of this narrow dune belt would result in net shoreline recession. Net erosion by year 50 is likely to be between 30 and 45m. This area would be at increased risk should the Alt start to meander towards the shoreline as previously experienced.	
Blundellsands to Altcar (including River Alt)	Rubble has been placed at the toe of the dunes along much of this frontage; this is gradually being broken down by waves and moved alongshore. There is also a low level training bank, which extends to low water; this is in poor condition and is not much higher than the adjoining shore. Outfalls extend across the beach, which are protected by concrete casings and have an effect on the channel position. The Far Moss outfall is protected with rubble, but is prone to undermining and is likely to fail during this period. The entrance to Blundellsands Sailing Club is protected by a vertical concrete wall, but this is currently being undermined and is likely to fail in the next 5 years. On the landward side of Altcar Firing Range	The placed rubble will continue to be broken down and moved alongshore, but will continue to offer some limited protection to the backshore. The outfall structures are expected to fail during this period. The river bank protection to the landward side of Altcar Firing Range may remain for much of this period. There will also be erosion of the natural dune defence.	There is a risk that the river bank protection to the landward side of Altcar Firing Range may fail. Otherwise this shoreline will be undefended. There will also be erosion of the natural dune defence.

Location	Predicted Change for No Active Intervention		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
	there is stone river bank protection and shell pile retaining wall, which is expected to remain in place during this period. The Altcar Pumping Station prevents tidal inundation of the Lower Alt: it is assumed this will remain.		
	There will be ongoing erosion of the rubble, but this is likely to continue to provide some protection to the backshore during this period. There will be erosion of the tipped infill material during storms. Erosion could be between 20 and 30m by year 20. Beach levels have generally remained stable and assuming no major changes in the offshore bathymetry, this is expected to continue. However, this will be sensitive to changes in the meandering of the Alt. This is not, however, possible to predict, but would have an influence on both beach levels and aeolian and littoral transport patterns.	Although the rubble will continue to provide some protection, there will be increased risks of overtopping and exposure of the backing dunes and fill will increase as a result of sea level rise. Erosion could occur more frequently due to higher sea levels, but will depend on changes in the size of Formby Bank and the level of protection this will therefore afford. Therefore it is assumed that similar rates to those experienced historically will occur, with between 50 and 75m of erosion possible by year 50. There will be a high level of risk associated with movement of the Altcar channel, which could significantly accelerate erosion rates along this shoreline and the shoreline to the south. It is not, however, possible to predict future channel positions.	There will be continued recession of this shoreline. Actual rates will depend upon both frequency of storms and changes in the height of Formby Bank. Based on historical data, erosion could be between 100 and 150m by year 100. Failure of the Alt banks will result in erosion of the landward side of the Altcar dunes, but the width of these dunes should be sustained by growth on the landward side. There will be a high level of risk associated with movement of the Altcar channel, which could significantly accelerate erosion rates along this shoreline and the shoreline to the south. It is not, however, possible to predict future channel positions.
Sefton Dunes	There are no coastal defences along this frontage and only low level dune management is currently being carried out, mainly dealing with controlling visitor pressures. There is a secondary earth embankment at Cabin Hill, 500m inland, which is expected to remain.	No primary defences.	No primary defences.
	The current pattern of erosion and accretion along the dune coast is dependent upon a	The current trends are expected to continue, with erosion of Formby Point and accretion of	For this scenario, it is assumed that there are no major changes in either the offshore bathymetry or

Location	Predicted Change for No Active Intervention		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
	number of factors, but most significantly the nearshore and offshore bathymetry and the frequency of storms coinciding with high wave activity. There is no evidence to suggest that there will be significant changes in the offshore or nearshore bathymetry in the future, and similarly there is no conclusive evidence to suggest a significant change in the wind/wave regime. Therefore it is expected that during this period, the current trends of accretion and erosion will continue. Erosion of Formby Point will continue to release sediments to the coast, so there should be no shortage of sediment input to the system and this will be redistributed to the north and south. Sea level rise is not expected to result in significant change, therefore the current trends will continue as historically. There will therefore be around 40 to 70m erosion at Formby Point, but continued accretion of the areas to the north and south, which could be in the range of 5 to 75m to the north and 15 to 50m to the south. There is a possibility of the accretion zone moving further northwards, but this may be affected by recreational pressure along the Ainsdale frontage, which will also affect the extension of Smiths Slack saltmarsh.	the coast to north and south. During this period the effects of sea level rise may start to be felt. It is possible that sea level rise could accelerate the erosional trend at Formby Point due to higher water levels occurring during storm events, which results in dune slumping and therefore more extensive dune failure. During normal conditions, waves will cover the beach for longer periods, which could reduce the window when aeolian transport can take place. This is only expected to have a significant impact along the Formby Point stretch because beaches here are already narrow. However, the primary driver the dune erosion will be the frequency of storm events and the coincidence of surges with high wave activity. Actual erosion and accretion rates along the frontage will be dependent upon the future frequency and strength of storm events, which is when the majority of the dune erosion will take place. There is, however, currently large uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. Erosion of the dunes at Formby Point will release sediment to the beaches and dunes to the north and south, therefore the dune system as a whole is likely to remain relatively robust, with the main change being a change in orientation of the coastline as it becomes progressively flatter in form.	wind-wave climate; changes in either of these factors would have significant implications for the whole system, with a possible reversal of trends. It is therefore expected that there would be a continuation of the current trends, with continued erosion around Formby Point and associated accretion and dune progradation to the north and south. Dune erosion, even under accelerated sea level rise, would continue to predominately take place during storm events, when storm surges coincide with high winds and therefore significant wave activity. As a result of sea level rise, erosion during these events could be more severe, as critical water depths that result in dune slumping, could be achieved more frequently. This could result in a greater net erosion of the dunes. Around Formby Point the negative beach dune sediment budget could also be exacerbated by higher water levels, as the beach will be covered for longer periods, reducing the window of aeolian transport into the dunes, and potentially increasing the littoral drift of sediment to the north and south. Future changes to Taylor's Bank will also be a factor in evolution of this shoreline, as this currently is believed to focus waves onto Formby Point during storms. Erosion of the Formby shoreline will continue to feed areas to both the north and south and this supply of sediment and the resulting positive beach-dune budget along these areas, is expected

Location	Predicted Change for No Active Intervention		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
		There is likely to be increased blowout development and dune instability along the central eroding section, resulting in increased wind blow and further development of sand sheets in the back dune areas. Predictions of net change by year 50 are based upon an extrapolation of historical rates, with dune progradation along the southern stretch expected to fall within the band: 35 to 120m, dune erosion along the central section between 60 and 185m, and dune progradation to the north ranging from between 20 and 140m.	to counter the impacts of sea level rise, therefore accretion is expected to continue at rates similar to present. This accretion may also be supplemented from sand transport from the offshore. Erosion of these dunes will still take place during storm periods, but higher beach levels along this stretch will help dissipate waves and the supply of sediment from the Formby frontage is expected to enable dune recovery and subsequent dune growth. Actual erosion and accretion rates along the frontage will be dependent upon the future frequency and strength of storm events, which is when the majority of the dune erosion will take place. Predictions of net change by year 100 are based upon an extrapolation of historical rates, with dune progradation along the southern stretch expected to fall within the band: 70 to 240m, dune erosion along the central section between 120 and 370m and dune progradation to the north ranging from between 40 and 280m. It should be noted, however, that along the central section there will be increased blowout and sand sheet activity; therefore here the risk area in any one location may exceed the above estimates, by several tens of metres.
Southport	There is a sloping concrete revetment, topped by a recurved wave return wall along much of its length, which stretches from Weld Road to	The defences are likely to remain for much of this period, but without maintenance could start to deteriorate due to age and occasional storm	No defences (although those buried by dunes to the south may remain).

Location	Predicted Change for No Active Intervention		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
	Marshside Marsh, to the north of Southport Pier. This is expected to remain during this period.	damage, with greater risk along the northern more exposed stretches.	
	During this period there is expected to be a continuation of current trends. The shoreline position will remain fixed by defences, but there is likely to be a continued increase in beach levels, due to both littoral transport of sand eroded from Formby Point and onshore movement of sediment. As the beach levels and intertidal width increase, conditions are becoming more favourable for deposition of finer material. Therefore there is likely to be continued development of saltmarsh, both in terms of extent and vertical growth.	Despite continued increases in beach level and the associated protection that this affords to the defences, the defences will still be exposed to wave action during storm conditions. This exposure, together with general structural deterioration may result in the older stretches of defences starting to fail towards the middle to end of this period. This would result in inundation of low-lying areas, during storm periods only. Secondary flood embankments will prevent further inundation of residential areas.	The impacts of rising sea levels is expected to be offset partially by the continued increase in beach levels anticipated, due to feed to sediment from erosion of Formby Point and from the offshore and nearshore. Therefore, consequences of any defence failure will be mainly confined to storm periods, when waves can reach the back of the beach. Flood risk, in terms of extent and frequency, may increase due to high water levels. Secondary flood embankments should continue to prevent further inundation of residential areas. Failure of the training wall within the Ribble could have significant implications for this area as this could allow the channel to shift in position. There could also be associated changes in the flood-ebb tidal regime. Similarly this coast will also be affected by changes in management within the estuary – however, there are significant uncertainty regarding how the coast will respond, particularly under a scenario of sea level rise.

With Present Management Scenario Assessment Table: F - Sefton Coast (Seaforth to Crossens)

Location	Predicted Change for With Present Management		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
Crosby	All of the shoreline is currently defended by a stepped concrete revetment topped by a wave return wall. Landward of this is a promenade backed by a dwarf wall. Between the Boating Lake and Brighton le Sands this structure is partially buried by dunes. Maintenance works will be required during this period.	Maintenance and improvements will be required.	Maintenance and improvements will be required.
	The shoreline position will remain fixed by the shoreline defences. Training of the River Alt Channel will reduce the erosion risk. The beach is expected to remain relatively stable during this period.	The shoreline position will remain fixed by the shoreline defences. Training of the River Alt Channel will reduce the erosion risk. There could be some feed from the north, which should help maintain beach levels, but despite this, the level of risk from overtopping is likely to increase due to sea level rise.	The shoreline position will remain fixed by the shoreline defences. Training of the River Alt Channel will reduce the erosion risk. There could be some feed from the north, which should help maintain beach levels, but despite this, the level of risk from overtopping is likely to increase due to sea level rise.
Blundellsands to Altcar (including River Alt)	Rubble has been placed at the toe of the dunes along much of this frontage; this is gradually being broken down by waves and moved alongshore. There is also a low level training bank, which extends to low water; this is in poor condition and is not much higher than the adjoining shore; this would require maintenance early during this period. Outfalls extend across the beach, draining the low lying hinterland behind the dunes, and are protected by concrete casings and have an effect on the channel position. The Far Moss outfall is protected with rubble, but is prone to	The placed rubble will continue to be broken down and moved alongshore, but will continue to offer some protection to the backshore. It is not assumed that this will be upgraded. It is assumed that the River Alt channel will remain trained. The outfall structures will require maintenance and improvement. The river bank protection to the landward side of Altcar Firing Range may also require maintenance works.	Further maintenance works may be required.

Location	Predicted Change for With Present Management		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
	undermining and would therefore require further protection. The entrance to Blundellsands Sailing Club is protected by a vertical concrete wall, but this is currently being undermined and requires immediate attention. On the landward side of Altcar Firing Range there is stone river bank protection and shell pile retaining wall, which is expected to remain in place during this period. The Altcar Pumping Station prevents tidal inundation of the Lower Alt.		
	There will be ongoing erosion of the rubble, but this is likely to continue to provide some protection to the backshore during this period. There will be erosion of the tipped infill material during storms. Erosion could be between 20 and 30m by year 20. Beach levels have generally remained stable and assuming no major changes in the offshore bathymetry, this is expected to continue.	Although the rubble will continue to provide some protection, there will be increased risks of overtopping and exposure of the backing dunes and fill will increase as a result of sea level rise. Erosion could occur more frequently due to higher sea levels, but will depend on changes in the size of Formby Bank and the level of protection this will therefore afford. Therefore it is assumed that similar rates to those experienced historically will occur, with between 50 and 75m of erosion possible by year 50. Some risk will be reduced through continued work to control the position of the Alt channel.	There will be continued recession of this shoreline. Actual rates will depend upon both frequency of storms and changes in the height of Formby Bank. Based on historical data, erosion could be between 100 and 150m by year 100. Some risk will be reduced through continued work to control the position of the Alt channel.
Sefton Dunes	There are no coastal defences along this frontage and only low level dune management is currently being carried out, mainly dealing with controlling visitor pressures. There is a secondary earth	No primary defences.	No primary defences.

Location	Predicted Change for With Present Management		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
	embankment at Cabin Hill, 500m inland.		
	The current pattern of erosion and accretion along the dune coast is dependent upon a number of factors, but most significantly the nearshore and offshore bathymetry and the frequency of storms coinciding with high wave activity. There is no evidence to suggest that there will be significant changes in the offshore or nearshore bathymetry in the future, and similarly there is no conclusive evidence to suggest a significant change in the wind/wave regime. Therefore it is expected that during this period, the current trends of accretion and erosion will continue. Erosion of Formby Point will continue to release sediments to the coast, so there should be no shortage of sediment input to the system and this will be redistributed to the north and south. Sea level rise is not expected to result in significant change, therefore the current trends will continue as historically. There will therefore be around 40 to 70m erosion at Formby Point, but continued accretion of the areas to the north and south, which could be in the range of 5 to 75m to the north and 15 to 50m to the south. There is a possibility of the accretion zone moving further northwards, but this may be affected by recreational pressure along the Ainsdale frontage, which will also affect the	The current trends are expected to continue, with erosion of Formby Point and accretion of the coast to north and south. During this period the effects of sea level rise may start to be felt. It is possible that sea level rise could accelerate the erosional trend at Formby Point due to higher water levels occurring during storm events, which results in dune slumping and therefore more extensive dune failure. During normal conditions, waves will cover the beach for longer periods, which could reduce the window when aeolian transport can take place. This is only expected to have a significant impact along the Formby Point stretch because beaches here are already narrow. However, the primary driver the dune erosion will be the frequency of storm events and the coincidence of surges with high wave activity. There is currently large uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. Erosion of the dunes at Formby Point will release sediment to the beaches and dunes to the north and south, therefore the dune system as a whole is likely to remain relatively robust, with the main change being a change in orientation of the coastline as it becomes progressively flatter in form. There is likely to be increased blowout	For this scenario, it is assumed that there are no major changes in either the offshore bathymetry or wind-wave climate; changes in either of these factors would have significant implications for the whole system, with a possible reversal of trends. It is therefore expected that there would be a continuation of the current trends, with continued erosion around Formby Point and associated accretion and dune progradation to the north and south. Dune erosion, even under accelerated sea level rise, would continue to predominately take place during storm events, when storm surges coincide with high winds and therefore significant wave activity. As a result of sea level rise, erosion during these events could be more severe, as critical water depths that result in dune slumping, could be achieved more frequently. This could result in a greater net erosion of the dunes. Around Formby Point the negative beach dune sediment budget could also be exacerbated by higher water levels, as the beach will be covered for longer periods, reducing the window of aeolian transport into the dunes, and potentially increasing the littoral drift of sediment to the north and south. Future changes to Taylor's Bank will also be a factor in evolution of this shoreline, as this currently is believed to focus waves onto Formby

Location	Predicted Change for With Present Management		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
	extension of Smiths Slack saltmarsh.	development and dune instability along the central eroding section, resulting in increased wind blow and further development of sand sheets in the back dune areas. Risks may be controlled through dune management techniques to reduce wind blow and encourage sand trapping in these areas. Predictions of net change by year 50 are based upon an extrapolation of historical rates, with dune progradation along the southern stretch expected to fall within the band: 35 to 120m, dune erosion along the central section between 60 and 185m, and dune progradation to the north ranging from between 20 and 140m.	Point during storms. Erosion of the Formby shoreline will continue to feed areas to both the north and south and this supply of sediment and the resulting positive beach-dune budget along these areas, is expected to counter the impacts of sea level rise, therefore accretion is expected to continue at rates similar to present. This accretion may also be supplemented from sand transport from the offshore. Erosion of these dunes will still take place during storm periods, but higher beach levels along this stretch will help dissipate waves and the supply of sediment from the Formby frontage is expected to enable dune recovery and subsequent dune growth. Actual erosion and accretion rates along the frontage will be dependent upon the future frequency and strength of storm events, which is when the majority of the dune erosion will take place. Predictions of net change by year 50 are based upon an extrapolation of historical rates, with dune progradation along the southern stretch expected to fall within the band: 70 to 240m, dune erosion along the central section between 120 and 370m and dune progradation to the north ranging from between 40 and 280m. It should be noted, however, that along the central section there will be increased blowout and sand sheet activity. Risks may be controlled through

Location	Predicted Change for With Present Management		
	Years 0 – 20	Years 20 – 50	Years 50 – 100
			dune management techniques to reduce wind blow and encourage sand trapping in these areas.
Southport	There is a sloping concrete revetment, topped by a recurved wave return wall along much of its length, which stretches from Weld Road to Marshside Marsh, to the north of Southport Pier.	Maintenance and improvement works may be required (needs may differ along the length of defences) to prevent overtopping.	Maintenance and improvement works may be required to prevent overtopping.
	During this period there is expected to be a continuation of current trends. The shoreline position will remain fixed by defences, but there is likely to be a continued increase in beach levels, due to both littoral transport of sand eroded from Formby Point and onshore movement of sediment. This is likely to be continued development of saltmarsh, both in terms of extent and vertical growth.	The shoreline position will remain fixed by the sea defences; these are likely to require maintenance during this period. Assuming a scenario of continued management within the Ribble as well, the system is expected to remain relatively stable, with the beaches fronting Southport's seawall remaining stable or continuing to accrete.	The shoreline position will remain fixed by the sea defences; these are likely to require maintenance during this period. Assuming a scenario of continued management within the Ribble as well, the system is expected to remain relatively stable, with the beaches fronting Southport's seawall remaining stable or continuing to accrete.

5 Supporting Information

No Active Intervention Data interpretation: F - Sefton Coast (Seaforth to Crossens)

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Crosby	No data is available on historical change, although at Blundellsands there were several metres of erosion due to movement of the Alt Channel in the 1920/30s. Assumed that rates would be similar to those experienced along Crosby to Altcar frontage.	Assumed defences would remain for much of period and even where they fail, would continue to afford some protection.	Used Crosby to Altcar rates. However, a key control will be any changes in the Alt channel position.	Used Crosby to Altcar rates, although this rate could increase due to sea level rise. However, a key control will be any changes in the Alt channel position.	This stretch is significantly affected by the Mersey and the associated offshore bathymetry and therefore future changes in the estuarine regime in response to either natural or man-made changes. Changes in the position of the Alt channel could also cause significant erosion.
Blundellsands to Altcar (including River Alt)	Average erosion rates of 1 to 1.5m Sefton Council, 2000)	Continuation of historical rates assumed, although changes in the position of the Alt channel could have a significant impact.	Key control will be any changes in the Alt channel position. Historical rates used to project future change.	Key control will be any changes in the Alt channel position. Historical rates used to project future change.	This stretch is significantly affected by the Mersey and the associated offshore bathymetry and therefore future changes in the estuarine regime in response to either natural or man-made changes. Changes in the position of the Alt channel could also cause significant erosion.
Sefton Dunes	Average erosion/accretion rates determined from long-term dune measurements, quoted in Sefton Council (2007c); Pye and Blott (2008)	Historical data shows quite consistent trends, therefore linear extrapolation assumed to be appropriate.	Bruun Rule considered inappropriate for this stretch, due to the complexity of the system and littoral relationships	Bruun Rule considered inappropriate for this stretch, due to the complexity of the system and littoral relationships	This coast is significantly affected by changes in offshore bathymetry and storm strength, direction and frequency. All these factors have significant uncertainties.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	and Coastal Engineering UK Ltd (2005: +0.7 and +2.4m/year south of Formby Point: Albert Road and Range Lane. -1.2 and -3.7m/year around Formby Point (Alexandra Road to Fisherman's Path +0.4 to +2.8m/year north of Formby Point (Ainsdale Nature Reserve to South of Shore Road)		between adjacent stretches. Key control will be storm frequency, but there is insufficient evidence to suggest that this will change in the future, therefore best estimate is linear extrapolation of historical trends.	between adjacent stretches. Key control will be storm frequency, but there is insufficient evidence to suggest that this will change in the future, therefore best estimate is linear extrapolation of historical trends.	There is a slight possibility that, due to future changes within the Mersey and Ribble estuaries and their associated banks and any changes in the climatic regime, there could be a reverse in trends.
Southport	Evidence of growth of beach and sandflats over the last 150 years. Growth of saltmarsh suggests influx of silts which can settle due to protection afforded by offshore area.	Shoreline position will be held. Beach accretion will continue due to supply of sediment.	Shoreline position will be held. It is assumed there will be an adequate supply of sediment from offshore and alongshore sources to maintain the trend of accretion.	Shoreline position will be held. It is assumed there will be an adequate supply of sediment from offshore and alongshore sources to maintain the trend of accretion.	This stretch is significantly affected by the Ribble and therefore future changes in the estuarine regime in response to either natural or man-made changes.

With Present Management Data interpretation: F - Sefton Coast (Seaforth to Crossens)

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Crosby	No data is available on historical change.	Shoreline position will be held.	Shoreline position will be held.	Shoreline position will be held.	This stretch is significantly affected by the Mersey and the associated offshore bathymetry and therefore future changes in the estuarine regime in response to either natural or man-made changes.
Blundellsands to Altcar (including River Alt)	Average erosion rates of 1 to 1.5m Sefton Council, 2000)	Continuation of historical rates assumed, although changes in the position of the Alt channel could have a significant impact.	Key control will be any changes in the Alt channel position. Historical rates used to project future change.	Key control will be any changes in the Alt channel position. Historical rates used to project future change.	This stretch is significantly affected by the Mersey and the associated offshore bathymetry and therefore future changes in the estuarine regime in response to either natural or man-made changes.
Sefton Dunes	Average erosion/accretion rates determined from long-term dune measurements, quoted in Sefton Council (2007c); Pye and Blott (2008) and Coastal Engineering UK Ltd (2005: +0.7 and +2.4m/year south of Formby Point: Albert Road and Range Lane. -1.2 and -3.7m/year around Formby Point (Alexandra Road to Fisherman's Path +0.4 to +2.8m/year north of Formby Point (Ainsdale	Historical data shows quite consistent trends, therefore linear extrapolation assumed to be appropriate.	Bruun Rule considered inappropriate for this stretch, due to the complexity of the system and littoral relationships between adjacent stretches. Key control will be storm frequency, but there is insufficient evidence to suggest that this will change in the future, therefore best estimate is linear extrapolation of historical trends.	Bruun Rule considered inappropriate for this stretch, due to the complexity of the system and littoral relationships between adjacent stretches. Key control will be storm frequency, but there is insufficient evidence to suggest that this will change in the future, therefore best estimate is linear extrapolation of historical trends.	This coast is significantly affected by changes in offshore bathymetry and storm strength, direction and frequency. All these factors have significant uncertainties. There is a slight possibility that, due to future changes within the Mersey and Ribble estuaries and their associated banks and any changes in the climatic regime, there could be a reverse in trends.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	Nature Reserve to South of Shore Road)				
Southport	Evidence of growth of beach and sandflats over the last 150 years. Growth of saltmarsh suggests influx of silts which can settle due to protection afforded by offshore area. Defences only in use during storm conditions, therefore failure will be mainly due to age (Coastal Engineering Consultancy Services, 2003)	Shoreline position will be held.	Shoreline position will be held.	Shoreline position will be held.	This stretch is significantly affected by the Ribble and therefore future changes in the estuarine regime in response to either natural or man-made changes.

References: F - Sefton Coast (Seaforth to Crossens)

Blott S J, Pye K, van der Wal D and Neal A (2006). **Long-term morphological change and its causes in the Mersey Estuary, NW England**. Geomorphology, Vol. 81, p185-206.

Coastal Engineering UK Ltd (2005). **Local Monitoring Report 2003/4: Coastal process review 1999-2003**. Report produced for Sefton Council April 2005.

Coastal Engineering UK Ltd (2007). **Local Monitoring Report 2005/6: Coastal process review 2005**. Report produced for Sefton Council January 2007, revised April 2007.

Coastal Engineering Consultancy Services (2003) **Coastal Defence Baseline Inspection Report 2001/2**.

Coastal Engineering Consultancy Services (2002) **Crosby Marine Lake to Formby Point Strategy Study: Shoreline Survey and Inspection,** November 2001. Report produced for HR Wallingford.

Crosby A G (2007). **The impact of sand extraction at Formby Point**, Merseyside: Historical report on research in local authority records and other archival sources prepared for Sefton Council as part of the project 'The impact of sand extraction at Formby Point, Merseyside', supported through Defra's Aggregates Levy Sustainability Fund: Application TAL0183. November 2007.

Halcrow (2002). **Futurecoast**. CD produced as part of the Futurecoast project for Defra.

Heaps N S and Jones J E (1978). **Recent storm surges in the Irish Sea.** In Marine forecasting: Proceedings of the 10th International Liege Colloquium on Ocean Hydrodynamics.

HR Wallingford (2001). **Dredging in Area 457 in Liverpool Bay; Coastal Impact Study, Stage 1**. Report EX 4389.

HR Wallingford (2002). **Crosby Marine Lake to Formby Point Coastal Defence Strategy Study**. Part 1: Preliminary Studies. Report EX 4496. Report prepared for Sefton Council.

Jay H (1998). **Beach-dune sediment exchange and morphodynamic responses: implications for shoreline management, the Sefton Coast, NW England**. Unpublished PhD, October 1998. pp 339.

Mersey and Weaver River Authority (1971). **River Alt Pumping Station Mersey and Weaver River Authority**.

Neal A (1993). **Sedimentology and morphodynamics of a Holocene coastal dune barrier complex, Northwest England.** Unpublished PhD Thesis, University of Reading.

Pye K (1990). **Physical and human influences on coastal dune development between the Ribble and Mersey estuaries, northwest England.** Coastal Dunes: Form and process. Edited by K F Nordstrom, N P Psuty and R W G Cater. John Wiley and Sons Ltd. p 339 - 359.

Pye K and Blott S J (2008). **Decadal-scale variation in dune erosion and accretion rates: An investigation of the significance of changing storm tide frequency and magnitude on the Sefton coast, UK**. Geomorphology.

Pye K and Neal A (1993a). **Statigraphy and age structure of the Sefton dune complex: preliminary results of field drilling investigations.** In: D Atkinson and J A Houston (eds) The Sand Dunes of the Sefton Coast. National Museums of Merseyside, Liverpool. p41-44.

Pye K and Neal A (1993b). **The Sefton Coast and Ribble Estuary. Holocene evolution, modern sedimentary environments and coastal zone management.** Prepared for a British Sedimentological Research Group field excursion. Published by Cambridge Environmental Research Consultants Ltd.

Pye K and Neal A (1994). **Coastal dune erosion at Formby Point, north Merseyside, England: causes and mechanisms**. Marine Geology 119, 39-56.

Pye K (2001). **Long-term geomorphological changes and how they may affect the dune coasts of Europe**. In: Houston J A, Edmondson S E and Rooney P J (Eds.). Coastal Dune Management - Shared Experience of European Conservation Practice. Liverpool University Press, Liverpool, pp. 17-23

Pye and van der Wal (2001). **Historical Trend Analysis (HTA) as a tool for long-term morphological prediction in estuaries.** Presented as Annex 2 of the Sandwinning at Horse Bank, Southport Public Enquiry. July 2001.

Sefton Council (2000). **Coastal Defence Issues and Strategy**. Sefton Council.

Sefton Council (2002). **Saltmarsh Report**, Sefton. June 2002.

Sefton Council (2007a). **Report on the evolution of the Bog Hole Channel located on the intertidal foreshore at Southport.** Report prepared by M Newton, G Lymbery and P Wisse.

Sefton Council (2007b). **Coastal defence: Nicotine Waste Tipping on the Sefton Coast Sand Dunes**. May 2007. Report prepared by L Gilmore, M Newton, G Lymbery and P Wisse.

Sefton Council (2007c). **Coastal defence: Report on Coastal Erosion predictions for Formby Point, Formby, Merseyside.** Parts 1 and 2. July 2007. Report prepared by G Lymbery, P Wisse and M Newton.

Sefton Council (2007d). **Coastal defence: report on the evolution of salt marsh on the Sefton coast**. August 2007. Report prepared by M Newton, G Lymbery and P Wisse.

Sefton Council (2007e). **Coastal defence: Report on the Changing Morphology of the Lower Alt, from Altmouth Pumping Station to the Sea**. October 2007. Report prepared by M Newton, G Lymbery and P Wisse.

Sefton Council (2007f). **Coastal defence: Report on Hard Sea Defences on the Sefton Coast**. October 2007. Report prepared by M Newton, G Lymbery and P Wisse.

Shoreline Management Partnership (1999a) **Sub-cell 11a: Great Ormes Head to Formby Point. Context Report**. December 1999.

Shoreline Management Partnership (1999b) **Sub-cell 11b: Formby Point to River Wyre. Context Report**. June 1999.

Smith T (2002) **History of Tidal Flooding in Sefton**. Article published on http://www.seftoncoast.org.uk/articles/02winter_tidalflooding.html Winter 2002. [Accessed from website: Aug 2008].

Smith, A J (1982) **A Guide to the Sefton Coast Database**. Sefton MBC

Van der Wal D and Pye K (2000). **The use of bathymetric surveys in determining long-term morphological changes in estuaries.** Internal Research Report CS2. Presented as Annex 4 of the Sandwinning at Horse Bank, Southport Public Enquiry. July 2001.

Van der Wal, D., Pye, K. and Neal, A. (2002) **Long-term morphological change in the Ribble Estuary, northwest England.** Marine Geology 189, 249-266.