North West Estuaries Processes Reports

Dee Estuary

Prepared for
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North West Estuaries Processes Report

Dee Estuary

Sefton Council

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Contents

Glossary

Term	Definition
Accretion	Accumulation of sediment due to the natural action of waves, currents and wind.
Advance the Line (ATL)	Advance the Line. A Shoreline Management Plan policy to build new defences on the seaward side of the existing defence line to reclaim land.
AIMS	Asset Information Management System. National database being developed by Environment Agency to replace NFCDD.
Bathymetry	The seabed elevation and depth of water in relation to it.
Coastal Change	Physical change to the shoreline, i.e. erosion, coastal landslip, permanent inundation and coastal accretion.
CD	Chart Datum.
Clay	Sediment particles smaller than 0.002 mm.
Cell Eleven Regional Monitoring Strategy (CERMS)	Regional Monitoring Strategy for the area known as Cell 11, which extends from Llandudno to Solway Firth.
Cell Eleven Tide and Sediment Study (CETaSS)	Regional sediment transport study for coastal Cell 11, undertaken in two main stages to support the development and implementation of the second round shoreline management plan (SMP2). The study included modelling of tides, waves and sediment transport alongside desk based studies with a focus on issues and uncertainties identified in the SMP1s and the initial scoping phase.
Coastal Erosion	A natural process that occurs as a result of waves, tides or currents – in other words, the sea – striking the shore. Sediment or rocks are washed away (but can be a sediment source for elsewhere), and our coastline changes shape as a result. This may include cliff instability, where coastal processes result in landslides or rock falls.
Coastal Landsliding/Instability	Process that involves slope failure and mass movement of a coastal slope or cliff and may result in deposition of debris on the beach and foreshore. Some landslides are very large and extend a considerable distance inland, offshore and deep below beach level and care must be taken to ensure their true extent is recognised. Cliff instability and erosion is a four stage process involving detachment of particles or blocks of material, transport of this material through the cliff system, its deposition on the foreshore and its removal by wave and tidal action.
Coastal Narrowing (including Coastal Squeeze)	The process whereby rising sea levels and other factors such as increased storminess push the coastal habitats landwards. At the same time in areas where land claim or coastal defence has created a static, artificial margin between land and sea or where the land rises relative to the coastal plain, habitats become squeezed into a narrowing zone. Manifestation of this process is most obvious along the seaward margins of coastal habitats, especially salt marshes, when erosion takes place.
Coastal processes	A collective term covering the action of natural forces on the shoreline and nearshore seabed. Includes such processes as wave action tidal flows and sediment transport.
D_{50}	Median particle/ grain size in sediments; the 50^{th} percentile size of a distribution.
EA	Environment Agency.

Term	Definition
Ebb dominant	Stronger current on ebb tide than flood tide. Coarser sediments may be moved more by ebb direction currents than flood. The balance of net sediment transport depends on the relative strength and duration of ebb and flood currents.
Ebb-tide	The falling tide. Part of the tidal cycle between high water and the next low water.
Estuary	A semi-enclosed coastal body of water which has a free connection to the open sea and where freshwater mixes with saltwater.
Fetch	Distance over which a wind acts to produce waves - also termed fetch length.
Flood and Coastal Erosion Risk Management (FCERM)	Flood and coastal erosion risk management addresses the scientific and engineering issues of rainfall, runoff, rivers and flood inundation, and coastal erosion, as well as the human and socio-economic issues of planning, development and management.
Flood Defence Grant in Aid (FDGiA)	The mechanism by which most of the funding for flood and coastal defence works in England is provided by the Government. The grants are used to cover our operating costs and to fund capital projects.
Flood dominant	Stronger current on flood tide than ebb tide. Coarser sediments may be moved more by flood direction currents than ebb. The balance of net sediment transport depends on the relative strength and duration of ebb and flood currents.
Fluvial	Belonging to rivers streams or ponds. e.g. Fluvial flooding, fluvial plants.
Geomorphology/ Morphology	The form of the earth’s surface including the distribution of the land and water and the processes responsible for their movement.
Hard structure of rock outcrop (Hard point)	Man-made feature or natural rock outcrop which acts to locally limit the natural movement of the shoreline e.g. sea wall, rock groyne.
HAT	Highest Astronomical Tide. See Tide Levels.
Headland	Hard feature (natural or artificial) forming local limit of longshore extent of a beach.
Hinterland	The area landward of flood or coastal defences.
Hold the Line (HTL)	Hold the Line. A Shoreline Management Plan policy to maintain or change the level of protection provided by defences in their present location.
Holocene	An epoch of the Quaternary period, spanning the time from the end of the Pleistocene (10,000 years ago) to the present.
Hydrographic Survey	A field survey carried out to map the sea bed features which affect maritime navigation, marine construction, dredging, offshore oil exploration/drilling and related disciplines.
Infrastructure	The basic facilities and equipment for the functioning of the country or area, such as roads, rail lines, pipelines and power lines.
Intertidal zone	The zone between the high and low water marks.
LAT	Lowest Astronomical Tide. See Tide Levels.

Term	Definition
LiDAR	Light Detection and Ranging – a method of measuring land elevations using a laser, often from a light aeroplane.
Littoral transport (drift)	The movement of beach material in the littoral zone by waves and currents. Includes movement parallel (longshore drift) and perpendicular (cross-shore transport) to the shore.
LLFA	Lead Local Flood Authority. Responsible body for local flood risk management in accordance with the Flood and Water Management Act (FWMA) (2010).
Managed Realignment (MR)	A Shoreline Management Plan policy that allows the shoreline position to move backwards (or forwards) with management to control or limit movement.
MHWS	Mean High Water Springs. See Tide Levels.
MHWN	Mean High Water Neaps. See Tide Levels.
MLWN	Mean Low Water Neaps. See Tide Levels.
MLWS	Mean Low Water Springs. See Tide Levels.
MSL	Mean Sea Level. See Tide Levels.
Mud	A type of sediment containing more than 50% silt and clay size particles; may also contain sand and/or gravel and be described as sandy mud, gravelly mud etc.
Mudflats	Expanses of mud which are periodically exposed at low tide, often found adjacent to saltmarshes.
NFCDD	National Flood and Costal Defence Database. Database of flood defence assets developed by EA. Now being superseded by AIMS.
NTL	Normal Tidal Limit. The point to which the tide reaches in an estuary, under normal conditions i.e. in absence of storm surge and with typical river flow.
Neap tide	Tides over a 14 day period with lowest tidal range between high and low water.
No Active Intervention (NAI)	A Shoreline Management Plan policy that assumes that existing defences are no longer maintained and will fail over time or undefended frontages will be allowed to evolve naturally.
OD	Ordnance Datum - the standard reference level for Ordnance Survey maps throughout the UK from which the height of the land is measured. Currently based on mean sea level at Newlyn in Cornwall.
Partnership Funding	Funding contributions for flood and coastal erosion risk management from beyond traditional flood and coastal erosion risk management budgets (e.g. Flood Defence Grant in Aid (FDGiA); the grant by which government funds its share of the costs of FCERM projects in England).
Policy Unit (PU)	Sections of coastline for which a certain coastal defence management policy has been defined in the Shoreline Management Plan – see SMP.
Progradation	Seaward movement of the shoreline (mean high water mark) due to sediment accumulation on a beach, dunes, delta etc.

Term	Definition
Ramsar	Ramsar sites are wetlands of international importance, designated under the Ramsar Convention of 1971.
Regression	A seaward movement of the shoreline due to a fall in sea level.
Risk	A combination of both the probability of an event occurring and the expected consequences if it does occur. In the case of coastal change adaptation planning, risk relates to the impact and consequences of a hazard, which may be coastal erosion, coastal landsliding, coastal accretion or coastal flooding resulting in regular or permanent inundation.
Risk Management Authorities	Organisations that have a key role in flood and coastal erosion risk management as defined by the Flood and Water Management Act (2010). These are the Environment Agency, lead local flood authorities, district councils where there is no unitary authority, internal drainage boards, water companies, and highways authorities.
SAC	Special Area of Conservation. An area which has been given special protection under the European Union's Habitats Directive.
Sand	Sediment particles, often mainly of quartz, with a diameter of between 0.063mm and 2mm, generally classified as `fine', `medium', `coarse' or `very coarse'.
Saltmarshes	An ecosystem in the mid- to high intertidal zone which is vegetated by salt-tolerant plants.
Sediment sink	An area in which transported sediment is deposited and accumulates over time.
Sediment source	An area from which sediment is derived and becomes available for transport to a sediment sink.
Shoreline Management Plan (SMP)	A plan providing a large-scale assessment of the risk to people and to the developed, historic and natural environment associated with coastal processes. SMP2 refers specifically to the second generation SMP.
Silt	Sediment particles with a grain size between 0.002mm and 0.063mm, i.e. coarser than clay particles but finer than sand.
SPA	Special Protection Area. An area of land, water or sea which has been identified as being of international importance for the breeding, feeding, wintering or the migration of rare and vulnerable species of birds found within the European Union.
Spring tide	Tides over a 14 day period with highest tidal range between high and low water.
SSSI	Site of Special Scientific Interest (SSSI) National conservation designation given to sites of biological or geological interest in England, Wales and Scotland.
Storm surge	The local change in sea level associated with a change in atmospheric pressure and/ or onshore winds. Surges may be either positive (higher than predicted astronomical sea level) or negative (lower than predicted), and typically have a duration of a few hours to a few days.

Term	Definition
Strategy Plan	A long term documented plan for coastal management, including all necessary work to meet defined flood or coastal defence objectives for the target area. It is designed to provide the basis for decision making and action related to the provision and management of flood or coastal defences. Strategy Plans develop the policies recommended in SMPs by defining the preferred approach to shoreline management requirements over a 100 year period.
Tidal range	Microtidal < 2m; Mesotidal 2m - 4m; Macrotidal >4m; Hypertidal > 8m.
Tide	The rise and fall of the sea caused by the gravitational pull of the moon and sun.
Tide levels	(1) High astronomical tide (HAT), lowest astronomical tide (LAT): the highest and lowest tidal levels, respectively, which can be predicted to occur under average meteorological conditions. (2) Mean high water springs (MHWS): the height of mean high water springs is the average throughout a year of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest. (3) Mean low water springs (MLWS): the height of mean low water springs is the average height obtained by the two successive low waters during the same periods. (4) Mean high water neaps (MHWN): the height of mean high water neaps is the average of the heights throughout the year of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is least. (5) Mean low water neaps (MLWN): the height of mean low water neaps is the average height obtained by the two successive low waters during the same periods. (6) Mean high water (MHW), mean low water (MLW): mean high/low water, as shown on Ordnance Survey Maps, is defined as the arithmetic mean of the published values of mean high/low water springs and mean high/low water neaps.
Tidal prism	Volume of water entering and leaving an estuary during each tide, i.e. the difference between low water volume and high water volume.
Training walls	A wall typically constructed of rubble or masonry to constrain or guide the movement of an intertidal or sub-tidal channel.
Transgression	A rise in mean sea level responsible for landward movement of the shoreline.
Turbidity maximum	Location of high concentration of suspended sediment in an estuary; associated with fresh / seawater mixing with vertical and horizontal salinity gradient resulting in residual vertical circulation and flocculation of suspended sediment. Location varies during the tide and with variations in river flow.
Up-drift	Longshore drift is the movement of beach materials along the shore, if a location is described as up-drift; it is located further up the sediment pathway (closer to the sediment source) than an alternative area; the opposite of down-drift.
Wave Height	The vertical distance between a wave crest and the next trough.

Executive summary

The Dee Estuary is located within Liverpool Bay in sub-cell 11a, which extends from the Great Orme's Head (North Wales) to Southport. The Dee is nationally and internationally important for its habitats and wildlife and the entire estuary is designated as SSSI, SAC and SPA.

The River Dee rises in the eastern part of Snowdonia and drains a catchment area of approximately 2,088km^2. The maximum fluvial flow recorded at Chester the Weir since 1894 is 184 m^3 s^{-1} and the average flow is approximately 35 m^3 s^{-1}. The estuary can be considered to extend from a line between Point of Ayr and Hilbre Point at the mouth to the normal tidal limit at Chester Weir. The Estuary is a drowned, glacially over-deepened valley bounded by Triassic sandstones and Carboniferous Coal Measures which are extensively mantled by glacial till and outwash sands and gravels. Glacial till forms an eroding cliff along part of the east shore of the estuary near Thurstaston.

The estuary mouth is wide, with several channels and sand banks. On the western side near Point of Ayr is a sand and gravel spit complex, while the eastern side is defined by a sandstone outcrop at Hilbre Point, West Kirby. The estuary has a well-developed ebb tidal delta and within the estuary extensive intertidal flats and saltmarshes are exposed at low tide. The banks at the mouth of the estuary reduce wave penetration into the estuary, although significant wave action can occur during high spring tides, especially on the English shore. The main source of sediment to the estuary is the Irish Sea, although erosion of the glacial till cliffs and the suspended load of the River Dee provide secondary sources.

The SMP2 estimated that around 5,500 residential and 1,700 non-residential properties, along with 3,700ha of agricultural land, would be at risk in the long term for a No Active Intervention (Do Nothing) approach to flood and erosion risk management. There is major industry and regional / national infrastructure within the long term risk area.

The Estuary is macro-tidal, the mean spring tidal range at Hilbre Island being 7.6m, but at Connah's Quay near the estuary head the spring tidal range is restricted to 3.4m due to river flow. Flood tidal currents are stronger than ebb currents in most of the estuary, encouraging net sediment import and retention within the estuary. Residual currents within Liverpool Bay contribute to net landward transport of sand and silt into the estuary. The estuary interacts with processes in Liverpool Bay as far west as the River Clwyd and eastwards to the River Mersey.

The evolution of the outer Dee Estuary has been profoundly affected by human interventions, within the Dee itself and also in Liverpool Bay. Interventions have included construction of a tidal weir at Chester (originally built in 1093), extensive reclamation (c.25% of the original estuary area), construction of coastal defences along the North Wales coast which have reduced alongshore sediment supply, training and dredging of the Crosby Channel in Liverpool Bay, and planting of *Spartina* which encouraged the development of saltmarshes especially between Parkgate and Heswall. Of particular importance was the creation of the New Cut after 1732 to improve navigation up to Chester. This fixed the main low water channel close to the Welsh shore and encouraged rapid intertidal sedimentation along the English shore. Sediment accretion was enhanced following the introduction of *Spartina* to the estuary in 1928. The Dee training walls play a major role in determining the stability of the estuary. If they were removed or fell to dis-repair the estuarine channels would revert to a much more dynamic pattern of behaviour, with the potential for intertidal erosion on the English side of the estuary and navigation problems on the Welsh side.

The estuary is currently continuing to import sediment with saltmarshes showing vertical accretion of 2 to 8 mm/yr. The rate of marsh expansion near the estuary mouth has decreased in recent decades but accumulation of windblown sand continues to occur near the Point of Ayr and at Hoylake. The saltmarsh edge along the western side of the estuary is generally eroding where not protected by rock armour, but sedimentation continues in the sub-tidal area around Mostyn Docks, which require regular maintenance dredging.

Future sea level rise will tend to increase the tidal volume and, in the absence of compensating sedimentation, could cause the tidal channels to widen and/or deepen, leading to increased saltmarsh edge erosion along the Welsh side of estuary (where not protected) and further reduced marsh expansion on the Wirral shore. However, it would be unlikely to have a significant impact on the extent of saltmarsh as a whole, and any negative effect could be offset if the rate of sediment movement into the estuary. Coastal squeeze is considered not likely to be a major problem in next 100 years since there is no evidence to suggest that the increased sediment demand created by sea level rise will not be balanced by sediment supply from the Irish Sea.

The long term vision in the SMP2 is to maintain protection to assets where necessary but to provide more accommodation space where practical to do so. Along the east bank saltmarsh should be allowed to roll back where possible and undefended cliffs should be allowed to erode naturally. In the trained river sections the plan is to continue to manage flood risks to local industry and transport routes. Opportunities for managed realignment are limited by the topography but should be exploited where practicable.

Current monitoring data incorporated within CERMS is largely limited to intertidal profile surveys on the English shore between Heswall and West Kirby and on the Welsh shore between Mostyn and Point of Ayr. Additional topographic and bathymetric data collection is carried out by the Port of Mostyn and other members of the Tidal Dee User Group but this data, including swath bathymetry and LiDAR, is not currently available within CERMS. There are a number of tide and other water level gauges within the estuary but the data have also not been collated within CERMS. Extensive sediment sampling has been undertaken as part of CERMS in the mid and outer estuary but the inner estuary and large sand banks at the mouth of the estuary have not been sampled. There have been a number of short-term data collection campaigns within the estuary, largely for research purposes, which have provided data on tidal currents, waves and suspended sediments, but no long-term or systematic estuary-wide collection of synoptic water level, wave or sediment data has been undertaken. It is recommended that a further synoptic swath bathymetry and LiDAR survey be undertaken before 2016, and that at least two AWACs and / or wave buoys be deployed for a minimum 1 month period at the entrance to the estuary and in the inner estuary to improve calibration and validation of numerical models. Gaps in the spatial coverage of sediment samples should also be filled by a further programme of sampling.

1 Introduction

This report summarises the existing understanding of the Dee Estuary (refer to Figure 1.1). It draws on information from the second round SMP, the Cell Eleven Tidal and Sediment Transport Study (CETaSS) and other more recent studies. It provides a summary of:

- The physical processes and evolution of the estuary;
- The SMP policies for the estuary;
- The existing monitoring data that exists;
- Gaps in understanding; and
- Recommendations for further monitoring, additional studies, changes to SMP policies and flood risk ratings.

This report forms one of a series of similar reports for the major estuaries on the coast of North West England.

Figure 1.1 Location of the Dee Estuary.

2 Coastal Setting

The Dee Estuary is located within Liverpool Bay in sub-cell 11a, which extends from the Great Orme's Head (North Wales) to Southport, see Figure 2.1.

Figure 2.1 Overview of Cell 11 study area, showing SMP2 sub-cell frontages (source: Halcrow, 2010c).

The River Dee rises in the eastern part of Snowdonia and drains a catchment area of approximately 2088 km^2 (Environment Agency wales, 2008) (Figure 2.2).

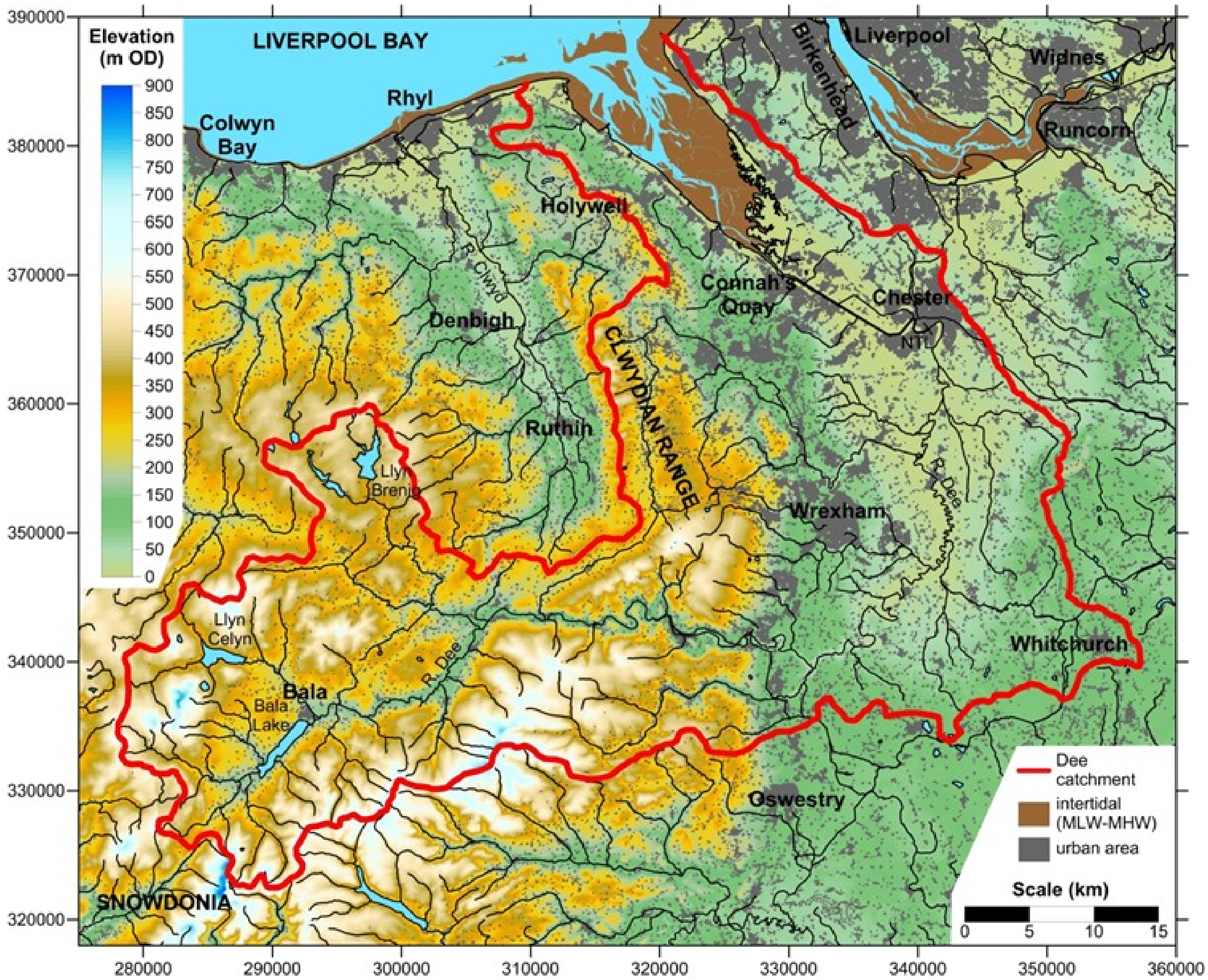


Figure 2.2 The River Dee catchment, showing the main urban areas and general extent of the intertidal zone. Source: adapted from Ordnance Survey Open Data, after Pye and Blott (2013).

3 Estuary Review

3.1 Description

The estuary can be considered to extend from its mouth, defined by a line between Point of Ayr spit and Hilbre Point to the normal tidal limit at Chester Weir (Halcrow, 2010d). The Dee Estuary is a drowned, glacially over-deepened valley that formed due to geological structural controls (Gresswell, 1964) between Triassic sandstones and Carboniferous coal measures, is broad and rectangular in shape, and has been significantly in-filled (Halcrow, 2012a). The solid geology surrounding the estuary is extensively mantled by glacial till and areas of outwash sands and gravels. Glacial till forms an eroding cliff along part of the east shore of the estuary near Thurstaston (Glasser *et al*., 2001; Halcrow, 2010b).

The mouth is wide, with several channels and sand banks, and there is a small spit on the western side of the mouth, known as the Point of Ayr. The eastern side of the mouth on the Wirral is at Hilbre Point, West Kirby, a hard sandstone outcrop, with detached outcrops (the Hilbre Islands) approximately 1.5km to the south west (Figure 3.1). There is a well-developed ebb tidal delta. The interior of the estuary is wide, with well-developed sand and mudflats, and extensive saltmarshes.

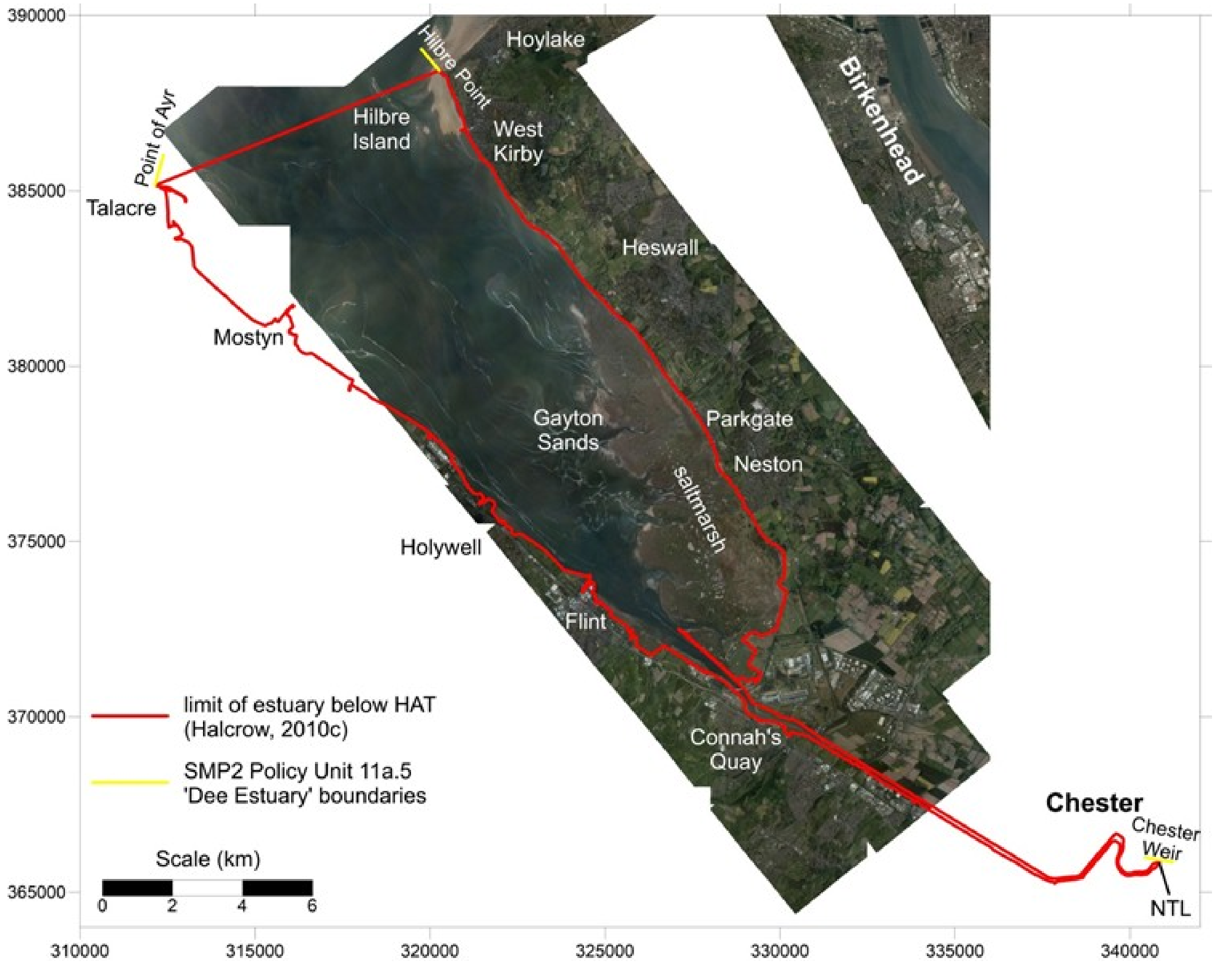


Figure 3.1 Limits of the Dee Estuary and SMP2 Policy Unit 11a.5.

The shoreline management plan (SMP2) estimated that there would be around 5,500 residential and 1,700 non-residential properties along with 3,700ha of agricultural land at risk in the long term for a No Active Intervention (Do Nothing) approach to flood and erosion risk management. There is also major industry and regional / national infrastructure within the long term risk area.

The Dee estuary is nationally and internationally important for its habitats and wildlife and the entire estuary is designated as SSSI, SAC and SPA (Figure 3.2).

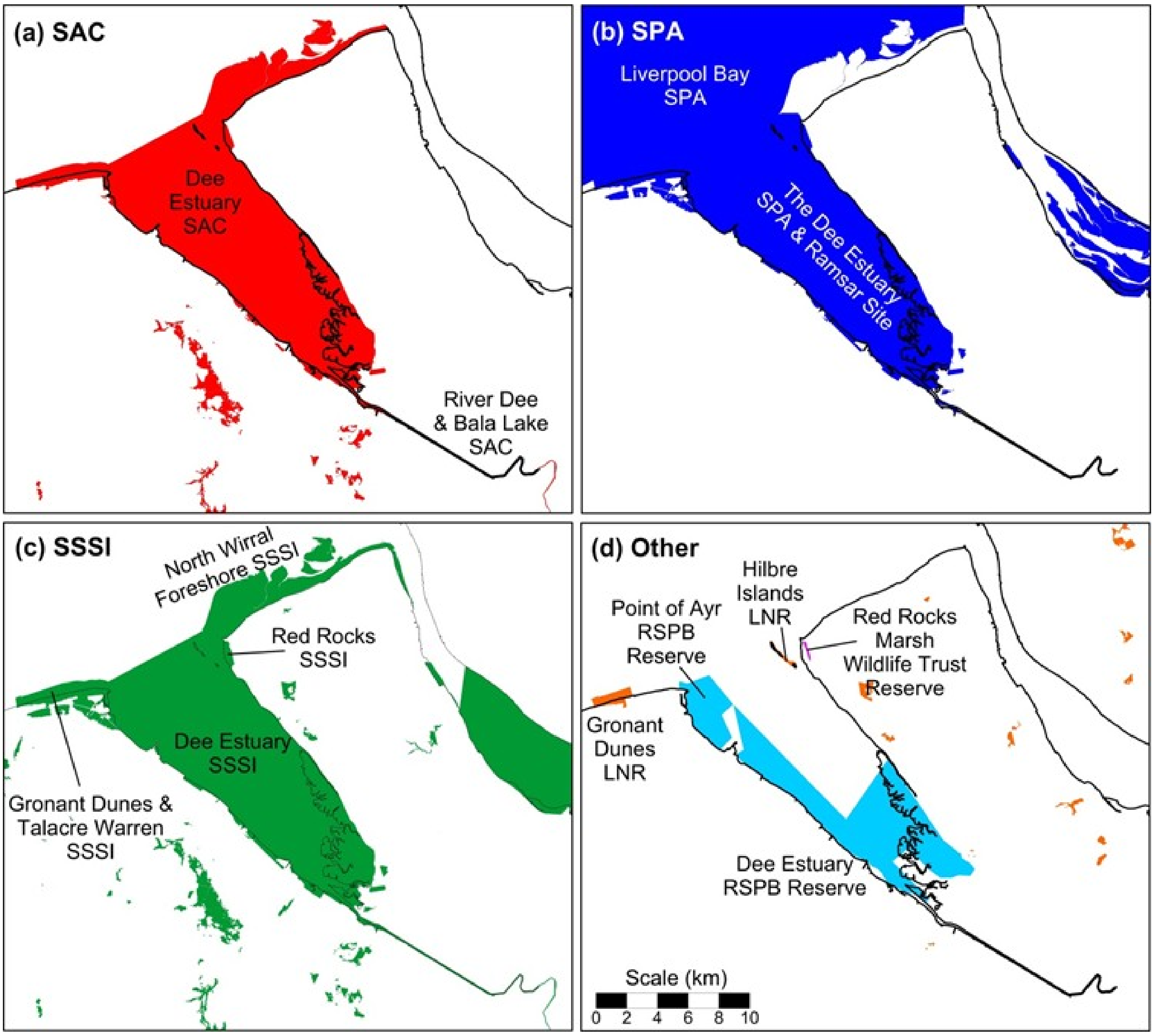


Figure 3.2 Nature conservation designations and reserves in and surrounding the Dee Estuary.

3.2 Coastal Processes

The Dee Estuary is macrotidal, mean spring and mean neap tidal ranges at Hilbre Island being 7.6m and 4.1m, respectively. Near the head of the estuary, at Connah's Quay, the mean spring tidal range is approximately 3.4m and the mean neap tidal range is approximately 1.7m. Principal tidal levels in the Dee according to Admiralty tidal tables are shown in Table 3.1.

Table 3.1 Tidal levels (mOD) at Secondary Ports in the Dee Estuary. Source: Based on Admiralty Tide Tables (2012)

	LAT	MLWS	MLWN	MSL	MHWN	MHWS	HAT
Hilbre Island	-4.93	-3.63	-1.83	0.22	2.27	4.07	5.27
Mostyn Docks	-4.50	-4.50	-4.50	-4.50	2.20	4.00	4.90
Connah's Quay	-0.75	-0.75	-0.75	-0.75	2.25	3.95	4.85
Chester	0.60	0.60	0.60	0.60	2.60	4.60	5.60

During the winter months storm surges can raise predicted high water levels by up to 2m (Halcrow, 2010b).

The fluvial discharge at Chester Weir reaches a maximum between October and March and is normally at a minimum between May and September. The maximum flow recorded at the Weir since 1894 is 184 $m^3 s^{-1}$, and the average flow is approximately 35 $m^3 s^{-1}$. Flows in the river are regulated by a series of weirs, dams and reservoirs along its length (Lambert, 1988).

Freshwater influence is significant near the head of the estuary. The average salinity of the estuary varies from about 26 ppt near the head to about 33 ppt near the mouth; the estuary is generally considered to be partially mixed.

The tidal flow in the Dee estuary is flood dominant, which implies stronger flood tide currents and net sediment movement into the estuary, especially across the shallow water intertidal areas, and residual currents ensure landward transport of both sand and silt into the estuary from Liverpool Bay (HR Wallingford, 2004; Moore *et al*., 2009; Bolanos and Souza, 2010; Halcrow, 2010b).

The estuary is a major sink for both mud and sand. The transport of sand sized sediment into this area has led to the formation of a number of sand banks at the mouth of the Dee Estuary including the West Hoyle Spit, West Hoyle Bank, East Hoyle Spit and East Hoyle Bank. These banks provide some protection against incoming wave to shores of the outer Dee and the open coast either side (Halcrow, 2010b).

The key source of sediment to the Dee is the onshore movement of sediment from the Irish Sea. Within the estuary the eroding till cliffs also represent minor sources of sediment (Halcrow, 2010c). Although the Dee Estuary acts as a large sink for muds and silts, there is still sand transport across the mouth via West Hoyle Bank and East Hoyle Spit.

Barber (2006) discusses how the monitoring work carried out by the Tidal Dee User Group (TDUG) over the last fifteen years shows the estuary interaction to extend westwards to the outlet of the Afon Clwyd and eastwards to the River Mersey. The eastward influence interacts not only with the open coast but also with the Mersey Estuary, making this boundary less easy to delineate. There is evidence of the Dee Estuary behaviour dominating nearshore coastal processes on the adjacent coast to Leasowe Lighthouse within the Wallasey Embankment frontage, with Mersey estuary nearshore dominance further to the east (Halcrow, 2010b).

Evolution of the outer Dee Estuary (and the neighbouring Mersey Estuary), in the recent past, has been dominated by changes resulting from human intervention not just within the Dee itself but also along adjacent open coast frontages. Dredging and training of the Crosby Channel to the Port of Liverpool has been shown to have had significant impacts on the Dee Estuary downstream of Greenfield (Halcrow, 2010b).

Annual average littoral and subtidal transport vectors based on numerical modelling from the CETaSS (Halcrow, 2010c) are shown in Figure 3.3. It can be seen that the sediment pathways from offshore and alongshore are directed towards the mouths of the Dee and Mersey.

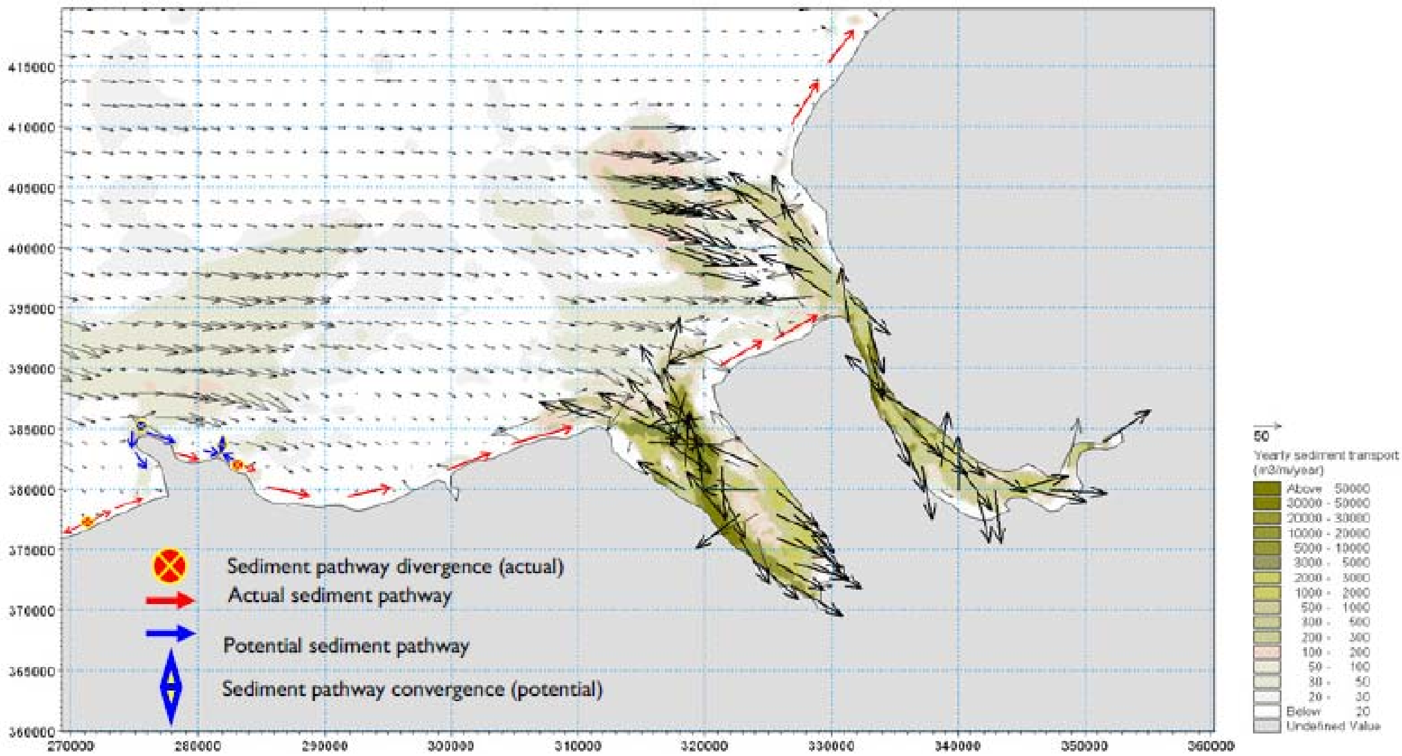


Figure 3.3 Map showing sediment transport in the vicinity of Dee Estuary (from Halcrow, 2010c).

Much of the lower intertidal and sub-tidal zone of the Dee estuary is sandy, although there is a trend towards more muddy sediments in an up-estuary direction. Samples collected from the intertidal zone as part of the CERMS campaign in 2009-10 revealed a wide range of sample types ranging from clean sand to very slightly sandy mud. Gravel is rare except at the top of the beach in the outer part of the estuary, especially on the English side and at the Point of Ayr (Pye *et al*., 2010), (Figure 3.4). Further sediment sampling in 2012 indicated that the mid and outer estuary sand banks and channels are also composed mainly of sands and slightly muddy sands. However, few samples have so far been collected from the subtidal and lower intertidal areas in the inner part of the estuary.

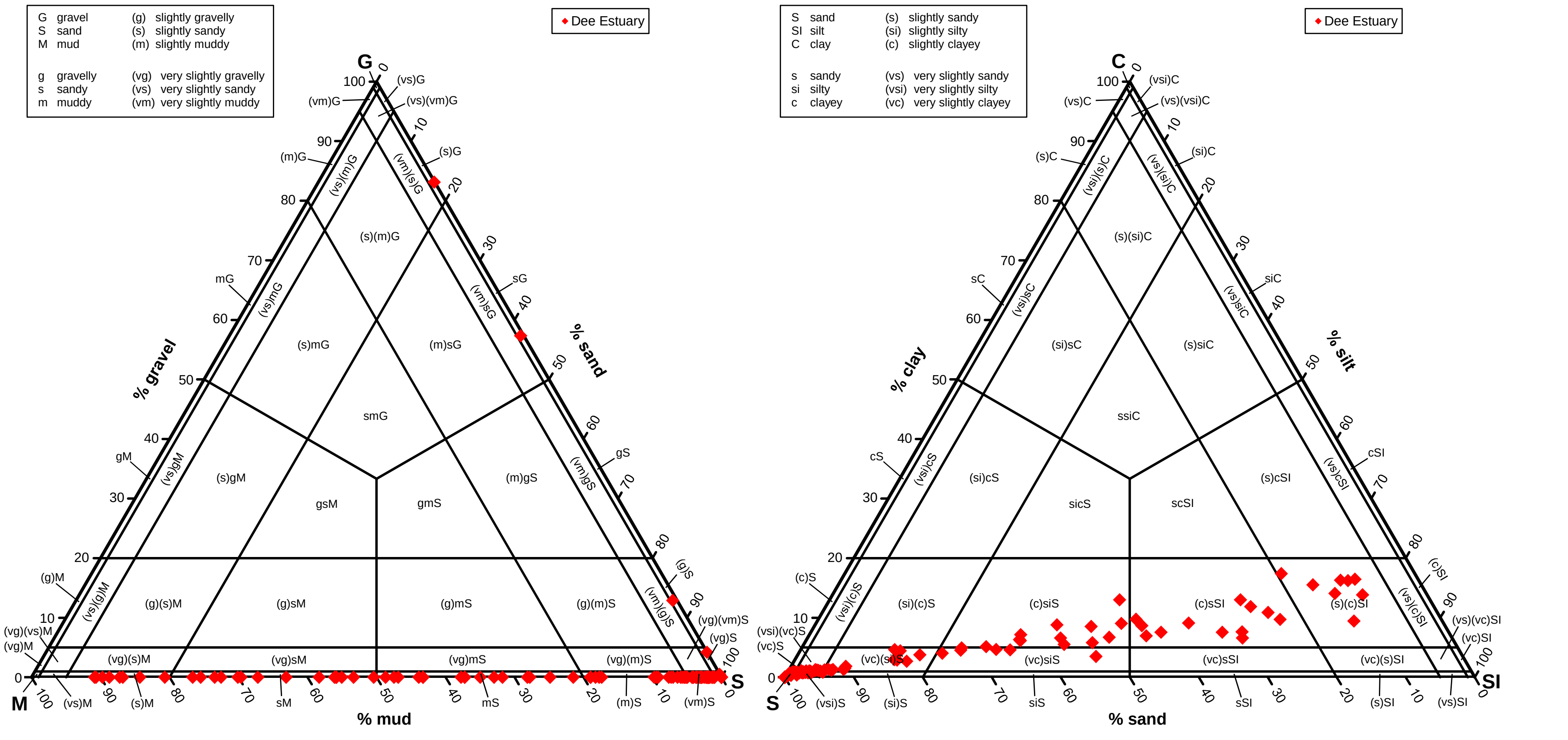


Figure 3.4 Gravel-Sand-Mud and Sand-Silt-Clay trigons, based on the classification of Blott and Pye (2012), for sediment samples collected within the Dee Estuary in 2009-12 (data from Pye et al., 2010).

3.3 Past Changes

The Dee Estuary has been infilling since the beginning of the postglacial marine transgression, having - probably been first flooded around 7500 to 8000 years ago. Originally the estuary was almost rectangular in form, over 30km long and 8km wide and extended as far as Chester (now the tidal limit). During the last 5,000 years relative mean sea-level in the north-east Irish Sea is thought to have remained quite stable and within a metre of present mean sea-level (Shennan and Horton, 2002, Halcrow, 2010b). This infilling has been aided by the supply of sediment from alongshore and offshore regions, coupled with the flood dominant tidal currents within the estuary. Additionally, there have been a number of anthropogenic modifications of the estuary, from the 11th century onwards which have further increased the natural tendency for siltation.

The main interventions have been:

- Construction of a tidal weir at Chester (originally built in 1093), which has reduced the tidal prism and velocities.
- Extensive reclamation (c.25% of the original estuary area) at the upper end of the estuary which has significantly reduced the tidal prism from the mid-18th century onwards and led to a narrow inner estuary. Some reclamations may also date back to Roman times.
- Defences along the North Wales coast which have reduced alongshore sediment supply.
- Training and dredging of the Crosby Channel in Liverpool Bay, which has led to sedimentation outside the trained areas.
- Planting of *Spartina* and expansion to form extensive marshes between Parkgate and Heswall.

These are described in more detail in Halcrow (2010b, c).

In Roman times the estuary was navigable by small vessels as far as Chester, although the main channel was sufficiently shallow near Flint to be forded at low tide. A weir was constructed at Chester in Norman times in order to drive water mills, the result being to reduce flow velocities and enhance siltation downstream of the weir. Embanking and reclamation contributed to a reduction in tidal prism and associated tidal current velocities. An out-port was established at Shotwick by 1450, but continued siltation during the 15th and 16th centuries led to the development of new embarkation facilities first at Neston and then Parkgate. In the 18th and early 19th centuries Parkgate was the most important ferry port in northwest England for travel to Ireland.

In 1732 Parliamentary approval was sought to dig a new channel to improve navigation up to Chester, and to allow enclosure of a large area of marshland on either side. The embankments and training walls associated with the New Cut were improved and extended several times during the 19th century, allowing further land claim between Shotwick and Burton Point. In 1975 a major embankment was built between the end of the New Cut and Burton Point, and additional areas were embanked along the western side of the estuary near Connah's Quay, Flint and Mostyn (Webster, 1930; Marker, 1967; Pye, 1996). Approximately 5000 ha has been enclosed since 1732, representing almost 25% of the original area of the estuary.

Sediment accretion was enhanced from the 1930s onwards by the introduction of *Spartina*, which was initially planted at Connah's Quay in 1928 (Taylor and Burrows, 1975). It spread rapidly between the 1940s and 1970s, despite efforts to control it.

At present, the estuary is continuing to import sediment with the saltmarshes showing vertical accretion at rates of 2 to 8 mm/yr. Halcrow (2010d) reported that the rates of marsh expansion near the estuary mouth decreased in the late 1980s and 1990s, although sedimentation in the low water channel continues. Further accretion was reported for the Point of Ayr spit, located east of Talacre, which has extended south-eastwards and grown vertically through development of dunes. The accreting sediment has been sourced mainly from the dune frontage further west near Point of Ayr lighthouse, which has been eroding for several decades (Pye and Blott, 2012). In 2004-05 beach recharge using sand dredged from the Port of Mostyn navigation channel temporarily slowed this erosion but much of the sediment has been lost into the dunes or eastwards along the spit and into the estuary. The accretion is partially rebuilding a former area of enclosed marsh (Parlor Dee) which existed in the mid-19th century but was subsequently lost to erosion. Accretion was also reported by Halcrow (2010d) for the intertidal areas between Hillbre Island and Hoylake, where blown sand accumulation against the promenade has posed a problem in recent years.

The saltmarsh edge along the western side of the estuary has been eroding for several decades (Pye, 1996; Halcrow, 2011). Large sections of the marsh frontage near Bagilt and Flint are now protected by rock armour, but unprotected sections continue to erode at up to 0.5 m/yr (Halcrow, 2011).

Approximately 810,000m^3 of sediment was capital dredged from the Mostyn Approach Channel in 2001-02, the sediment being disposed of in Liverpool Bay. Maintenance dredging of a further 349,000m^3 of sediment was subsequently undertaken in 2002-2003 (Pethick, 2004); some of this material was used to nourish the beach and frontal dunes at Talacre, as described above. Further maintenance dredging has been undertaken since that time, and regular monitoring of the surrounding banks and channels has been undertaken by the Port of Mostyn.

3.4 Future Behaviour

Halcrow (2010b) concluded that the estuary is still responding to the effects of the extensive reclamation that has taken place in the past. This, coupled with the supply of sediment from alongshore and offshore, means that the estuary is likely to continue to accrete overall, although the rate of expansion of the intertidal areas may reduce further due to sea level rise. Halcrow (2010b) considered that the potential increases in tidal prism that could occur due to potential managed realignment would not be sufficient to cause significant estuary wide effects.

Halcrow (2010d) noted that sea level rise will tend to increase the tidal volume and, in the absence of compensating sedimentation, place pressure on the tidal channels to widen and/or deepen. This could lead to increased erosion of the saltmarsh edge along the Welsh side of estuary (where not protected) and slow the expansion of saltmarsh on the Wirral side. However, it would be unlikely to have a significant impact on the extent of saltmarsh as a whole, and any negative effect could be offset if the rate of sediment movement into the estuary increases and the narrowing of the estuary entrance continues due to encourage accretion in the Point of Ayr and Hilbre Island - Hilbre Point areas. Halcrow (2010b) concluded that coastal squeeze is not likely to be a major problem in the Dee over the next 100 years, and there is no evidence to suggest that the increased sediment demand created by sea level rise will not be balanced by sediment supply from the Irish Sea.

3.5 Conceptual Model of Estuary Behaviour

A conceptual model for the Cell 11a area, showing sediment transport pathways, control features and sediment sources and stores is provided in Figure 3.5. A more detailed diagram has been developed for the Dee estuary in Figure 3.6.

The Dee estuary is a wide, relatively shallow estuary which has extensive intertidal flats and saltmarshes exposed at low tide. The estuary has acted a sink for sediments derived mainly from Liverpool Bay throughout the middle and later Holocene. Extensive embanking and land claim from Roman times onwards decreased the tidal prism of the estuary, leading to reduced tidal current velocities and enhanced sediment accretion. Creation of the New Cut in the 18th century, together with further embanking and land claim, caused a major perturbation to the estuary system, and caused the main low water channel to become fixed on the Welsh side of the estuary. Accretion was enhanced on the English side of the estuary, leading to rapid expansion of saltmarsh in the 20th century. Sediment accretion and saltmarsh expansion has slowed down in recent decades as the estuary approaches a new dynamic equilibrium. Slow saltmarsh edge erosion continues along parts of the Welsh shore of the estuary which are not protected.

The Dee training walls play a major role in determining the stability of the estuary. If they were removed or fell to dis-repair the estuarine channels would revert to a much more dynamic pattern of behaviour, with the potential for intertidal erosion on the English side of the estuary and navigation problems on the Welsh side.

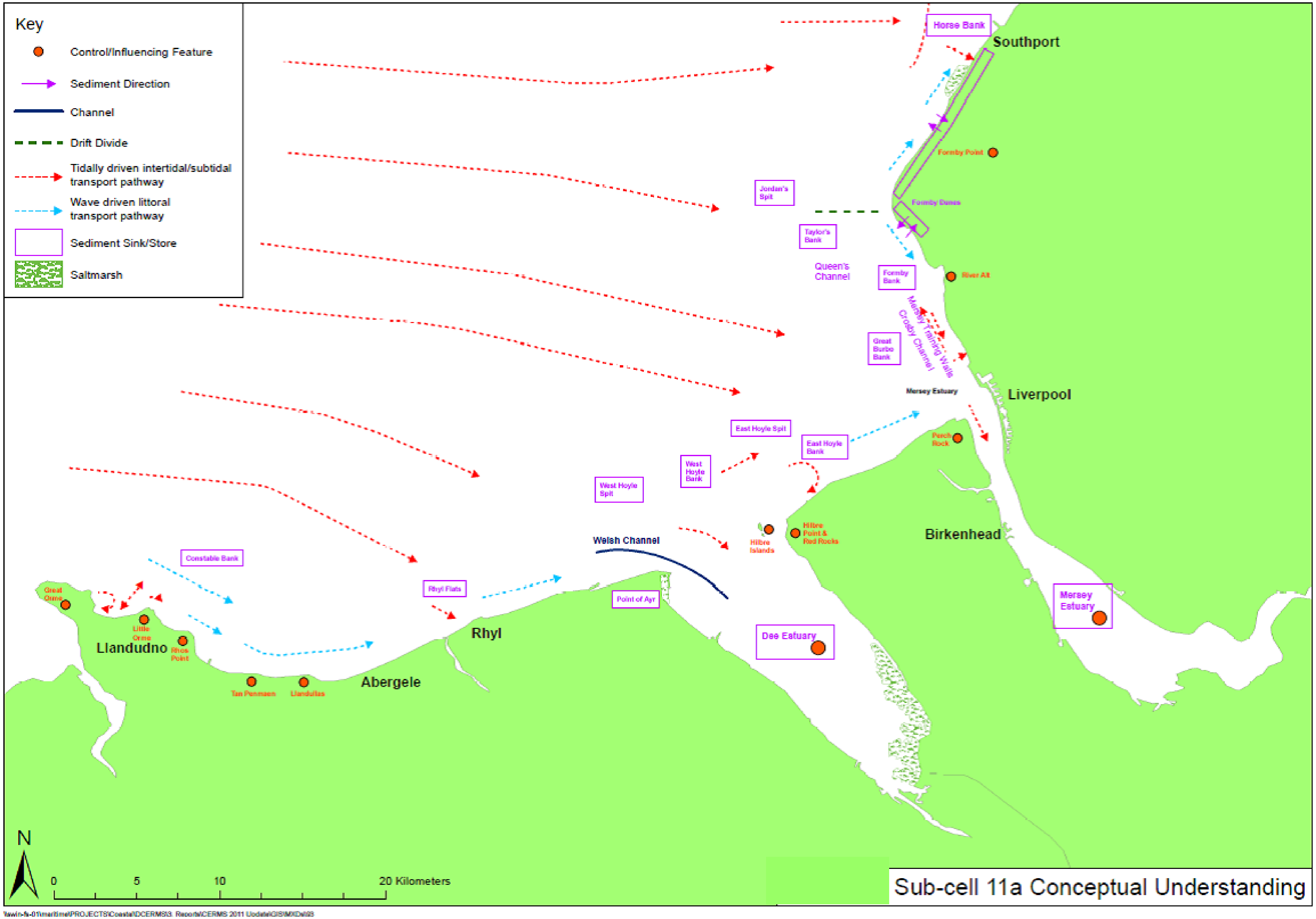


Figure 3.5 A simple conceptual model for the Cell 11a area (source: Halcrow, 2010d)

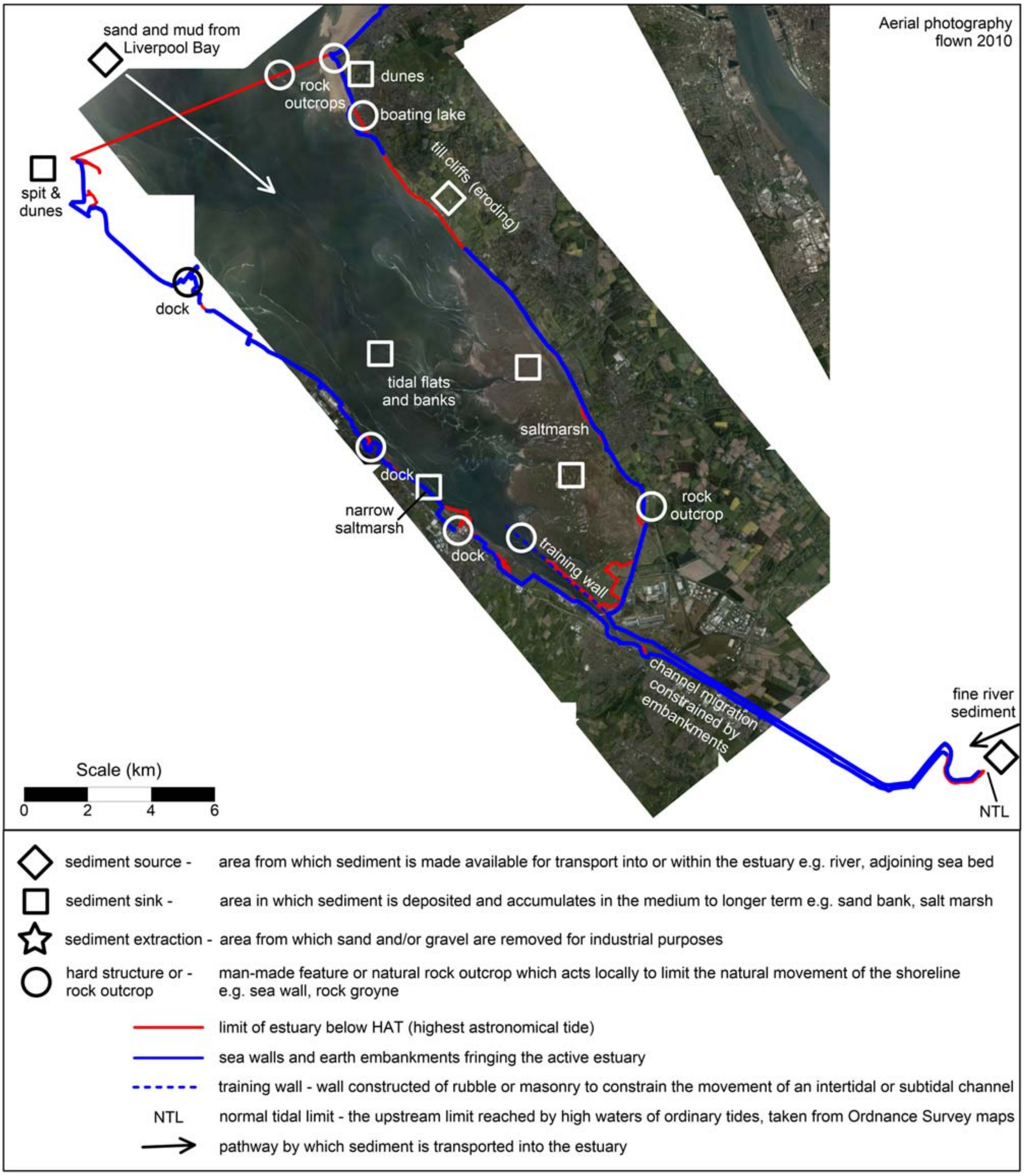


Figure 3.6 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Dee Estuary

3.6 Coastal Defences and SMP Policies

A list of the coastal defences in the Dee Estuary from the SMP2 (Halcrow, 2010b) is provided in Appendix A.

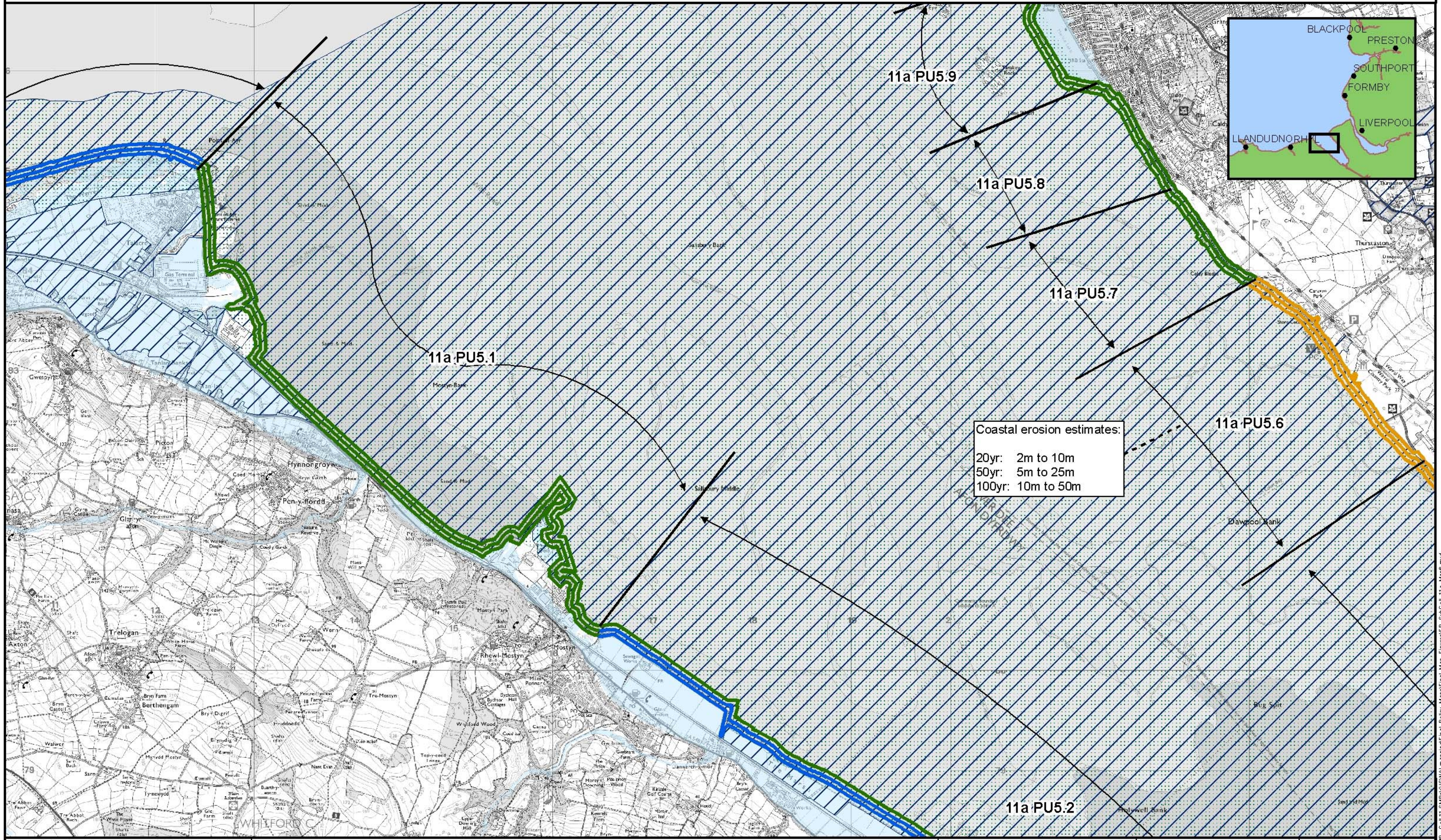
The long term vision in the SMP2 for the Dee Estuary is to maintain protection to assets where necessary but to provide more accommodation space where possible and practical to do so. The shape and size of the estuary itself is largely controlled by the local topography and geology so there is little to be gained by localised realignment where limited opportunities exist, although some habitat creation is possible. Along the east bank the salt marsh should be allowed to continue to roll back across gently rising ground and undefended cliffs will be allowed to erode naturally. The plan in the trained river sections is to continue to manage flood risks to local industry and transport routes.

Maintaining the defences in the inner estuary and public / private maintenance of defences along the eastern shore will ensure that the majority of the social objectives are met. Although the extent of the opportunities is limited by the topography, by incorporating areas of managed realignment the estuary will be able to resume a more natural form in some locations. The adopted SMP2 policies are shown on the maps in Figure 3.7 below.

North West England and North Wales Shoreline Management Plan 2

Sub-Cell 11a: Area: 5 Map: 1

North West & North Wales Coastline
a partnership for coastal defence management



N

0 0.3 0.6 1.2 Kilometres

Scale: 1:35,000

Legend

- National Nature Conservation Designations
- International Nature Conservation Designations
- Scheduled Monuments
- Coastal flood risk area under extreme events, Environment Agency Flood Map, 2008
- Policy Unit Boundary
- Policy Unit Extent

Shoreline Management Policies

- Hold the Line (HTL)
- Managed Realignment (MR)
- No Active Intervention (NAI)

0 - 20 years
20 - 50 years
50 - 100 years
From 2010

Note that the policy lines on the map show the preferred shoreline management policy for each period and do not represent either the shoreline or defence location

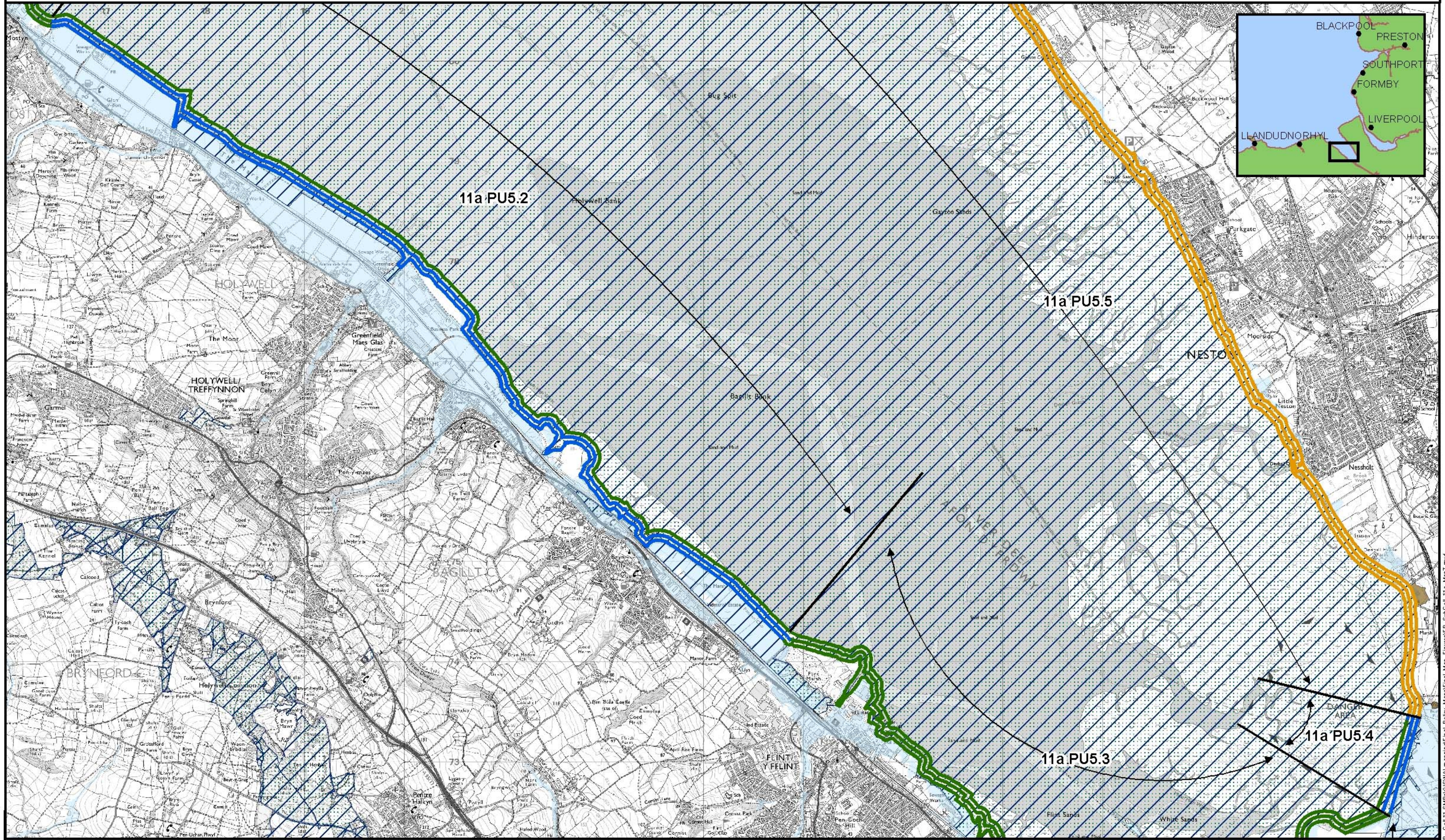
Halcrow

Boxes showing cumulative erosion estimates represent the expected minimum and maximum erosion distance from the shoreline position in 2010. They are only shown where there is a NAI policy and coastal erosion is the main risk

North West England and North Wales Shoreline Management Plan 2

Sub-Cell 11a: Area: 5 Map: 2

North West & North Wales Coastline
a partnership for coastal defence management



N

0 0.25 0.5 1 Kilometres

Scale: 1:35,000

Legend

- National Nature Conservation Designations
- International Nature Conservation Designations
- Scheduled Monuments
- Coastal flood risk area under extreme events, Environment Agency Flood Map, 2008
- Policy Unit Boundary
- Policy Unit Extent

Shoreline Management Policies

- Hold the Line (HTL)
- Managed Realignment (MR)
- No Active Intervention (NAI)

0 - 20 years

20 - 50 years

50 - 100 years

From 2010

Note that the policy lines on the map show the preferred shoreline management policy for each period and do not represent either the shoreline or defence location

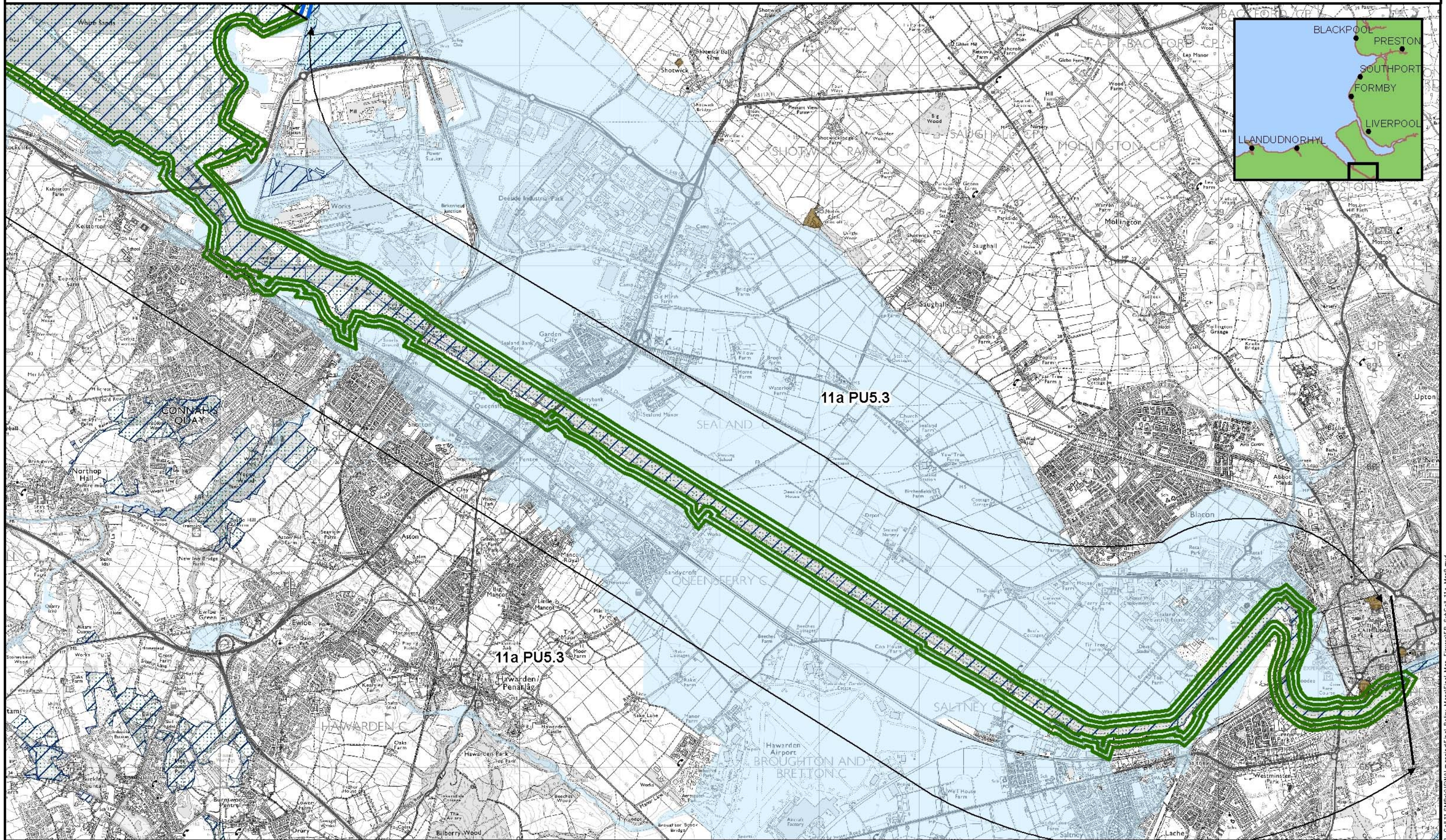
Halcrow

Boxes showing cumulative erosion estimates represent the expected minimum and maximum erosion distance from the shoreline position in 2010. They are only shown where there is a NAI policy and coastal erosion is the main risk

North West England and North Wales Shoreline Management Plan 2

Sub-Cell 11a: Area: 5 Map: 3

North West & North Wales Coastline
a partnership for coastal defence management



N

0 0.3 0.6 1.2 Kilometres

Scale: 1:35,000

Legend

- National Nature Conservation Designations
- International Nature Conservation Designations
- Scheduled Monuments
- Coastal flood risk area under extreme events, Environment Agency Flood Map, 2008
- Policy Unit Boundary
- Policy Unit Extent

Shoreline Management Policies

- Hold the Line (HTL)
- Managed Realignment (MR)
- No Active Intervention (NAI)

0 - 20 years
20 - 50 years
50 - 100 years
From 2010

Note that the policy lines on the map show the preferred shoreline management policy for each period and do not represent either the shoreline or defence location

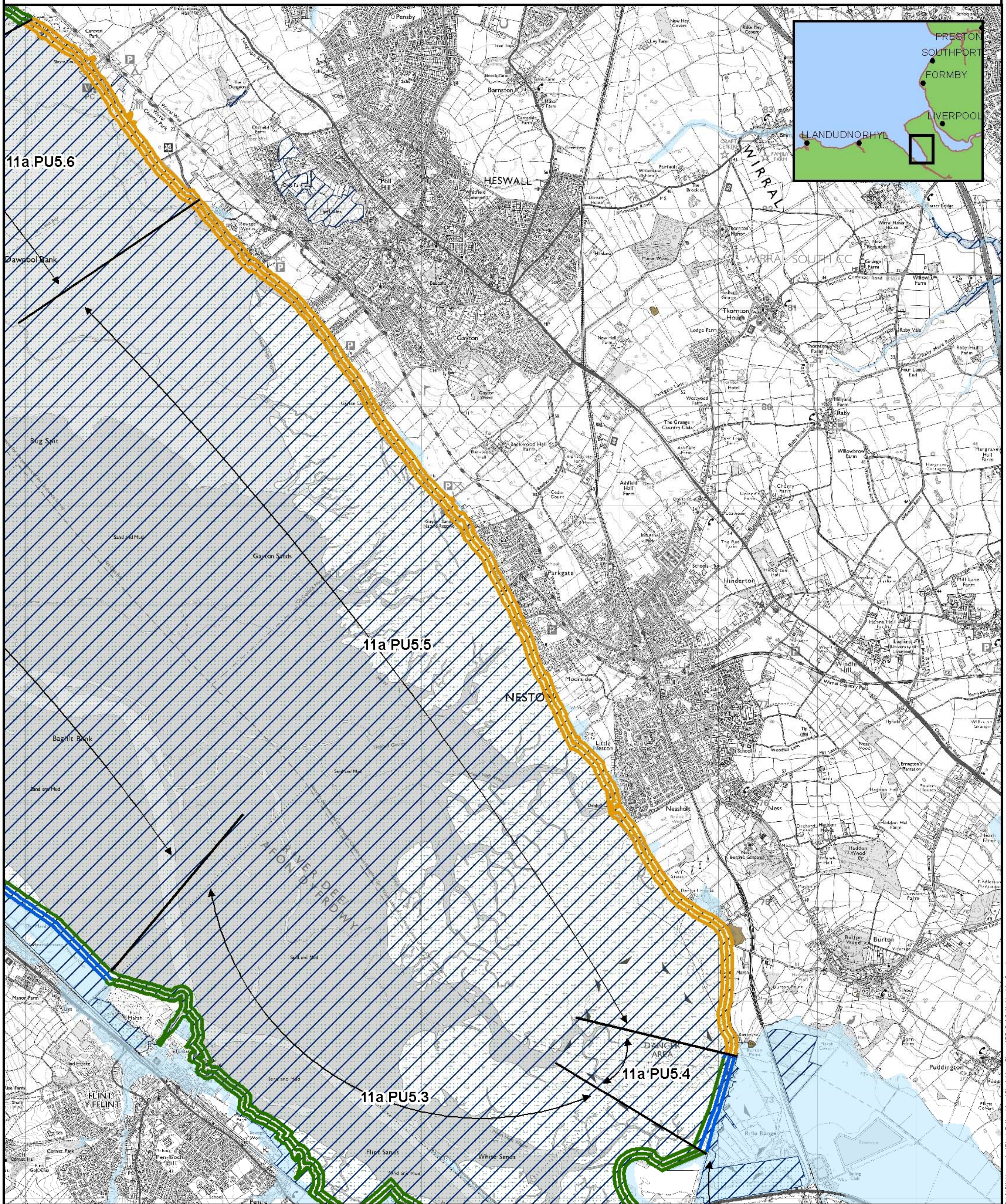
Halcrow

Boxes showing cumulative erosion estimates represent the expected minimum and maximum erosion distance from the shoreline position in 2010. They are only shown where there is a NAI policy and coastal erosion is the main risk

North West England and North Wales Shoreline Management Plan 2

Sub-Cell 11a: Area: 5 Map: 4

North West & North Wales Coastline
a partnership for coastal defence management



Legend

- National Nature Conservation Designations
- International Nature Conservation Designations
- Scheduled Monuments
- Coastal flood risk area under extreme events, Environment Agency Flood Map 2008

Shoreline Management Policies

- Hold the Line (HTL)
- Managed Realignment (MR)
- No Active Intervention (NAI)
- Policy Unit Boundary
- Policy Unit Extent

0 - 20 years
20 - 50 years
50 - 100 years
From 2010

Note that the policy lines on the map show the preferred shoreline management policy for each period and do not represent either the shoreline or defence location

Halcrow

N
0 0.25 0.5 1 Kilometres
Scale: 1:35,000

Boxes showing cumulative erosion estimates represent the expected minimum and maximum erosion distance from the shoreline position in 2010. They are only shown where there is a NAI policy and coastal erosion is the main risk

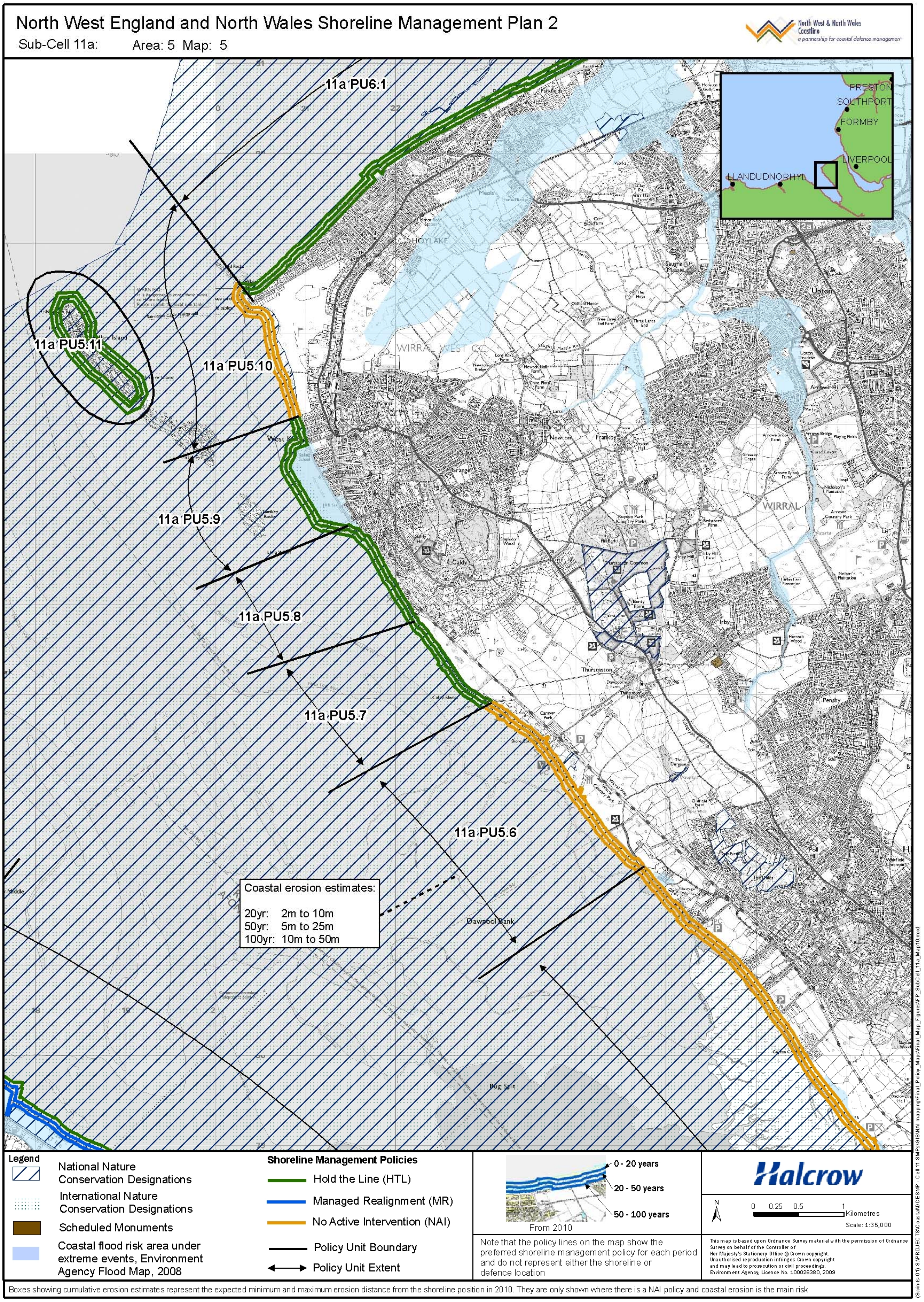


Figure 3.7 SMP2 Policy maps for the Dee (from Halcrow, 2010a).

Since the finalisation of the SMP2, The Environment Agency Wales (now Natural Resources Wales) has developed a more detailed flood risk management strategy for the Dee, covering the Welsh shore from Talacre to Chester and the east shore to Neston. Although the strategy was completed in March 2013 (Environment Agency Wales, 2013), technical reports had not been released and were not made available to this study. The consultation draft and non-technical summary indicate that the strategy endorses the recommendations in the SMP2 for monitoring coastal processes, particularly sediment transport studies and morphological change monitoring. In addition, it recommends a beach management and recharge strategy with associated monitoring involving Flintshire CC, Denbighshire CC and CCW (now part of Natural Resources Wales). The strategy proposals broadly align with the policies in the SMP2 and generally support holding the line with some sites identified for localised realignment. The strategy environmental assessment included consideration of the potential for coastal squeeze of estuarine habitats and estimates showed no losses in the first epoch (up to 2030) and limited losses of between 140ha and 280ha in the 2nd epoch (2030 to 2060) using lower end and upper end estimates of sea level rise, respectively, based on the EA climate change guidance (EA, 2011).

Wirral Council are currently in the process of developing a coastal strategy for all of their shoreline, including the Dee seaward of Neston.

3.7 Existing Monitoring Data

Details of the monitoring data being collected for the Dee Estuary and an assessment of the value that this data brings is summarised in Table 3.2 The map in Figure 3.8 shows the location of beach profiles and data collection stations.

Table 3.2 Existing monitoring data collected and value assessment.

Description of monitoring data collected	Assessment of value of data collection	Reference to further information
Beach profile data. Sparse coverage on the west bank close to the mouth and detailed coverage on the east bank close to the mouth of the estuary.	Beach monitoring ensures that coastal managers have an understanding of the changes occurring on the coastline and can take pro-active rather than re-active approaches to management.	CERMS Update Report, Section 2.4.1 (Halcrow, 2010f).
Monitoring of the position of the seaward edge of the saltmarsh along the Welsh coast of the River Dee between Talacre and Connah's Quay has been carried out bi-annually since autumn 2002.	As above.	CERMS Update Report, Section 2.5.1 (Halcrow, 2010f)
Tide gauge 1 (Mostyn Dock), located on the west bank of the estuary. Owned by Port of Mostyn Dock. Captures water level. Data is available from 2000 to present.	Useful for monitoring long-term trends in water level (particularly extreme water levels and any sea level rise) and use in interpretation of measured beach and bathy data and hydrodynamic modelling.	CERMS Update Report, Section 2.4.1 (Halcrow, 2010f) CERMS Tide Gauge Review (Halcrow, 2010g)
Tide gauge 2 (End of Dee Training Wall), located on the west bank of the estuary, towards the head of the estuary. Owned by Airbus UK Captures water level. The period of data available is not specified in the CERMS Tide Gauge Report (Halcrow, 2010g).	Useful for monitoring long-term trends in water level (particularly extreme water levels and any sea level rise) and use in interpretation of measured beach and bathy data and hydrodynamic modelling.	CERMS Tide Gauge Review (Halcrow, 2010g)

Description of monitoring data collected	Assessment of value of data collection	Reference to further information
Tide gauge 3 (Summers Jetty / Corus Jetty), located towards the upper estuary. Owned by Environment Agency NW. Captures water level. Data is available from 27/07/95 to present.	Useful for monitoring long-term trends in water level (particularly extreme water levels and any sea level rise) and use in interpretation of measured beach and bathy data and hydrodynamic modelling.	CERMS Update Report, Section 2.4.1 (Halcrow, 2010f) CERMS Tide Gauge Review (Halcrow, 2010g)
Tide gauge 4 (West Kirby/Marine Lake), located on the east bank of the estuary. Refer to environmental data station below.	Refer to environmental data station below.	Refer to environmental data station below.
Tide gauge 5 (Hilbre Island), located on the east bank of the estuary but just offshore. Owned by Mersey Dock and Harbour Company (MDHC), (now Peel Ports). Captures water level. Data is available from 1956 – 2009. Digital record available from 1964-81 (intermittently) and since 2000. Unreliable data from 2007. Decommissioned by MDHC in 2009. Possible that NOC/POL/CERMS may take over to continue long record.	Useful for monitoring long-term trends in water level (particularly extreme water levels and any sea level rise) and use in interpretation of measured beach and bathy data and hydrodynamic modelling.	CERMS Update Report, Section 2.4.1 (Halcrow, 2010f). CERMS Tide Gauge Review (Halcrow, 2010g).
Marine X-band radar system (Hilbre Island), located on the east bank at mouth of the estuary. Owned by NOC. Captures wave height and direction. Data is available from 2003 to present.	Useful for monitoring waves, bedform movement and use in hydrodynamic modelling.	CERMS Update Report, Section 2.4.1 (Halcrow, 2010f).
Wind station (Hilbre Point), located on the east bank at mouth of the estuary. Owned by NOC No longer available since closure of the Liverpool Bay Coastal Observatory at the end of 2012 Captures wind speed and direction, temperature and barometric pressure. The period of data available is not specified in the CERMS Update Report (Halcrow, 2010f).	Useful for monitoring long-term trends in water level, wind speed and weather patterns and use in hydrodynamic modelling.	CERMS Update Report, Section 2.4.1 (Halcrow, 2010f).
Environmental data station (West Kirby/Marine Lake) located on east bank at mouth of the estuary. Owned by Metropolitan Borough of Wirral. Captures water level, wind speed and direction, temperature and barometric pressure. Digital data is available from 01/08/2008 to present.	Useful for monitoring long-term trends in water level, wind speed and weather patterns and use in hydrodynamic modelling.	CERMS Update Report, Section 2.4.1 (Halcrow, 2010f). CERMS Tide Gauge Review (Halcrow, 2010g).

Description of monitoring data collected	Assessment of value of data collection	Reference to further information
Bathymetric surveys, dredging records, environmental monitoring. Surveys of the approach channel and navigation channels are undertaken by Port of Mostyn. Other surveys and monitoring related to navigation and environmental assets are collected by NRW.	Data not available to CERMS but may have value to assist in understanding of processes and change.	Natural Resources Wales (formerly EA Wales) is the navigation authority in the Dee Conservancy.
Hydrographic monitoring by Airbus. The navigation channel to the Airbus berth and precision tidal level monitoring at several stations is undertaken to facilitate the transportation of Airbus wings from Broughton.	Data not available to CERMS but may have value to assist in understanding of processes and change.	Tidal Dee Users Group

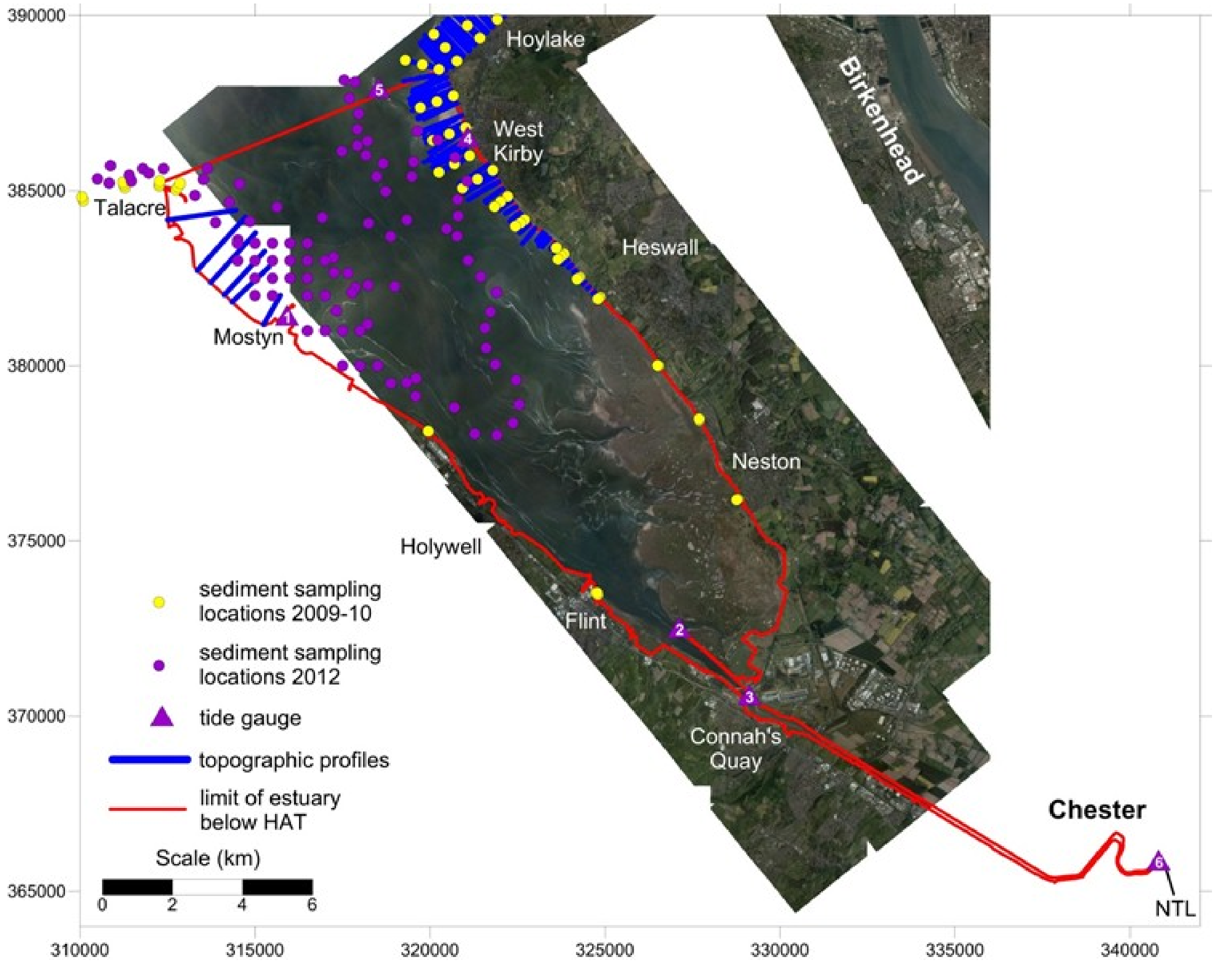


Figure 3.8 Summary of available monitoring data for the Dee Estuary. Tide gauges located at: (1) Mostyn Dock (operated by Port of Mostyn Dock); (2) End of Dee Training Wall (operated by Airbus UK); (3) Summers Jetty, Connah's Quay (operated by the EA); (4) Marine Lake, West Kirby (operated by Metropolitan Borough of Wirral); (5) Hilbre Island (operated by MDHC to 2009); and (6) Chester Weir (operated by the EA).

The Tidal Dee Users Group and Port of Mostyn collect a large amount of monitoring data which is currently not available for interpretation within CERMS.

The Tidal Dee Users Group maintain a database which includes residual flow of the Dee at Chester Weir and river discharge at the Chester Suspension Bridge - see Tidal Dee Users Group (2007). It is understood the data includes swath bathymetry surveys. Estimates of sediment volume change between 2003 and 2006 were made; it is not known if similar assessments for later periods have been made.

3.8 Gaps in Understanding

In Cell 11 a number of previous reports have identified gaps in understanding, including issues and uncertainties related to coastal and estuarine processes and shoreline management. Some of the uncertainties identified in the earlier studies (e.g. SMP1, Futurecoast) were subsequently addressed by the later studies (e.g. CETaSS, SMP2, CERMS; EA, 2011). The CERMS regional baseline understanding report (Halcrow, 2010b) provided a full listing of previous uncertainties in the Cell 11 area.

For the present report we have reviewed the list of uncertainties previously identified for the Dee Estuary and have identified the most important areas where future studies/monitoring are required (Table 3.3). We have organised these by thematic areas:

- Flood and coastal defences
- Habitat losses and creation
- Coastal and estuary morphodynamics
- Port developments
- Water quality
- Data collation

We have noted where these actions might be best undertaken by the CERMS group or by other parties.

Due to the strong linkages between coastal processes in the whole of Liverpool Bay and the Dee estuary, the issues and recommendations listed below should be considered alongside the wider issues and generic recommendations for the other Cell 11 estuaries. This is considered within the main overarching report (CH2M HILL, 2013).

In the context of the other estuaries in Cell 11, the Dee has been highly studied and there are significantly more data available than for many of the other estuaries. However, much of the information believed to be available to the Tidal Dee User Group still needs to be brought into the CERMS programme. Due to this and the fact that FCERM strategy studies have been recently completed, the priority under the CERMS programme for undertaking new data collection and processes studies in the Dee is reduced in comparison with other estuaries in Cell 11.

Table 3.3 Data gaps and recommendations

Issue	Location	Comments	Recommendations
Flood and coastal defences Defence condition, ownership condition and maintenance data require review. A number of morphodynamic issues have relevance to defence provision, see below	Whole estuary	The defence data in Appendix A is taken from the SMP2 and based on a range of sources. Since the SMP2 strategy studies have been undertaken by Natural Resources Wales and Wirral Council. It is not known if an updated defence database for the overall estuary has been compiled, but this is recommended if not. This is low priority as a strategy has already been developed, but should be done before the next SMP review.	1. Update defence database using data from the two strategies. Continue ongoing maintenance and monitoring. (See item 1 in Appendix B) **Urgency – low** **Importance – medium** **Difficulty – low** **Overall Priority - low**
Habitat losses and creation Viability of managed realignment and flood storage	Whole estuary	The SMP2 and Dee strategy have recommended the feasibility of managed realignment is investigated for a number of sites. This will require Dee Estuary wide modelling and geomorphological studies considering managed realignment, habitat creation and flood storage options to inform implementation of the estuary wide strategy and develop any necessary mitigation for impact on the internationally designated sites.	2. The modelling and investigations will require good quality baseline and monitoring data on the estuary to calibrate and test models. Much data already exists for the Dee, but future monitoring should prioritise data required for these studies (see below). **Urgency – medium** **Importance – medium** **Difficulty – medium** **Overall Priority - medium**
Coastal and estuary morphodynamics Uncertainty over the future sediment supply to the estuary.	Estuary and adjacent coast	The SMP2 recommended monitoring and a sediment transport study to develop a strategic approach to beach management and beach recharge for the whole north Wales frontage from Little Orme through to the Dee estuary. Developing further recommendations for the studies required for the north Wales coast is beyond the scope of this study. However, the CERMS programme should work closely with Natural Resources Wales and the North Wales Local Authorities to encourage strategic monitoring of the North Wales coast including LiDAR, beach profiles and bathymetric surveys and sediment sampling to gather and share data to inform the proposed studies.	3. Collection and analysis of sediment samples from within the Dee estuary and adjacent parts of Liverpool Bay. (see item 2 in Appendix B) **Urgency – medium** **Importance – medium** **Difficulty – medium** **Overall Priority - medium**

Issue	Location	Comments	Recommendations
Coastal and estuary morphodynamics Future morphological evolution of estuaries under SLR and ability to keep pace with sea level rise in the medium and longer term	Whole estuary	It is unclear if sea level rise, changed wave climate or changes to river flows will maintain or increase the landward movement of sediment (both silt and sand), and whether the positive sediment fluxes will be sufficient to keep pace with sea level rise (particularly in the longer term) and therefore there is uncertainty over potential for future coastal squeeze and requirements for RHCP in long term. While baseline bathymetry data exists future updates are required in order to monitor ongoing change and calibrate models of future evolution	4. Collection of synoptic swath bathymetry and LiDAR surveys. The last combined swath / Lidar survey commissioned by the Tidal Dee User Group was in 2006, so a repeat is recommended by 2016. (See item 3 in Appendix B). **Urgency – medium** **Importance – medium** **Difficulty – medium** **Overall Priority - medium**
Coastal and estuary morphodynamics Uncertainty over future evolution of banks and channels. Bathymetry at the mouth may be important for hydrodynamics and impacts water levels in the estuary and thus flood risk.	Banks and channels in outer Dee	Also of interest to navigation. Consider collaboration with Port of Mostyn and others in TDUG for future data collection.	As above.
Port developments Port operation, maintenance and development, including dredging and training walls, play an important role in determining the morphodynamics of the Dee estuary.	Whole estuary	Activities related to port operations will be subject to normal planning and concerning requirements. Aspects of estuary morphology related to these activities are best covered under scheme specific assessments and studies.	5. Work with TDUG to Collate publically available data from development studies as and when it becomes available. NRW & LA's to review EIA submissions to that check that estuary morphology and changes to FCERM risk is considered in EIA studies and scoping documents. Seek opportunities for collating underlying data sources such as bathymetry, numerical models etc during consultations. **Urgency - low** **Importance – high** **Difficulty – medium** **Overall Priority - medium**
Water quality There are a large number of	Whole estuary	The SMP2 Action Plan recommended a Dee estuary wide study to investigate links between land	6. Any data or results of modelling undertaken should be incorporated into CERMS database and made available for future

Issue	Location	Comments	Recommendations
former landfill sites around the estuary that could be impacted by erosion and / or managed realignment of defences.		contamination and flood risk management options in order to inform long term strategy on the requirements for implementation of measures to address any problems arising from this study including consideration of removal of contamination so as not to constrain future management.	studies. **Urgency - low** **Importance – medium** **Difficulty – medium** **Overall Priority - low**
Data collation Data is collected by a number of organisations within the Tidal Dee Users Group. However, uncertain if the data is available to the wider coastal group.	Whole estuary	Data sharing agreements.	7. Strengthen links between CERMS and TDUG. **Urgency - medium** **Importance – medium** **Difficulty – low** **Overall Priority - medium**

4 Discussion and Conclusions

Within the context of flood and coastal erosion risk management across the Cell 11, the Dee estuary has significant risks due to the development in reclaimed areas, particularly in the flood plain of the inner Dee. Due to the potential future impacts of the coastal defences on the internationally important environmental assets in the estuary it has a relatively high priority for monitoring. However, in recent years the Dee has been studied in more detail than most of the other Cell 11 estuaries. Furthermore, subsequent to the SMP2 development, strategy studies for coastal flood and erosion risk management have already been undertaken, reducing the urgency of short term data collection and coastal process studies in comparison to other Cell 11 estuaries where post SMP2 strategies are yet to be developed.

Full details of the Dee Strategy and Wirral coastal strategy that have been under development by Natural Resources Wales and Wirral Council respectively were not available for this review. Once they have been finalised and action plans put in place for delivery this report should be reviewed and updated to include any further specific monitoring actions that have been identified that need to be incorporated within CERMS.

The review of available monitoring data has highlighted that there is a significant amount of existing monitoring data held and ongoing monitoring underway by members of the Tidal Dee Users Group. A priority should therefore be to make this data available through CERMS and NRW for future shoreline management studies and coastal defence research.

There are strong sediment transport linkages between the North Wales coast and the Dee estuary. The SMP2 recommended a sediment transport and beach management study for the coast up-drift of the Dee. This study is still needed and would be logically led by Natural Resources Wales or the Welsh Coastal Authorities.

A number of additional studies are recommended to address the gaps in understanding identified in Section 3 of this report. Details of the issue/ uncertainty, the source of the recommended study, recommended study and purpose, and an assessment of the study priority are presented in Table 3.3 and further information on specific studies / data collection recommendations are given in Appendix B.

5 References

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Appendix A: Coastal Defences in the Dee Estuary

Appendix A: Coastal Defences in the Dee Estuary

This data has been sourced from the SMP2 (Halcrow, 2010b).

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Point of Ayr, Llanasea Embankment National Grid: (312430E 384975N) to (312758E 384022N)	Unknown	Earth embankment with outfall discharge channels.	>10	Saltmarsh	Flintshire CC coastal defence inspection 2007. Residual life from 2008 condition inspection.
Point of Ayr Colliery National Grid: (312758E 384022N) to (312911E 383748N)	Built in 1990s	Rock revetment	20-30	Sand and marsh foreshore	Flintshire CC coastal defence inspection 2007
Sluice House Gutter National Grid: (312911E 383748N) to (312899E 383622N)	Unknown	Natural shoreline with disused sheet pile wall.	N/A	Saltmarsh; Gutter channel	Flintshire CC coastal defence inspection 2007
Tanlan Banks, Colliery Tip National Grid: (312899E 383622N) to (313339E 382739N)	Built in 1990s	Rock revetment	20-30	Sand and mud foreshore	Flintshire CC coastal defence inspection 2007
Ffynnongroyw Sea Wall National Grid: (313339E 382739N) to (316179E 380603N)	Built in 1845 and refurbished with concrete units in 1990 following breaches.	Masonry faced vertical seawall with occasional rock toe.	10-20	Sand and mud foreshore, shingle and cobble lower shore.	Flintshire CC coastal defence inspection 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Mostyn Industrial Estate 1 National Grid: (316179E 380603N) to (316500E 380350N)	N/A	Natural shoreline with tipped rubble	N/A	Sand and shingle foreshore	Flintshire CC coastal defence inspection 2007
Glan-y-Don Embankment National Grid: (316500E 380350N) to (317721E 379623N)	Unknown probably 1800s.	Blockwork revetment. Sections of revetment are covered with concrete and there is an informal wall along structure crest. Remedial works necessary.	<10	Cobble and shingle upper shore with sandy lower shore.	Flintshire CC coastal defence inspection 2007
Mostyn Ship - Llannerch-y-Mor Gutter National Grid: (317721E 379623N) to (317809E 379435N)	Unknown - possibly old quay wall	Seawall	<20	Sand and mud foreshore	Flintshire CC coastal defence inspection 2007
The Marsh, Llannerch-y-Mor National Grid: (317809E 379435N) to (320032E 378076N)	Unknown	Rock revetment supplemented with demolition rubble. Secondary earth flood embankment. Crest remedial works are recommended.	10-20	Cobble and shingle upper shore with sandy lower shore.	Flintshire CC coastal defence inspection 2007
Greenfield Dock National Grid: (320032E 378076N) to (320077E 378015N)	Built in late 1990s	Rock revetment. New quay wall on upstream side.	20-30	Sand and mud foreshore	Flintshire CC coastal defence inspection 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Greenfield Works 2 National Grid: (320077E 378015N) to (320597E 377322N)	Constructed in 1970s	Broken concrete / demolition rubble revetment. Informal structure presenting a safety hazard with reinforcing bar exposed at surface.	10-20	Sand and mud foreshore.	Flintshire CC coastal defence inspection 2007
Greenfield Works 1 National Grid: (320597E 377322N) to (320794E 377059N)	N/A	Natural shoreline with rubble revetment in some sections.	N/A	Saltmarsh	Flintshire CC coastal defence inspection 2007
Greenfield Marsh 2 National Grid: (320794E 377059N) to (321289E 376336N)	Built in late 1800s	Block faced embankment	10-20	Saltmarsh	Flintshire CC coastal defence inspection 2007
Bagillt Clinks National Grid: (321289E 376336N) to (321379E 376069N)	N/A	Natural shoreline	N/A	Saltmarsh	Flintshire CC coastal defence inspection 2007
Whelston Gutter National Grid: (321379E 376069N) to (321620E 376184N)	N/A	Timber piles which are remnants of past dock walls. Otherwise natural defences.	N/A	Sand with upper vegetated marsh sections. Gutter mostly silted up with small channel meandering through.	Flintshire CC coastal defence inspection 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Bagillt Landfill National Grid: (321620E 376184N) to (321848E 376087N)	Sections constructed in 1992, 1998 and 2002.	Rock revetment	<20	Sand and mud foreshore.	Flintshire CC coastal defence inspection 2007
Bagillt Marsh National Grid: (321848E 376087N) to (322475E 375197N)	Unknown	Earth embankment	>10	Saltmarsh upper shore with sand and mud lower shore.	Flintshire CC coastal defence inspection 2007. Residual life from 2008 condition inspection.
Panton Cop – Lord Vivian's Embankment National Grid: (322475E 375197N) to (323805E 374215N)	Built in 1892	Earth embankment with blockwork facing on seaward side. Future defence options need to be considered.	5-10	Sand and mud foreshore.	Flintshire CC coastal defence inspection 2007
Flint Marsh National Grid: (323805E 374215N) to (324184E 374095N)	N/A	Natural shoreline	N/A	Saltmarsh upper shore with sand and mud lower shore	Flintshire CC coastal defence inspection 2007
Flint Point National Grid: (324184E 374095N) to (324554E 373898N)	Built in 1992	Rock revetment with fishtail rock groyne.	<20	Sand and mud foreshore.	Flintshire CC coastal defence inspection 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Flint Gutter National Grid: (324554E 373898N) to (324631E 373851N)	N/A	Natural shoreline	N/A	Saltmarsh upper shore with sand and mud lower shore.	Flintshire CC coastal defence inspection 2007
Castle Park, Flint National Grid: (324631E 373851N) to (324684E 373629N)	Built in 1992	Rock revetment with fishtail rock groyne	<20	Sand and mud foreshore	Flintshire CC coastal defence inspection 2007
Flint Castle National Grid: (324684E 373629N) to (324877E 373234N)	N/A	Natural shoreline	N/A	Saltmarsh upper shore with sand and mud lower shore.	Flintshire CC coastal defence inspection 2007
Flint National Grid: (324877E 373234N) to (325171E 373017N)	N/A	Gabion mattress. Remedial work required.	5-10	Saltmarsh upper shore with sand and mud lower shore.	Flintshire CC coastal defence inspection 2007
Marsh Farm, Flint National Grid: (325171E 373017N) to (325526E 372355N)	N/A	Natural shoreline	N/A	Saltmarsh upper shore with sand and mud lower shore.	Flintshire CC coastal defence inspection 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Network Rail Wall, Flint Sands National Grid: (325526E 372355N) to (326322E 371750N)	Built in 1870s	Vertical masonry seawall	>10	Saltmarsh upper shore with sand and mud lower shore.	Flintshire CC coastal defence inspection 2007. Residual life from 2008 condition inspection.
Connahs Quay Power Station / RSPB National Grid: (326322E 371750N) to (329280E 370000N)	Stone protection around Dee bridge abutments built in 1990s.	Natural shoreline with some areas of stone protection around bridge and intermittent bunding.	N/A	Saltmarsh upper shore with sand and mud lower shore.	Flintshire CC coastal defence inspection 2007 (revised 2008).
Connahs Quay Dock and Wharf National Grid: (329280E 370000N) to (329855E 369857N)	New wall built in 2003.	Various quay wall structures with intermittent sloping revetment. The new main quay wall comprises a steel sheet piled wall with a concrete capping beam. The older structures are a mixture of concrete, timber, steel and blockwork faced structures.	5-10	Sand and mud foreshore	Flintshire CC coastal defence inspection 2007
Connahs Quay 1a National Grid: (329855E 369857N) to (329995E 369782N)	Majority of defences built in 1739 but some improvement works in the late 1980s.	Sloping gabion mattress and steep block seawall	5-10	Sand and mud foreshore	Flintshire CC coastal defence inspection 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Connahs Quay to Wepre Gutter National Grid: (329995E 369782N) to (330252E 369445N)	Unknown	Earth embankment	Unknown	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008)
Wepre Gutter to Hawarden Bridge National Grid: (330267E 369443N) to (331025E 369305N)	Between Wepre Gutter and the Cop in Chester, defences built in 1739.	Earth embankment	Unknown	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008)
Hawarden Bridge to Shotton Pumping Station National Grid: (331025E 369305N) to (331519E 368951N)	Unknown	Earth embankment	Unknown	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008)
Shotton Pumping Station to Bascule Bridge National Grid: (331606E 368954N) to (332115E 368639N)	Unknown	Earth embankment	Unknown	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008)
Bascule Bridge to upstream sewage works National Grid: (332115E 368639N) to (332536E 368392N)	N/A	No defences	N/A	Vegetated river banks and channel	Defences interpreted from Google Earth (accessed 08/08/2008)

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Upstream sewage works to Brymau Four Estate National Grid: (332536E 368392N) to (337614E 365335N)	Unknown	Earth embankment	Unknown	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008)
Brymau Four Estate to Brymau One Estate National Grid: (337614E 365335N) to (338330E 365348N)	N/A	No defences	N/A	Vegetated river banks and channel	Defences interpreted from Google Earth (accessed 08/08/2008)
Brymau One Estate National Grid: (338330E 365348N) to (338569E 365396N)	Unknown	Vertical quay wall	Unknown	River channel	Defences interpreted from Google Earth (accessed 08/08/2008)
Brymau One Estate to footpath to Saltney Junction National Grid: (338569E 365396N) to (338749E 365536N)	N/A	No defences	N/A	Vegetated river banks and channel	Defences interpreted from Google Earth (accessed 08/08/2008)
Footpath to Saltney Junction to opposite Dee Lock National Grid: (338749E 365536N) to (339648E 366409N)	Unknown	Earth embankment	Unknown	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008)

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Opposite Dee Lock to weir, Chester National Grid: (339648E 366409N) to (340861E 365857N)	N/A	No defences	N/A	Vegetated river banks and channel	Defences interpreted from Google Earth (accessed 08/08/2008)
Weir at Chester to railway bridge National Grid: (340663E 365801N) to (339688E 365906N)	Unknown	Vertical wall with tree-lined grass bank	Unknown	Vegetated river banks and channel	Defences interpreted from Google Earth (accessed 08/08/2008)
Railway bridge to Dee Lock National Grid: (339688E 365906N) to (339806E 366531N)	Unknown	Vertical wall	Unknown	River channel	Defences interpreted from Google Earth (accessed 08/08/2008)
Dee Lock to Hawarden Bridge National Grid: (339806E 366531N) to (331130E 369441N)	Unknown	Earth embankment	Unknown	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008)
2nd Dee Crossing to Hawarden Bridge National Grid: (331130E 369441N) to (329010E 370720N)	Unknown	Earth embankment with masonry core	>10	Sand and mud foreshore with areas of marsh.	Flintshire CC coastal defence inspection 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
2nd Dee Crossing to Flint Sands National Grid: (329010E 370720N) to (325870E 373560N)	Unknown	Earth embankment fronted with rock armour and leading into River Dee training wall.	>10	Expansive saltmarsh area to landward, river channel runs along toe.	Flintshire CC coastal defence inspection 2008 (in preparation).
White Sands Embankment National Grid: (329440E 371250N) to (329200E 371740N)	Earth embankment	Earth embankment	> 5	Saltmarsh	Residual life estimated from SMP 1 and EA oblique coastal area photos Cell 11.
Broken Embankment National Grid: (329800E 372200N) to (330200E 373600N)	Earth embankment built in the 1980s.	Earth embankment	> 5	Saltmarsh	Residual life estimated from SMP 1 and EA oblique coastal area photos Cell 11.
Manorial Road, Moorside National Grid: (328269E 377316N) to (328066E 377776N)	Unknown	Private walls forming property boundaries.	>5	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008). Residual life from SMP1.
Manorial Road to Wirral Way, Wirral Country Park National Grid: (328066E 377776N) to (327314E 379088N)	Unknown	Masonry wall	>5	Saltmarsh	Defences interpreted from Google Earth (accessed 08/08/2008). Residual life from SMP1.

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Private frontage to Heswall Golf Club National Grid: (327117E 379234N) to (326522E 380049N)	Unknown	Embankment	>20	Saltmarsh	NFCDD
Heswall, north of Cottage Lane National Grid: (326522E 380049N) to (326249E 380483N)	N/A	Natural defence	N/A	Saltmarsh	NFCDD
Riverbank Road National Grid: (326278E 380419N) to (326190E 380600N)	Unknown	Sandstone block revetment	>10	Saltmarsh	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007. Residual life estimated from EA oblique coastal area photos Cell 11.
Riverbank Road (2) National Grid: (326249E 380479N) to (326110E 380691N)	Unknown	Vertical seawall	>20	Saltmarsh	NFCDD
Manners Lane, Heswall National Grid: (326110E 380691N) to (325933E 380921N)	Unknown	Vertical seawall	>20	Saltmarsh	NFCDD

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Marine Terrace Heswall National Grid: (325933E 380921N) to (325824E 381046N)	N/A	Natural defence	N/A	Saltmarsh	NFCDD
Banks Road to Marine Drive Heswall National Grid: (325824E 381046N) to (325359E 381458N)	N/A	Natural defence	N/A	Saltmarsh	NFCDD
Banks Road, Heswall National Grid: (325359E 381458N) to (325221E 381576N)	N/A	Natural defence	N/A	Saltmarsh	NFCDD
Moorings off Banks Road National Grid: (325221E 381576N) to (325079E 381723N)	N/A	Natural defence	N/A	Saltmarsh	NFCDD
Target Road sewage works National Grid: (325079E 381723N) to (324978E 381841N)	Unknown	Sheet steel piling with armour stone barrier	>20	Saltmarsh	NFCDD and Wirral Ground Shoreline Inspection September 2007

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Thurstaston Cliffs, Target Road National Grid: (324978E 381841N) to (324845E 381988N)	Unknown	Seawall	>20	Saltmarsh	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007
Target Road embankment National Grid: (324980E 381850N) to (324750E 382080N)	Substantially improved after the Towyn floods in 1990.	Clay embankment with rock armour revetment	>20	Saltmarsh and sand	NFCDD
North of Target Road, Heswall National Grid: (324845E 381988N) to (324626E 382185N)	N/A	Natural cliffs	N/A	Sandy beach	NFCDD
Thurstaston Cliffs National Grid: (324626E 382185N) to (323594E 383489N)	N/A	Natural cliffs	N/A	Mixed beach	NFCDD
Shore Cottages, Thurstaston National Grid: (323594E 383489N) to (323558E 383529N)	Unknown	Vertical wall protecting properties	>20	Sandy beach	NFCDD

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Thurstaston National Grid: (323558E 383529N) to (323018E 383923N)	N/A	Natural defence in form of cliffs	N/A	Mixed beach	NFCDD
Caldy Golf Club National Grid: (323018E 383923N) to (322246E 384806N)	Rock toe constructed 1988 (Southern half); 1993 (northern half).	Rock toe revetment to earth cliffs	>20	Mixed beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.
Shore Road, Caldy National Grid: (322246E 384806N) to (322212E 384849N)	Constructed 1980s	Rock toe revetment to earth cliffs	>20	Mixed beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.
Macdona Drive and Cubbins Green National Grid: (322217E 384849N) to (321771E 385635N)	Constructed 1980s	Rock armour	>20	Mixed beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.
West Kirby Private Frontage National Grid: (321771E 385635N) to (321495E 385884N)	Unknown	Sloping concrete revetment with crest wall.	>20	Mixed beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
West Kirby Marine Lake National Grid: (321495E 385884N) to (321017E 386785N)	Original masonry faced bund constructed 1899. Present wall constructed on new alignment 1986/7.	Embankment with sloping inner face protected with open stone asphalt and outer face with sheet piles and rock armour facing.	>20	Mixed beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.
South Parade National Grid: (321495E 385884N) to (320988E 386925N)	Original sloping sandstone block faced wall built in 1899. All apart from northern most 150 metres enclosed by Marine Lake wall.	Sloping sandstone block faced wall	>20	Mixed beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.
Lingdale to Riversdale Road National Grid: (320988E 386925N) to (320925E 387095N)	Southern most length constructed in late 1970s	Various private defences comprising vertical or sloping concrete walls and post/plank fences.	>20	Sandy beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.
Royal Liverpool Golf Club National Grid: (320925E 387095N) to (320387E 388298N)	Unknown	Natural dune belt with localised rock armour along toe of southern half of frontage.	>20	Saltmarsh and sand. Natural dunes	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.
Stanley Road, Hoylake National Grid: (320387E 388298N) to (320304E 388463N)	Sea wall built over / on top of sandstone rock outcrop (Red Rocks).	Vertical masonry or concrete seawall.	>20	Sandy beach	NFCDD. Defence type interpreted from photos in Wirral Ground Shoreline Inspection 2007.

Appendix B
Recommendations for further studies

Appendix B: Recommended further studies for the Dee Estuary

Recommended study	Outline scope	Outline cost estimate and priority
1. Update of flood and coastal defence database.	Study assumed to be led by EA, NRW or Sefton. Review data in Appendix A against latest held by EA NW & NRW on their Asset Information Management System (AIMS); the LLFA in their FWMA S21 register; defence condition data collected and used in the Dee and Wirral strategies; and defence monitoring data from Wirral, Denbighshire and Flintshire Council's defence inspections to compile latest data including mapping. Where data is not up to date undertake inspections. Update database and make available on SANDS and AIMS.	Estimated cost £10k to £20k, assuming packaged with other similar work in other estuaries or on open coast. Priority - medium as a strategy has already been developed since SMP2, but needed for national level studies such as NaFRA and should be done before the next SMP review
2. Sediment sample collection, analysis and pathway study.	Assumed to be led by Sefton, or NRW Undertake sediment sampling throughout Dee estuary to provide consistent set of baseline data covering upper, mid and lower intertidal and sub-tidal areas. Undertake analysis of the baseline data. Analysis to include full sediment sizing, mineralogical and chemical fingerprinting. The new data should be analysed to identify / confirm the sediment source – sink linkages in the conceptual model. This sediment study should be undertaken in combination with a wider analysis of sediment data from Liverpool Bay in order to identify offshore source pathway linkages. The aim of the study is to provide an improved understanding of mechanisms for supply of fine grained sediment to the estuary, improved models for testing managed realignment and reduced uncertainty over the future development of intertidal habitats and managed realignment sites in the medium to long term.	Estimated costs: Sediment sampling and analysis £10 to £20k? Sediment pathway analysis £10k? Priority Medium – needed before next SMP review
3. Bathymetric and LiDAR surveys of whole estuary, including adjacent areas of Liverpool Bay	Assumed to be led by Sefton or EA / NRW with contributions from others such as Airbus, Port of Mostyn, Natural England and Network Rail Full surveys to be undertaken at 5 to 10 year intervals. Undertake LiDAR survey of whole estuary at low tide. Swath bathymetry surveys at high tide to ensure overlap and allow creation of a seamless data set suitable for use in high resolution modelling and volumetric calculations.	Estimated cost: £75k to £125k Priority – Next survey required by 2016, then at 5 or ten year intervals.