



Appendix J1 Coastal Processes Study



Langstone Coastal Processes Study

Report

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1 Introduction and Background

The ~1km long Langstone frontage is located on the mainland, immediately north of Hayling Island. The internationally environmentally designated Langstone and Chichester Harbours merge at the point where the A3023, the only road crossing to Hayling Island, intersects the frontage (Figure 1.1). A number of residential properties as well as two public houses are located within a few metres of the water's edge.

The frontage is popular with locals and tourists due to its unique setting and is an important cultural heritage area, with 8 listed buildings in the Langstone Conservation Area and a historic wadeway from Langstone to Hayling Island. The foreshore here is mainly mudflat and saltmarsh with some sandy gravel areas adjacent to the seawall. Due to its sheltered nature, a low energy wave climate exists at the site.

The Portchester to Emsworth FCERM Strategy (2011) identified that 56 residential and 3 non-residential properties are currently at risk of tidal flooding from a 0.5% AEP (1 in 200 year) event under a Do Nothing scenario. In 100 years' time, as a result of predicted sea level rise, this increases to 81 residential and 5 non-residential properties at risk from a 0.5% AEP event. Flooding of four residential properties typically occurs along Langstone High Street annually. The Ship Inn car park also experiences regular flooding and there are other areas of the scheme such as Tower Gardens and The Saltings off the High Street and properties along the water's edge which have also recorded flood events and damage to structures. It is important to understand the coastal processes for engineering design and Environment Impact Assessment purposes. Figure 1.2 shows the present day Environment Agency Flood Zones 2 and 3 under a 1 in 1000 and 1 in 200 year Do Nothing scenario.

The relict spit from the old Hayling railway line lies to the west of Langstone Road (Figure 1.1). It currently offers some protection to the sailing club but is thought to be eroding. It is important to therefore understand how this will evolve in the future, the impact it may have and what (if any) works need to be carried out to stabilise the spit. The Lavant Spit is situated at the mouth of the Lavant Stream. It is a significant feature which likely affords some protection against approaching waves to the properties at Harbourside towards the western end of the scheme.

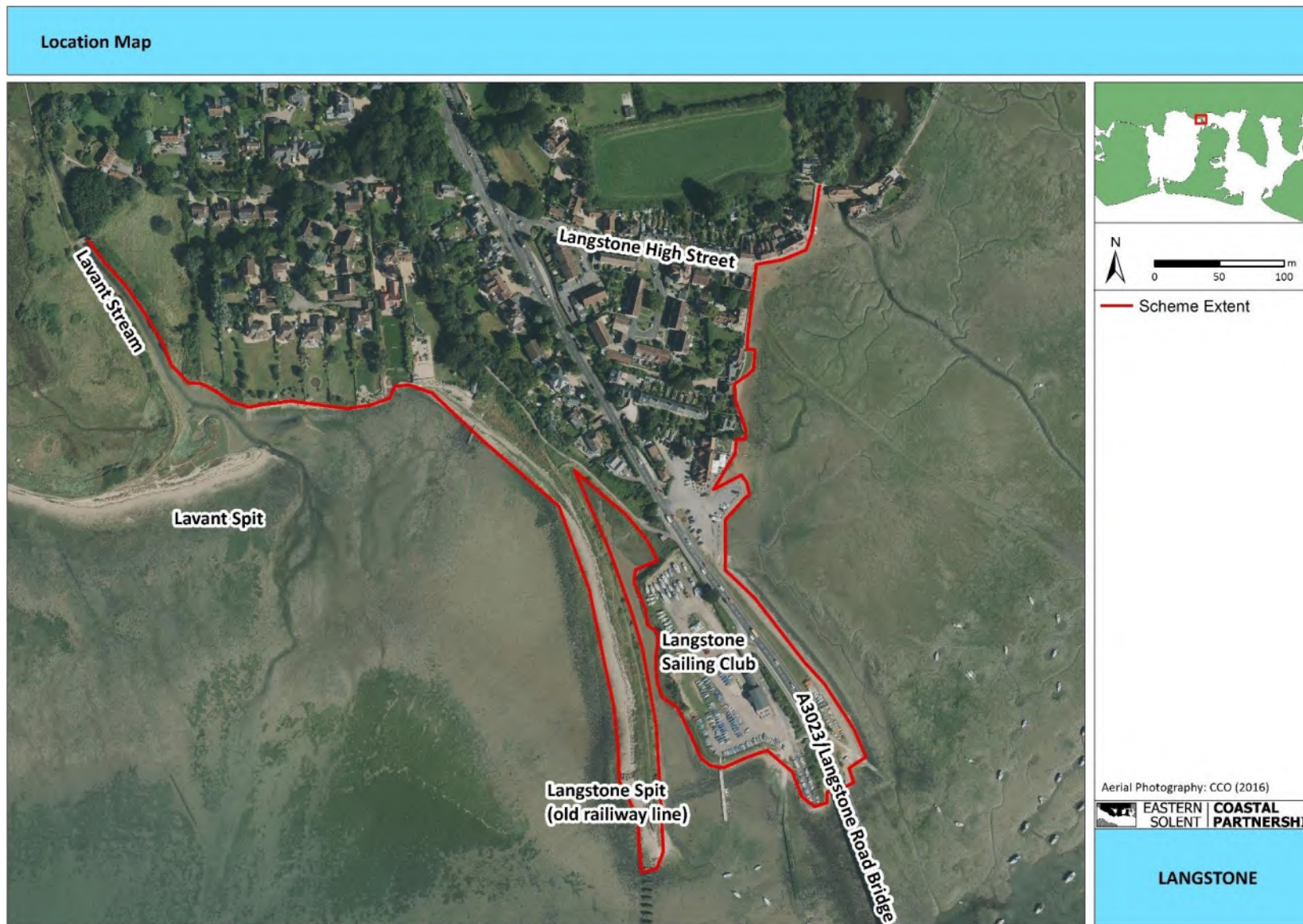


Figure 1.1 Key locations within the scheme area



Figure 1.2 Flood risk around the Langstone Scheme area

1.1 Aims

This study will report on the following:

- Baseline coastal processes conditions using the most up-to-date information available, including any climate change projections over the next 100 years for the whole scheme extent.
- The evolution of the Langstone Spit and Lavant Spit under a “Do Nothing” scenario for the short, medium and long term (20, 50 and 100 years).

2 Data, Information and Methods

2.1 Surveys and Aerial Photography

The Southeast Regional Coastal Monitoring Programme (SRCMP), has been collecting coastal data since 2002. The data used from the programme for the analysis in this study is as follows (Table 2.1):

Table 2.1 Data types used in the analysis and their sources

Data Type	Year	Source	Horizontal Accuracy (m)	Vertical Accuracy (m)
Lidar	2005	South-east Regional Coastal Monitoring Programme	0.4	±0.15
	2013	South-east Regional Coastal Monitoring Programme	0.4	±0.05
	2016	South-east Regional Coastal Monitoring Programme	0.4	±0.05
Aerial Photography	1946	© Crown Copyright/MOD, supplied by the National Monuments Record Centre		
	1963	© Crown Copyright Ordnance Survey. All rights reserved New Forest District Council 100026220 2005		
	1984	© Hampshire County Council		
	2002	South-east Regional Coastal Monitoring Programme		
	2005			
	2008			
	2013			
	2016			

The 2005 lidar data is a 2m gridded dataset, with a vertical accuracy of ±15cm. The 2013 and 2016 lidar data is gridded at 1m and has a vertical accuracy of ±5cm. The horizontal accuracy of all datasets is ±40cm, which is effectively absorbed in the pixels of the resolution (EA, 2016a). The lidar datasets have not been filtered and so still contain buildings and vegetation etc., which must be considered when the results are being analysed. Aerial photography for 2005 and 2016 is available which allows conclusions drawn from the lidar and difference plots to be verified.

This coastal processes report covers the following information and analysis:

1) Baseline conditions for the scheme frontage

- Carry out a review of any existing work (including The Portchester to Emsworth Strategy, the SCOPAC Sediment Transport Study and previous analysis by the Eastern Solent Coastal Partnership (ESCP) of spit movement). These will include information on waves, water levels and sediment type and movement.
- Use the Portchester to Emsworth Strategy (2012) to advise on waves and water levels. Information on this may also be available from the Portsea Island Coastal Strategy Study (PICSS) as well as other technical reports from the development of the North Portsea FCERM scheme, which included some modelling studies within Langstone Harbour.
- Review Environment Agency 2011 and 2016 latest guidance on climate change (sea level rise, increase in wave height and storminess). This will include values and percentages to add to existing levels to account for future change and ensure the scheme is built to last for its design life.
- Use aerial photography and the Solent Dynamic Coast Project (2008) for coastal habitat mapping and evolution. Saltmarsh is an effective natural dissipater of wave energy and has multiple habitat and species conservation designations (Figure 2.1 and Figure 2.2). It is therefore important to establish how it is evolving and how it may develop in the future.

2) Assess how the Langstone and Lavant spits have changed in the past and how they may evolve in the future

- Use the aerial photography (1946 – 2016) to digitise the position of the spits and map changes in the plan position over time
- Use lidar data (2005 – 2016) to take profile sections through the spit to measure more recent movement in finer detail.
- Use the same profile locations across the digitized spits and use the change to calculate a long-term erosion or accretion rate for the two spits. Use the measurements of the rates of change to project possible evolution in 20, 50 and 100 years' time, which will account for error and sensitivity testing.
- Make difference models to establish any hotspot areas of erosion along the frontage and gain further understanding of the spit movement. Carry out volumes analysis of the spits and hotspots of erosion in attempt to determine where the material on the spits is coming from and going to.
- Map contours for Mean High Water Springs (MHWS) to measure movement. This will give an objective validation of how the spits have been changing between 2005 and 2016.
- Use climate change predictions to assess if/when the spits may become inundated. At present the Langstone Spit is affording some protection to the Sailing Club and the Lavant Spit to the homes behind, but their function may be very different should sea levels rise enough that they effectively become inundated.
- The channel position over time at the Lavant Spit will give an indication of the relationship between water exiting the Lavant Stream and the spit size and position. This information can also be used to deduce future changes.

As part of this study, Dave Carter formerly from the University of Portsmouth produced a consultant's report, addressing specific issues which are listed below. The report is included as Appendix A at the end of this document and covers:

- The origin, use and position of the historic Langstone Wadeway
- The Langstone Railway Spit origin and evolution
- The Lavant Spit origin, evolution and feed

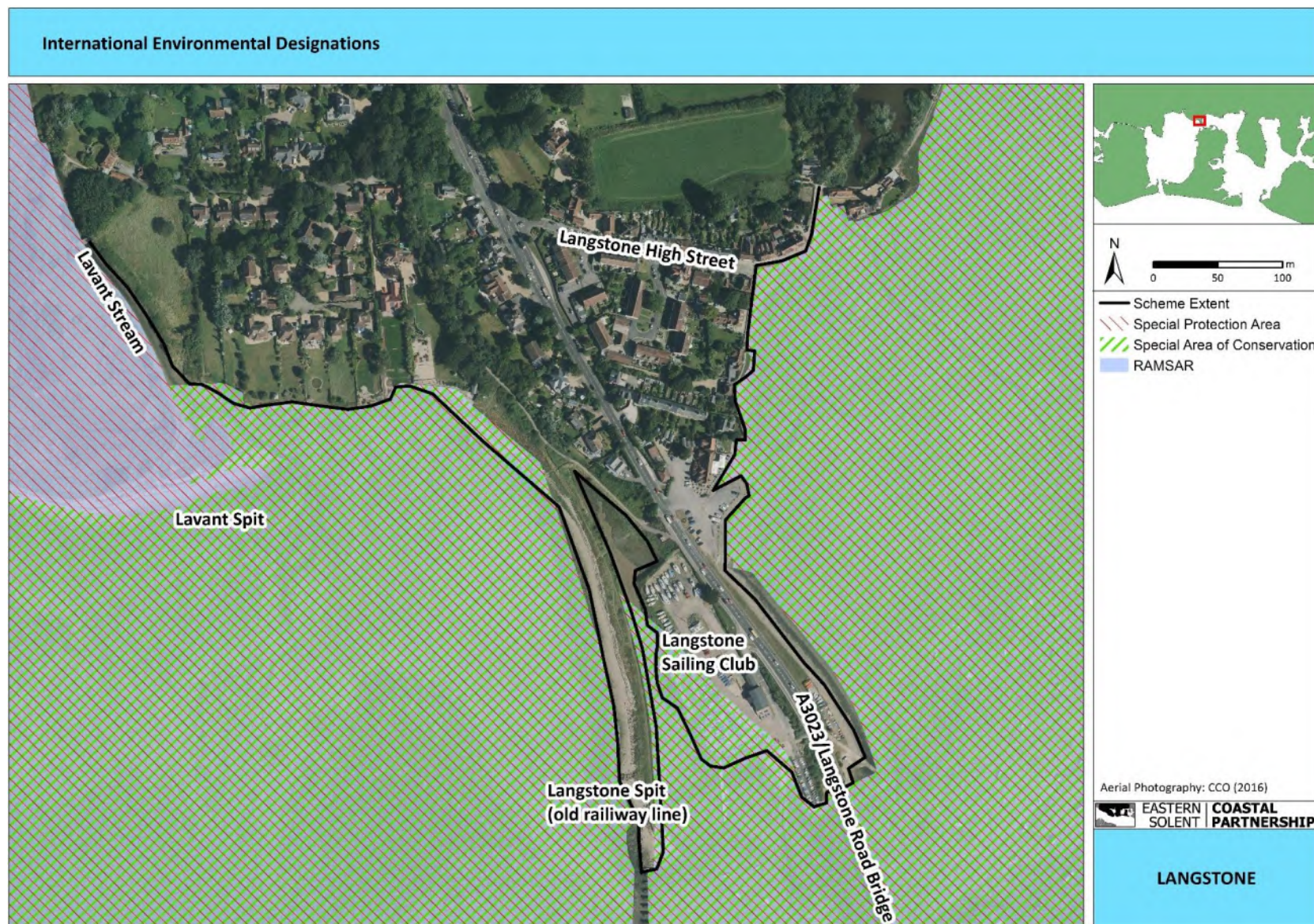


Figure 2.1 International environmental designations within the scheme area

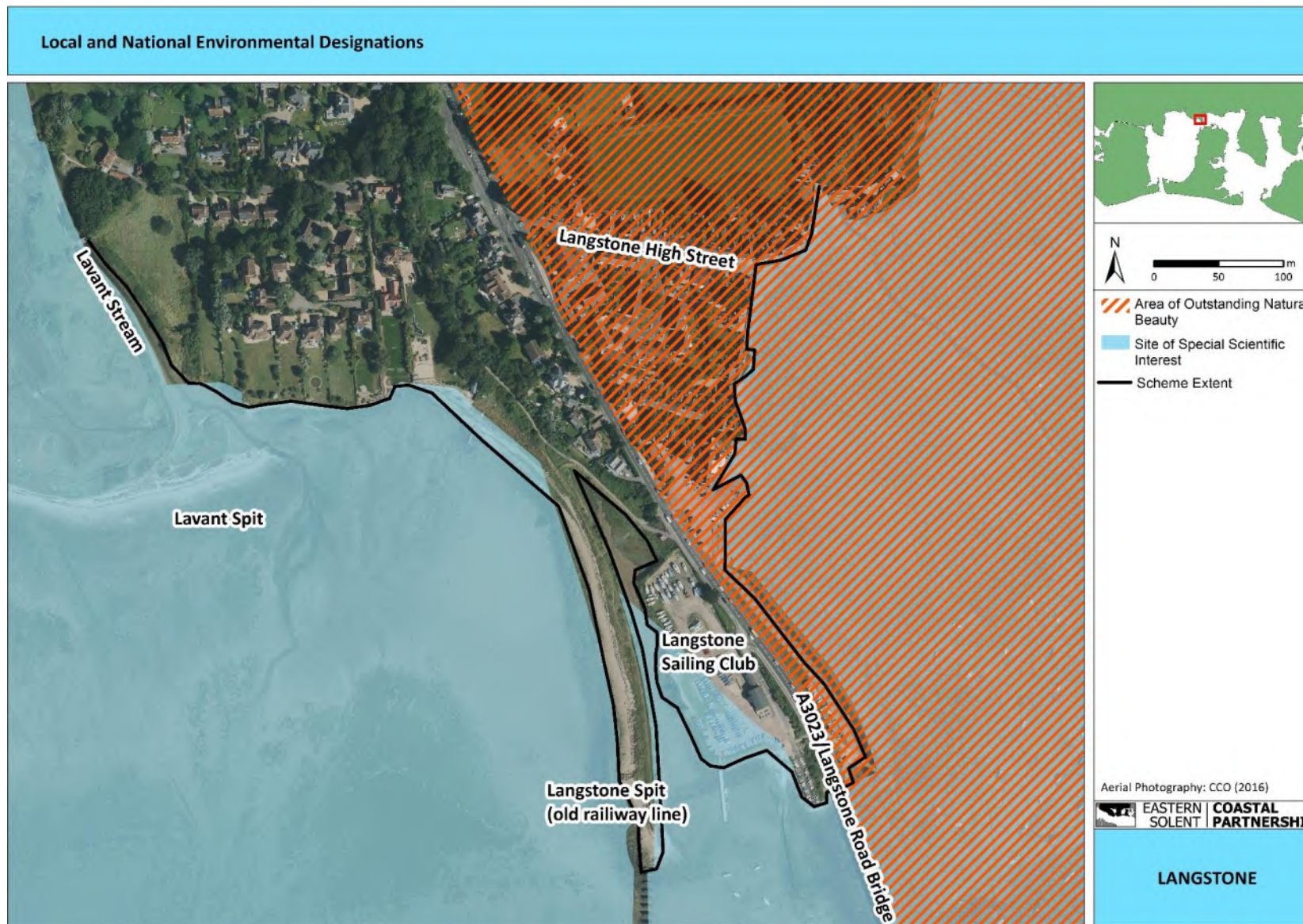


Figure 2.2 Local and National Environmental designations within the scheme area

3 Results

The results are presented in the following sections. Each section will outline the baseline understanding of the existing conditions, collating the available information from various sources and then follow on with the latest published climate change allowances.

3.1 Waves

3.1.1 Baseline

Wave data is readily available for the Solent and open coasts, however for the harbours the information is limited. There is a wave buoy off the coast of Hayling Island which has been in place since 2003 under the SRCMP. In addition, the NSSMP (2010) looked at the wave climate assessment, modelling waves derived from a long-term wind data set. The locations assessed in the study were all in the Solent and none inside the harbours.

The Portchester to Emsworth Strategy (2011) takes its wave data at this location from the East Solent SMP (1997), which precedes the North Solent SMP (2010) and is listed below (Table 3.1). These values are taken from Point 9 (Langstone East and West on Figure 3.1). The predominant wind is from the south-west/west.

Table 3.1 Design criteria for significant wave height (Hs) from the Strategy (Point 9 on Figure 3.1)

Design Criteria: Hs (m)		
1 in 1	1 in 10	1 in 50
0.97	1.13	1.24

The North Portsea Island CFERM Scheme included some modelling to establish wave conditions under a 1 in 200 year event in Langstone Harbour (RHDHV, 2014). The results show that the worst-case waves for the Langstone Scheme are under a southerly wind direction and are shown below (Figure 3.2). The maximum significant wave heights at the site of the scheme are in the range of 0.5-0.75m high. It should be noted that the study shows wave heights within the north of the harbour reaching up to 0.9m in height.

It can be assumed that wave heights and energy are low due to the extremely sheltered nature: the narrow harbour entrances restrict waves and the fetch is limited. A shallow harbour means that waves are depth limited near the shore. The main threat of flooding in this area is from still water level overtopping rather than wave overtopping.

The results from the studies above do not converge well and much of the data is outdated, it is therefore recommended that new extremes are developed for the Langstone FCERM design criteria.

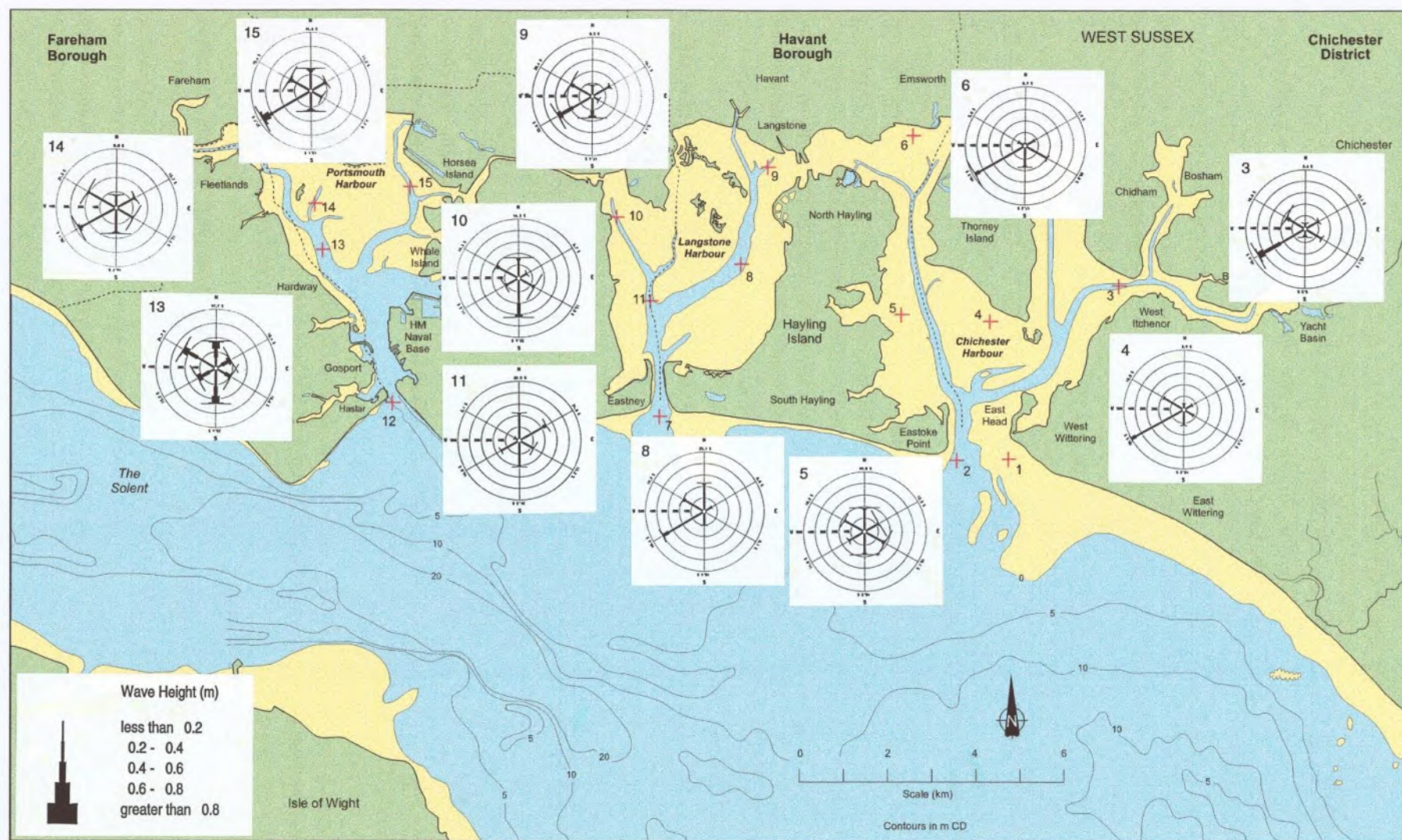


Figure 3.1 East Solent SMP (HR Wallingford, 1997)

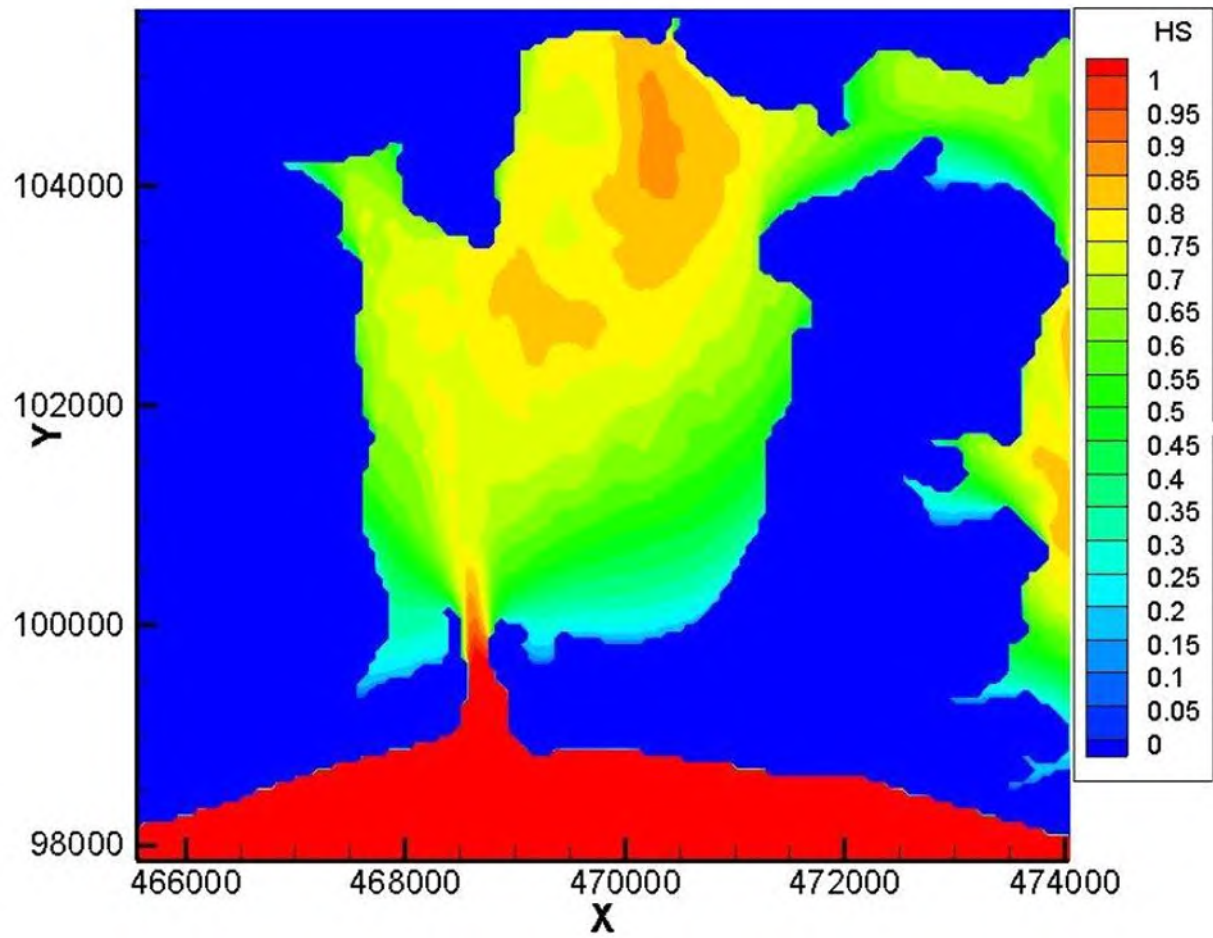


Figure 3.2 Significant wave height under a 1 in 200 year southerly wind condition (19.43m/s at 180°) (RHDHV, 2014).

3.1.2 Climate Change Allowances

The EA Flood Risk Assessments: Climate Change Allowances (2016) gives percentage change allowances for extreme wave heights for two different epochs. Wave heights may change due to changes in water depths that result from SLR and the frequency, duration and severity of storms and winds is also expected to change (EA, 2016). Table 3.2 shows the allowances that should be used for waves over the next 100 years due to climate change.

Table 3.2 Wave change allowances due to climate change, published by the EA (2016)

Applies around all the English coast	1990 to 2055	2056 to 2115
Offshore wind speed allowance	+5%	+10%
Offshore wind speed sensitivity test	+10%	+10%
Extreme wave height allowance	+5%	+10%
Extreme wave height sensitivity test	+10%	+10%

3.2 Tides

The tidal regime along the Solent is complex with an extended high water and spatially variable tides along the coastline. This section will summarise the existing published extreme water levels and tidal currents as well as sea level rise (SLR) due to climate change over the next 100 year period.

3.2.1 Baseline Water Levels

The water levels for both Portsmouth and Chichester are shown in Table 3.3 below (Admiralty Tide Tables, 2017):

Table 3.3 Current tide levels

	Portsmouth		Chichester	
	mCD	mOD	mCD	mOD
HAT	5.1	2.37	5.3	2.56
MHWS	4.7	1.97	4.9	2.16
MHW	4.25	1.52	4.45	1.71
MHWN	3.8	1.07	4	1.26
MWL	2.9	0.17	2.9	0.16
MLWN	1.9	-0.38	1.9	-0.84
MLW	1.35	-1.38	1.4	-1.34
MLWS	0.8	-1.93	0.9	-1.84
LAT	0.1	-2.36	0.2	-2.54

For extreme water levels, The Portchester to Emsworth Strategy drew on information from the East Solent SMP (1997) and the English Channel Extreme Tidal Level Review (ABPmer, 2004) to give extreme water levels up to a 1 in 100 year event at Portsmouth. The ABPmer 2004 study did not give levels inside the harbours, so values from the East Solent SMP (1997) were used. These are presented in the table below:

Table 3.4 Extreme water levels from the East Solent SMP (1997)

	Langstone East and West (Point 9, Figure 3.1 – above)			
Return Period	1 in 1	1 in 10	1 in 50	1 in 100
Water Level (mOD)	2.69	3.02	3.14	3.32

The North Solent SMP (2010) divided up the shoreline in to several zones to estimate the extreme 1 in 200 water level (Figure 3.3). Langstone sits inside area 15, between Hayling Island West and the Hampshire boundary.

Tidal zone	From	To	Extreme water levels (mOD) for a return period 1:200 year event							
			1990	2000	2010	2025	2055	2085	2108	2115
4	Hants boundary	Milford	2.2		2.3	2.3	2.6	3		3.4
5	Hurst	Keyhaven	2.3		2.4	2.4	2.7	3.1		3.5
6	Keyhaven	Tanners Lane	2.4		2.5	2.5	2.8	3.2		3.6
7	Tanners Lane	House-on-the-Shore	2.5		2.6	2.6	2.9	3.3		3.7
8	House-on-the-Shore	Beaulieu Beach Cottage	2.6		2.7	2.7	3	3.4		3.8
9	Beaulieu Beach Cottage	Lepe Country Park	2.7		2.8	2.8	3.1	3.5		3.9
10	Lepe Country Park	Stanswood Valley, Cadland	2.8		2.9	2.9	3.2	3.6		4
11	Stanswood Valley, Cadland to Hythe MOD	RVCP to Titchfield Haven	2.9		3	3	3.3	3.7		4.1
12	Titchfield Haven	Gilkicker Point	3		3.1	3.1	3.4	3.8		4.2
13	Gilkicker Point	Southsea Pier	3.1		3.2	3.2	3.5	3.9		4.3
14	Southsea Pier	Hayling Island west	3.2		3.3	3.3	3.6	4		4.4
15	Hayling Island west	Hants boundary	3.3		3.4	3.4	3.7	4.1		4.5

Figure 3.3 North Solent SMP extreme tidal data (data originates from EA)

The Environment Agency Coastal Flood Boundary Dataset was published in 2011 (EA, 2011). Extreme water levels were produced for Portsmouth Harbour which are quoted in Table 3.5 below.

Table 3.5 EA Coastal Flood Boundary Dataset (2011)

Extreme Water Levels at Portsmouth				
Return Period	1 in 1	1 in 10	1 in 50	1 in 200
Water Level (mOD)	2.56	2.81	2.98	3.12

The North Solent SMP also collated the information from several sources on extreme water levels. The extreme 1 in 200 year water levels for Langstone Harbour between 1990 and 2115 are presented in Table 3.6 for a range of return periods.

Table 3.6 Extreme water levels for Langstone Harbour (NSSMP, 2010)

Year	Water elevation mOD								
	1990	2000	2007	2010	2025	2055	2085	2107	2115
Mean Low Water Springs			-1.93	-1.92	-1.86	-1.60	-1.24	-0.91	-0.79
Mean Low Water Neaps			-0.83	-0.82	-0.76	-0.50	-0.14	0.19	0.31
Mean Sea Level			0.20	0.21	0.27	0.53	0.89	1.22	1.34
Mean High Water Neaps			1.17	1.18	1.24	1.50	1.86	2.19	2.31
Mean High Water Springs			2.07	2.08	2.14	2.40	2.76	3.09	3.21
1 in 20 yr	2.90	2.94	2.97	3.00	3.00	3.30	3.70	4.03	4.10
1 in 50 yr	3.00	3.04	3.07	3.10	3.10	3.40	3.80	4.13	4.20
1 in 100 yr	3.10	3.14	3.17	3.20	3.20	3.50	3.80	4.13	4.30
1 in 200 yr	3.20	3.24	3.27	3.28	3.34	3.60	3.96	4.29	4.41
1 in 1000 yr	3.40	3.44	3.47	3.50	3.50	3.80	4.20	4.53	4.60

	UK Hydrographic Office (as published in 2007)
	PUSH and NFDC/NFNP Strategic Flood Risk Assessment
	Pagham to East Head Coastal Defence Strategy
	Interpolated
	Not applicable

3.2.2 Sea Level Rise

The latest advice for adapting to climate change was updated in April 2016 by the Environment Agency (EA), Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities – from here on referred to as “EA 2016”. This guidance replaces the previous advice and includes updated sea level rise allowances for Flood and Coastal Risk Management (FCERM) based on the UK Climate Projections 2009 (UKCP09) climate change projections.

A range of scenarios are provided in the EA 2016 guidance, including low and high emissions scenarios demonstrating the range of future uncertainty. Upper end estimates have been developed based on a low probability high end scenario (UKCP09 H++ scenario) which is beyond the likely range but considered to be within physical plausibility. Based on the EA 2016 guidance the upper confidence bound (95 percentile) medium emissions scenario has been adopted as the appropriate ‘change factor’ (Table 3.7). For completeness, the other predictions are outlined in Figure 3.4.

The SLR values for the medium emissions 95% scenario are added to the 2020 baseline to establish water levels in 20, 50 and 100 years (Table 3.7 and Table 3.8).

Table 3.7 SLR predictions for present day to 2120 (EA 2016 Medium emissions 95%)

Year	2020	2040	2070	2120
SLR (mm)	0	120	344	740

Table 3.8 SLR and MHW for the next 100 years

Year		Sea Level Rise on top of 2020 values (m)	Mean High Water (Portsmouth)	
			mCD	mOD
0	2017	0	4.25	1.52
20	2037	0.12	4.37	1.64
50	2067	0.34	4.59	1.86
100	2117	0.74	4.99	2.26

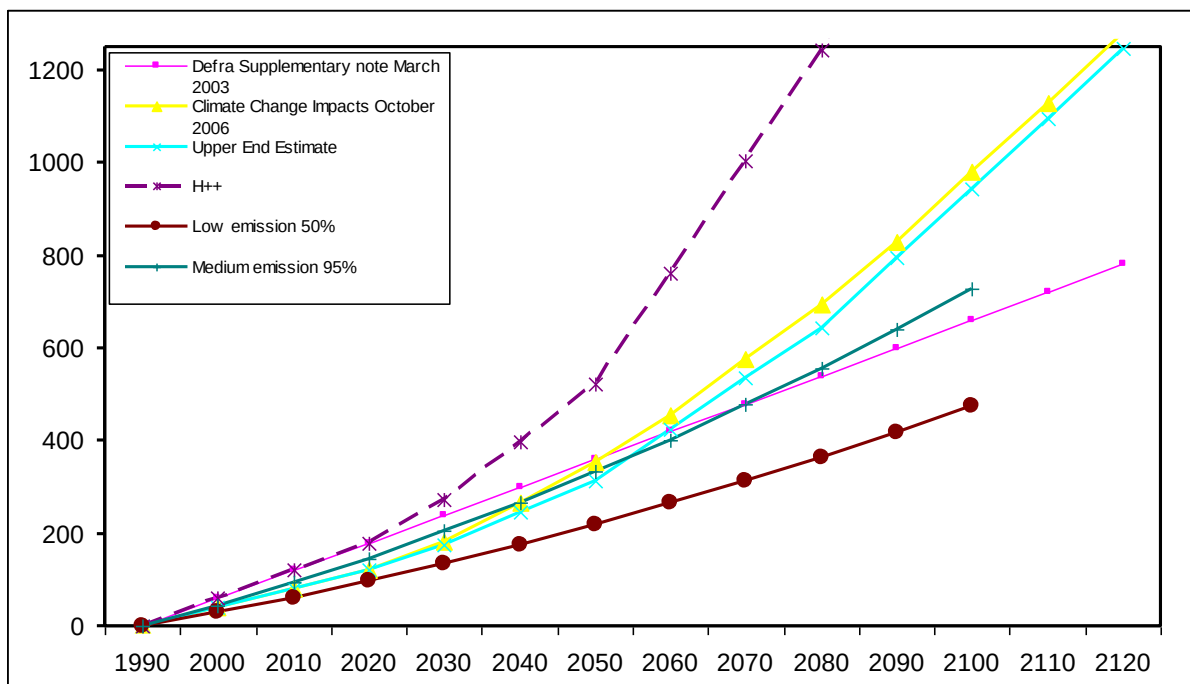


Figure 3.4 DEFRA 2003, 2006 and EA 2016 SLR predictions

The latest available extreme sea level guidance is detailed within the “Coastal Flood Boundary Conditions for UK Mainland and Islands” (Project: SC060064/TR4: Practical guidance design sea levels) (EA, 2011). These provide extreme peak sea levels of return period 1 in 1 year to 1 in 10,000 years), at a spacing of approximately 2km. The closest of these points to the Langstone study site is on the open coast and hence >8km away from the scheme area. This dataset uses robust methods to determine the joint probability of surge and tide to generate peak sea level probabilities. However, the study is for the ‘baseline’ year for mean sea level (MSL) in the year 2008. Figure 3.5 offsets the extreme sea level values for changes in MSL using the EA 2011 Medium Emissions (95%) scenario (Table 3.9). In theory any set of such scenarios could be applied to demonstrate the change to extreme sea level return periods over time due to MSLR.

Table 3.9 SLR 1990-2100 EA 2011 Medium Emissions (95%)

SLR between years		SLR since 1990 (mm)	SLR since 1990 (mm)	Rate in each time period (mm/yr)
	1990	0	0	0
1990	2000	0.044	44	4.4
2000	2010	0.093	93	4.9
2010	2020	0.146	146	5.3
2020	2030	0.204	204	5.8
2030	2040	0.266	266	6.2
2040	2050	0.332	332	6.6
2050	2100	0.728	728	7.92

The horizontal lines show the extremes as they are now (for the EA baseline analysis year 2008) and the sloping lines show the extremes offset for MSLR; for example, a 1 in 200-year event now will reduce to a 1 in 10 year event by 2090 due to an increase in MSL.

In Figure 3.5 the SMP1 (1997) and SMP2 (2010) (shown by the yellow triangles and red square markers) are added to the figure for comparison, alongside the Coastal Flood Boundary Dataset levels (EA, 2011). The offsetting is only applied to the EA (2011) levels around the 2008 baseline year. The SMP sea levels appear to be higher than the EA (2011) levels for equivalent return periods – for example the 1 in 200 year return period level for the SMP2 is almost 20cm higher than the EA (2011) 1 in 200 year level. It is difficult to generate a fair comparison between these different sets of return periods due to different methods and data lengths used. Also, whilst the EA (2011) values use the latest and most statistically robust techniques (i.e. the Skew Joint Probability Method which is detailed in the EA, 2011 report), it is also possible that differences arise due to the EA (2011) values consisting of an offshore point (outside the harbour and >8km away from the scheme area), hence this does not take account the harbour processes (e.g. different surge levels within a constrained water body compared to open coast).

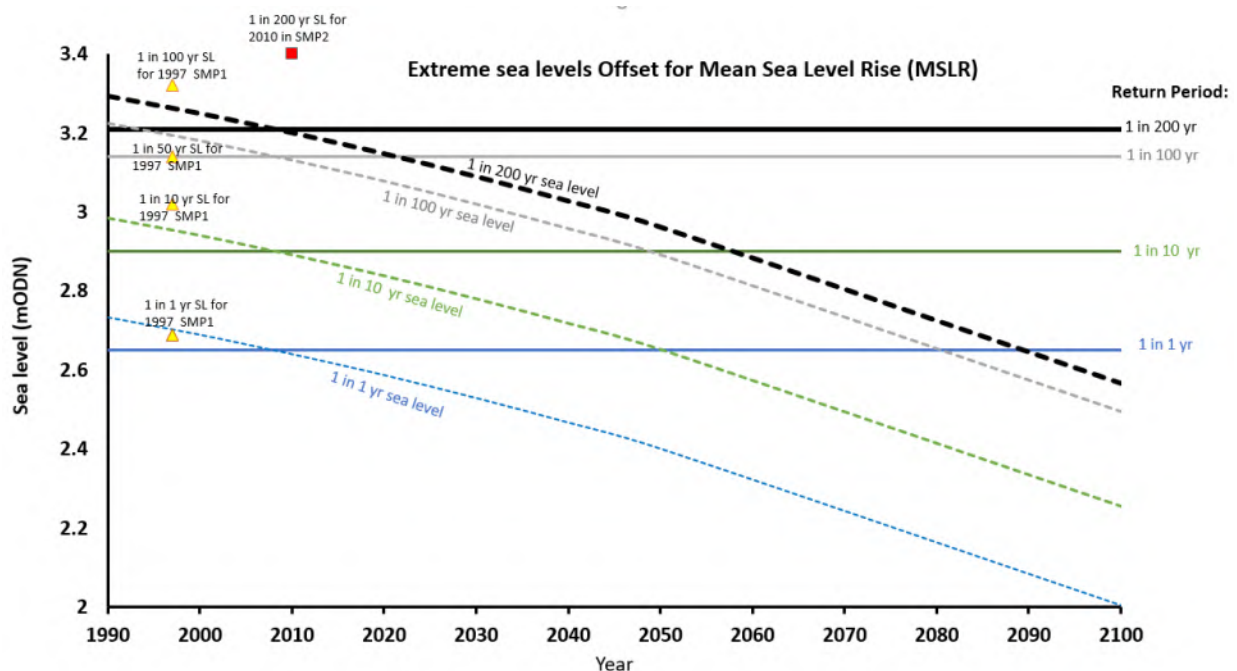


Figure 3.5 A comparison of SLR predictions for set return periods. Data from SMP1 (1997), SMP2 (2010) and EA (2016)

3.2.3 Tidal Currents

The tidal currents around the Solent are complex. The area experiences a double high tide where the tide rises following low water but the tidal stream slackens two hours before high water leading to a stand (known as the Young Flood Stand) before rising to high water which can take a further three hours (Pugh, 1989). The effect is most pronounced at Southampton but is evident throughout the Solent. The ebb tide is very short and therefore associated with strong currents. The tidal range across the East Solent is approximately 4m on average (SMP, 2010). Currents at Langstone, where it is shallow are generally weak and the strongest

currents are at the harbour entrances. The information included in the following section is harbour-wide.

Tidal current and water level data is shown in Figure 3.6. The current speed data have been taken from the Admiralty Tide Diamond D (Admiralty Chart no. 3418) and the tidal heights were extracted from POLTIPS – they represent a typical spring and neap tide from April 2018.

The data shows that during Spring tides, it takes approximately 6 hours for the flood tide to peak, slack water lasts approximately 2-2.5 hours and then there is a 3.5-4-hour ebb tide. This short ebb tide corresponds with the faster flows seen between 3-5 hours after high water. Although less pronounced, the effect is the same for the neap tides. The tide flows north-east (45°) on the flow and south-west (225°) on the ebb. The foreshore around the scheme is variable but is typically between approximately 0-1mOD in elevation, indicating that it is submerged between 4-6 hours over a spring tidal cycle. The North Solent SMP (2010) states that nearshore currents are typically less than 0.5m/s.

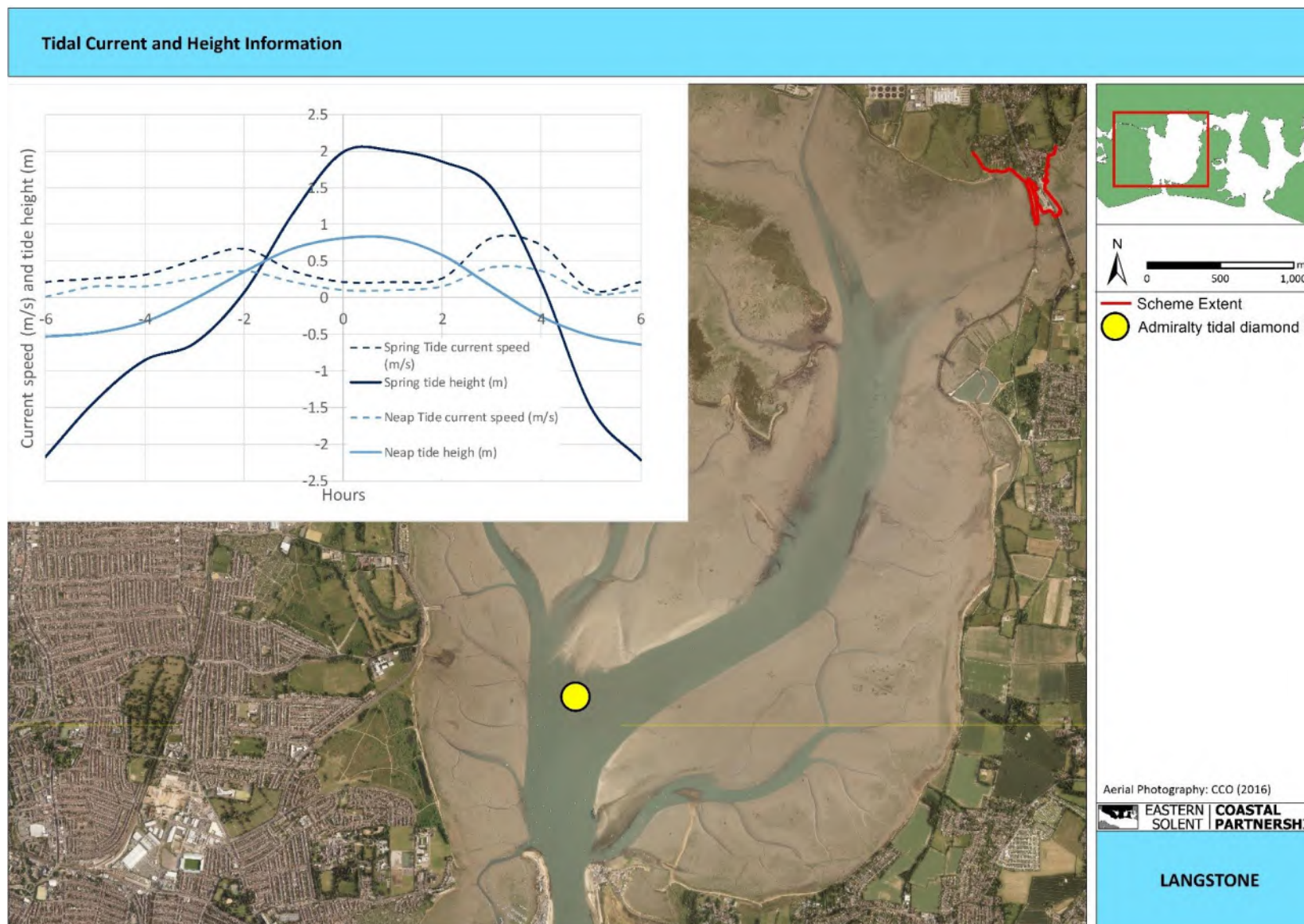


Figure 3.6 Tidal current data at Tidal Diamond D and water level data for Portsmouth Harbour

3.2.4 Change in Surge

The EA 2011 guidance suggests the addition of the figures in Table 3.10, regarding surge. The guidance does recognise that there is considerable uncertainty in these projections.

Table 3.10 EA 2011 guidance on change in surge

	Total potential change anticipated up to the 2020s	Total potential change anticipated up to the 2050s	Total potential change anticipated up to the 2080s
Upper end estimate	20cm	35cm	70cm
Change Factor	Ensure a rigorous assessment of the current coastal extreme water level has been undertaken	Ensure a rigorous assessment of the current coastal extreme water level has been undertaken	Ensure a rigorous assessment of the current coastal extreme water level has been undertaken

3.3 Joint Probability

Joint probability scenarios were not explored as part of the Portchester to Emsworth Strategy. The Portsea Island Coastal Strategy Study (PICSS, 2009) did look into joint probability scenarios, but the locations used for Langstone Harbour are not deemed close enough to the Langstone site to be able to be used: the closest point that was assessed is situated next to the Eastern Road/A2030 road bridge onto Portsea Island.

3.4 Peak Flow

3.4.1 Baseline

The Lavant Stream discharges into the western side of the scheme area. The amount of water exiting the stream will play an important factor in influencing how the Lavant Spit evolves in the future. The National River Flow Archive (NRFA) shows that the flow from the Lavant Stream rarely exceeds 0.01m³/s and is usually less than 0.005m³/s. The station is situated approximately 4km upstream from the mouth at Leigh Park, so values do need to be adjusted for.

3.4.2 Climate Change Allowances

Allowances for increased flow for the South East of England are as follows:

Table 3.11 Guidance on how peak river flow rates will increase with climate change (Environment Agency, 2016)

Allowance category	Total potential change anticipated for the 2020s (2015-2039)	Total potential change anticipated for the 2050s (2040-2069)	Total potential change anticipated for the 2080s (2070-2115)
Upper end	25%	50%	105%
Higher central	15%	30%	45%
Central	10%	20%	35%

3.5 SCOPAC Sediment Transport Study

The SCOPAC Sediment Transport Study (STS, 2012) is a comprehensive literature review of the existing published information detailing sediment movement along the south coast. It also incorporates analysis of Regional Monitoring Programme data between 2003-2012. Figure 3.7 and Figure 3.8 show the results of this study between Gilkicker Point and The Witterings, both inside and outside Portsmouth, Langstone and Chichester harbours.

Arrow FL1 represents the inputs from the Hermitage and Brockhampton Streams. The Hermitage discharges approximately 1.4million m³ of freshwater to the harbour each day (0.25% of the total spring tidal prism for Langstone Harbour) but this carries little to no suspended or bedload material (Portsmouth Polytechnic, 1976).

Arrow E1 at Warblington Castle represents erosion of the low cliffs of Brickearth near Warblington Castle. The cliff was 300m in length yielding small quantities of material but is now protected by an embankment upgraded in 1989, which is maintained to prevent breaching (Harlow, 1980).

The study records no significant inputs or erosion hotspots directly within the scheme area. Due to limited information available, changes in the Langstone and Lavant Spits are explored later in the report (Section 3.7 onwards).

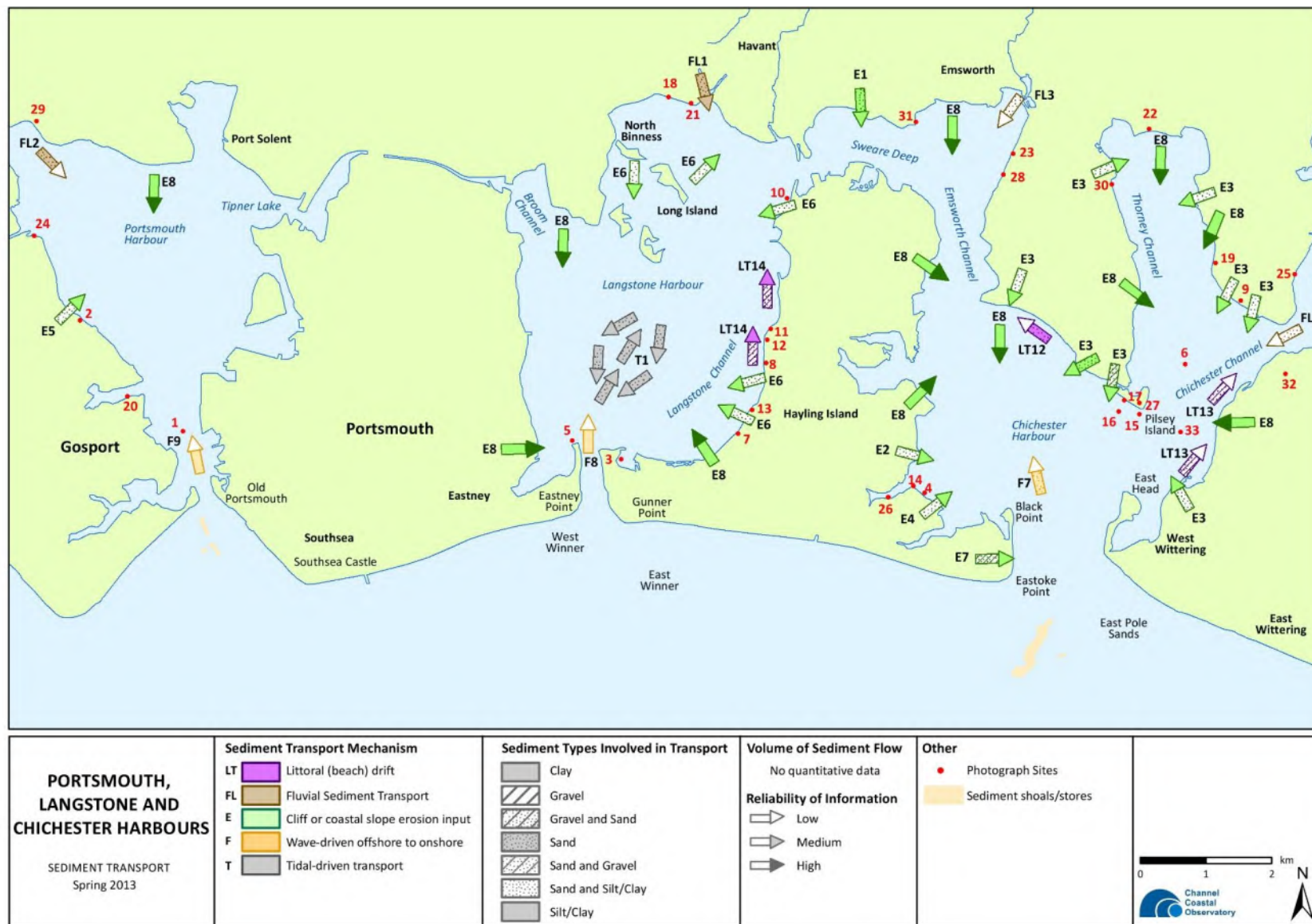


Figure 3.7 The results of the Sediment Transport Study for the harbours (SCOPAC, 2012)

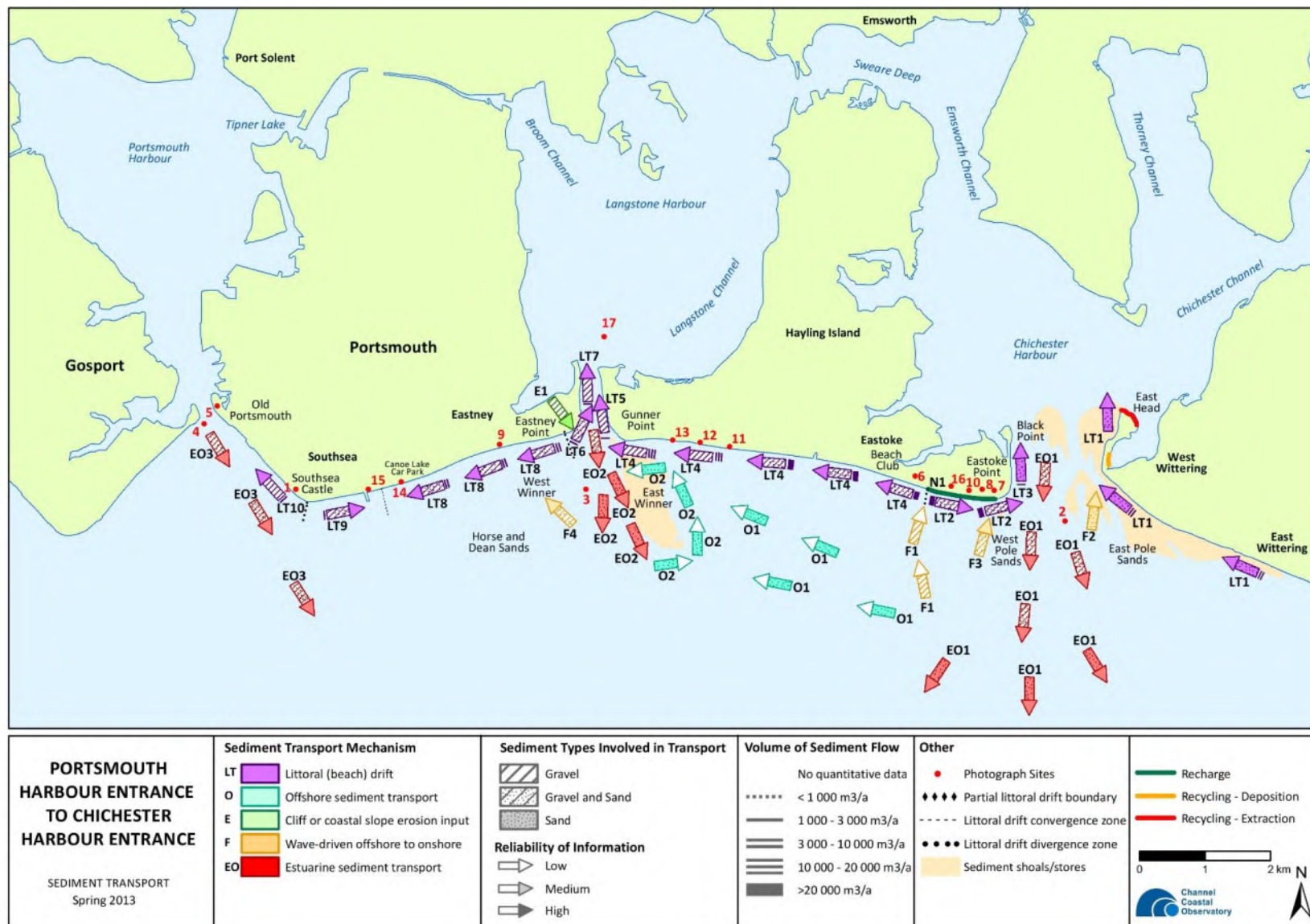


Figure 3.8 The results of the Sediment Transport Study for the open coast (SCOPAC, 2012)

3.6 Coastal Habitats

The Solent Dynamic Coast Project (SDCP, 2008) was conducted to inform the development of the North Solent SMP. The main aim of the study was to “Inform the North Solent SMP so that it may meet requirements under the EU Habitats and Birds Directive for inter-tidal habitats, allowing a more dynamic coastline to be achieved, where coastal wildlife habitats can adapt to sea level rise whilst protecting people and property”. Outputs from the study include mapping of present day (2005) habitats as well as projections in the future and these are detailed in the sections below.

Works were planned to carry out a managed realignment scheme at Southmoor, just west of the Langstone Scheme area. This involved the construction of set-back flood bunds and a breach through the existing defences. The site was recognised by the North Solent and Isle of Wight SMPs, the Portchester to Emsworth Coastal Strategy and the Regional Habitat Creation Programme to provide compensatory and mitigatory habitat that will be lost to coastal squeeze. However, this project has now been delayed and other options are being considered for the future of its management.

3.6.1 Baseline

To baseline the coastal habitats, the SDCP used a combination of two methods: historical aerial photography interpretation (HPI) and lidar/tidal elevation interpretation. Mudflat and saltmarsh development depend on the duration and frequency of inundation – mudflat exists between MLWS and MHWN and saltmarsh colonises between MHWS and HAT (Williams, 1994). Using a digital terrain model (from lidar) and known tidal levels, the lidar was “flooded” to determine the expected coverage. Figure 3.9 shows the results for the baseline (2005) situation.

The project also digitized the extent of saltmarsh from the available aerial photography to determine change over the years. This information will help in assessing how it may change into the future. The original results from the SDCP have been built upon, using updates from the 2008, 2013 and 2016 aerial photography. The results of the saltmarsh area are shown in Figure 3.13 and the graph included. The saltmarsh areas that were digitized for 1946 and 2016 are included in the map as an example. A sharp decrease in saltmarsh is evident – between 1946 and 2016, a reduction in over 161,000m² which equates to a 92% decrease. If this rate continues, there could be no saltmarsh left in the scheme area as early as 2030, however the rate is stabilizing so this loss may not be realised.

3.6.2 Climate Change Allowances

The SDCP project also looked into future changes. To assess how the saltmarsh and mudflat habitats may evolve in the future, sea level rise of 6mm/yr (DEFRA guidance, 2006) was added to the tidal levels and used to “flood” the lidar again. This was done for three times, each accounting for a different amount of vertical sediment accretion: 0mm/yr, 3mm/yr and 6mm/yr. The results presented below are for 2105 and are representative of the potential saltmarsh and mudflat sites in the event of removing sea defence structures (Figure 3.10, Figure 3.11, and Figure 3.12).

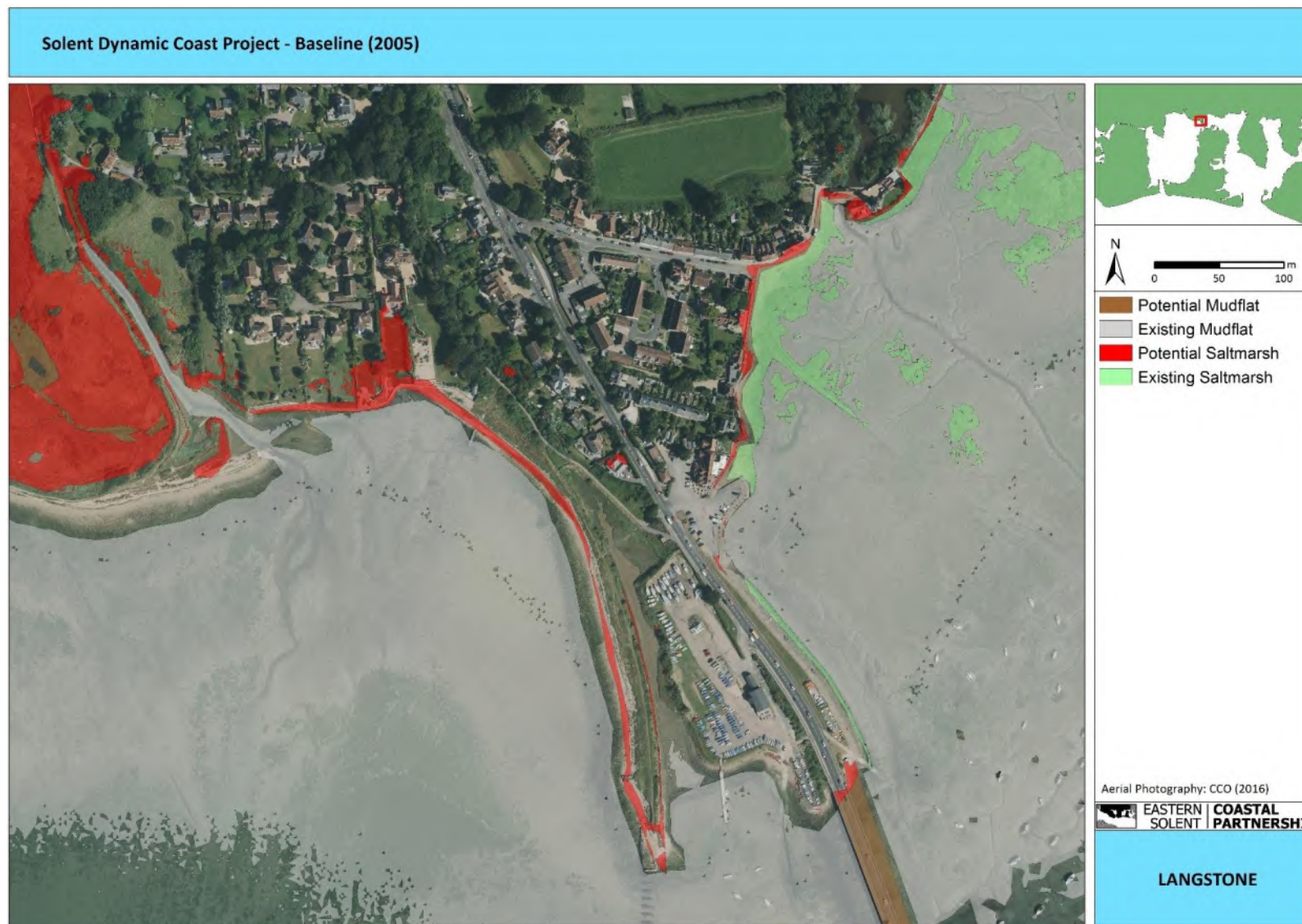


Figure 3.9 Actual and potential saltmarsh and mudflat habitats for the baseline (2005)

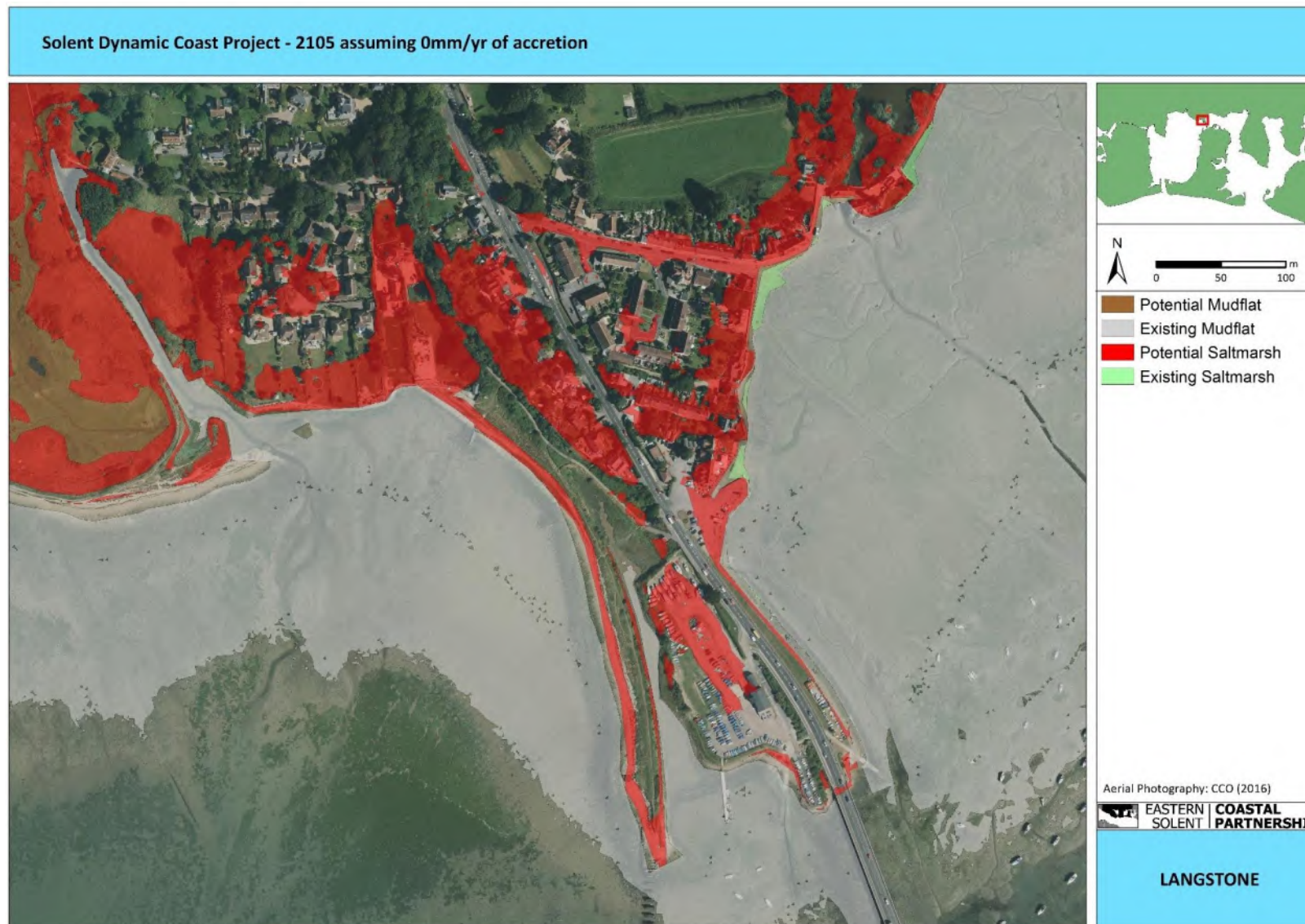


Figure 3.10 Predicted actual and potential saltmarsh and mudflat habitats for 2105 with no vertical sediment accretion

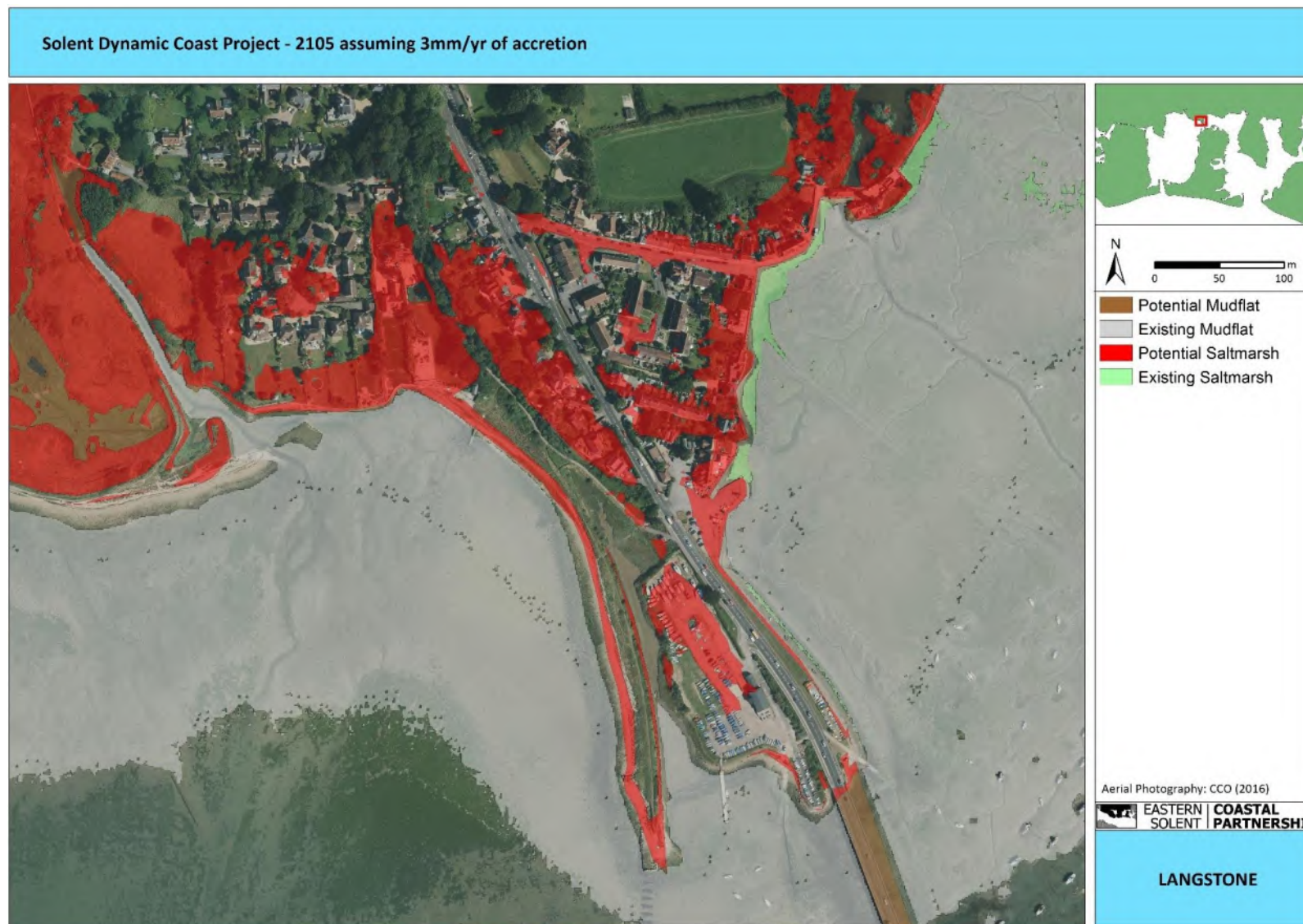


Figure 3.11 Predicted actual and potential saltmarsh and mudflat habitats for 2105 with 3mm/yr of vertical sediment accretion

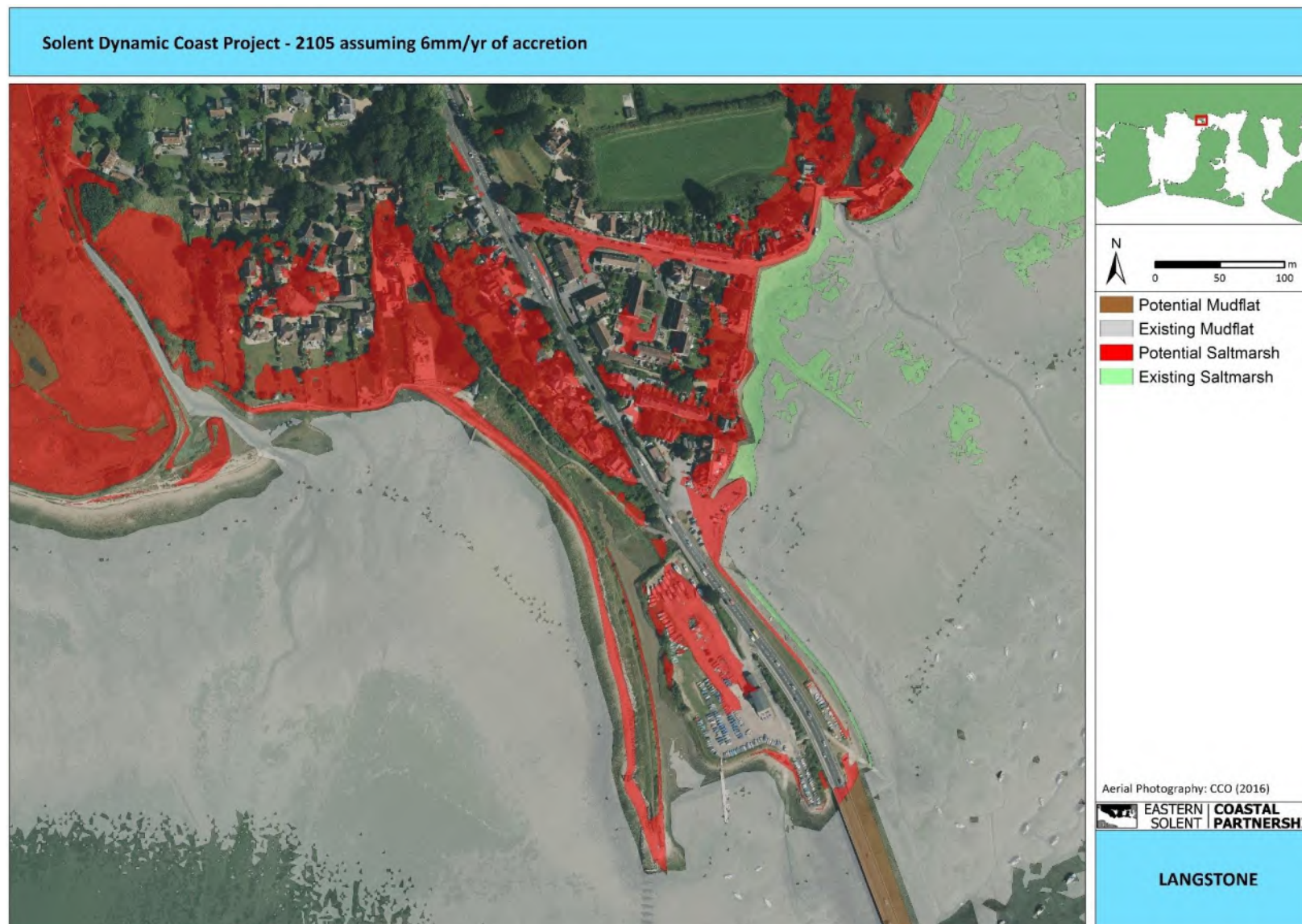


Figure 3.12 Predicted actual and potential saltmarsh and mudflat habitats for 2105 with 6mm/yr of vertical sediment accretion

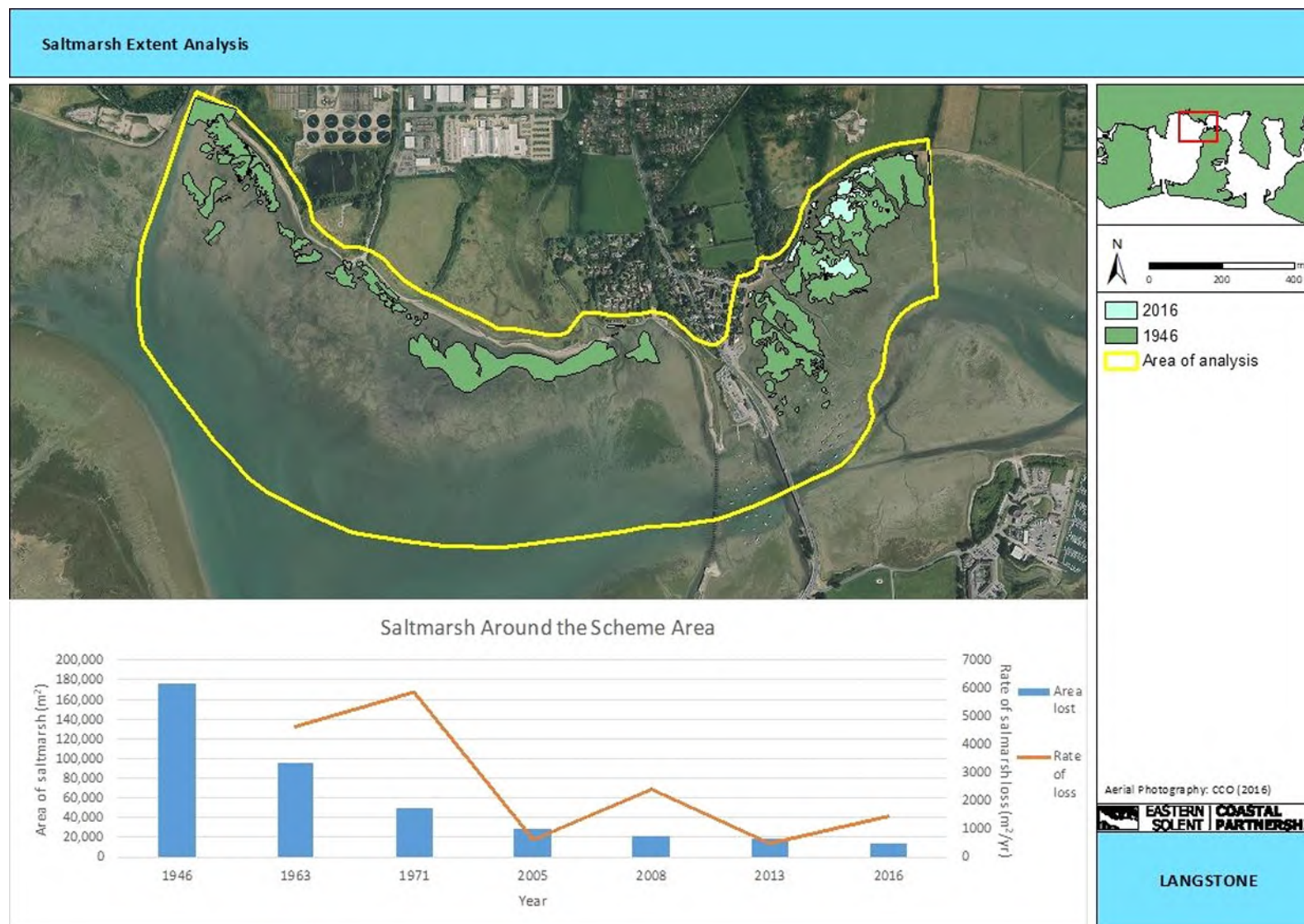


Figure 3.13 The area used for the saltmarsh extent analysis and the results. The 1946-2005 data has been extracted from the SDCP and the rest was digitized by the ESCP as part of this project.

3.7 Coastal Processes and Change

Changes in coastal processes were largely assessed using the lidar data and historical aerial photography. The following sections present data analysis, which is further discussed in Section 4.

3.7.1 Difference Plots and Profile Data

Lidar data from 2005 and 2016 was used to generate difference plots (Figure 3.14, Figure 3.15, and Figure 3.16) for the scheme area to identify any hotspot areas of erosion (areas of red on the difference plots) and accretion (areas of blue on the difference plots). As areas of interest, the Langstone and Lavant Spit difference plots (Figure 3.15 and Figure 3.16) are shown below in more detail.

Profile analysis was undertaken over the spits to understand in finer detail how they have been evolving. Cross-sections through lidar data from 2005, 2013 and 2016 were examined for a greater understanding on how the two spits have changed in elevation in more recent times. Figure 3.17 and Figure 3.18 show where the data was extracted from. The graphs that follow show the changes between 2005 and 2016 over the two spits (Figure 3.19 to Figure 3.28).

3.7.2 Changes in Mean High Water

Contours are run through the 2005, 2013 and 2016 DSMs to assess how the mean high water mark is changing. This also gives an indication of eroding or accreting areas and are useful to cross-check with the difference plots. Figure 3.29 shows the changes in mean high water between 2005 and 2016.



Figure 3.14 Langstone Scheme area difference plot (2005-2016)



Figure 3.15 Langstone Spit difference plot (2005-2016)



Figure 3.16 Lavant Spit difference plots (2005-2016)



Figure 3.17 Showing the profiles where cross-sectional data was extracted over the Langstone Spit



Figure 3.18 Showing the profiles where cross-sectional data was extracted over the Lavant Spit

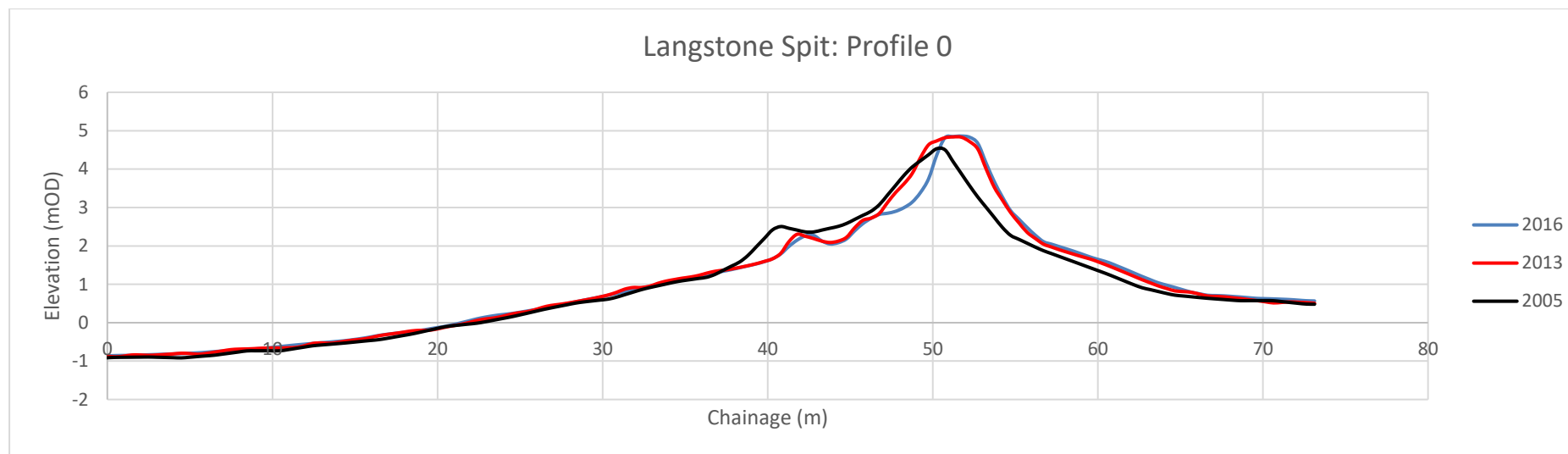


Figure 3.19 Langstone Spit cross-section profile 0

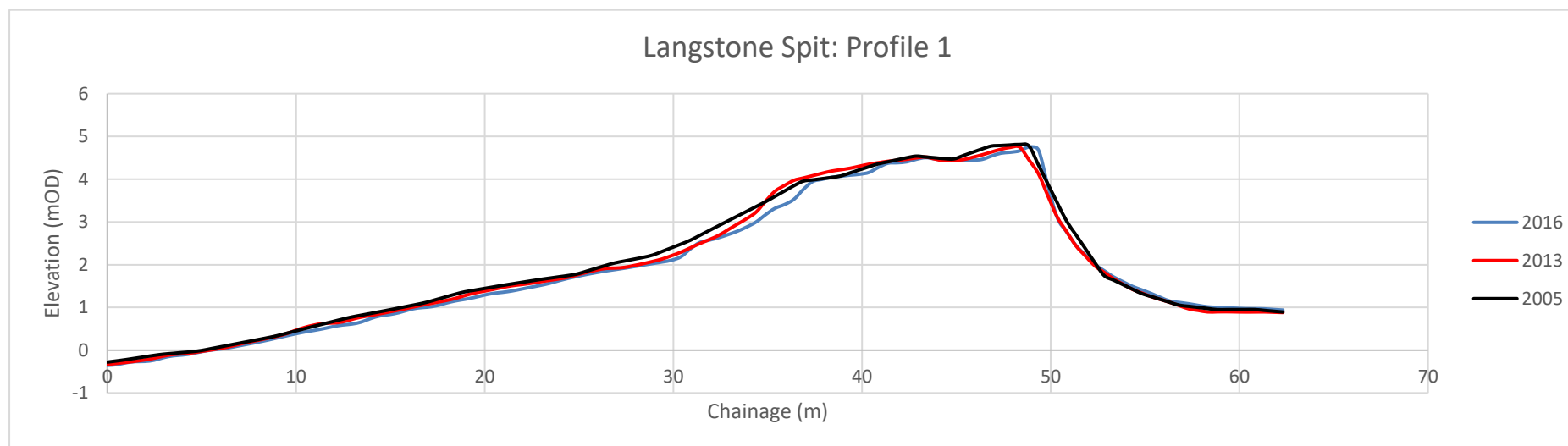


Figure 3.20 Langstone Spit cross-section profile 1

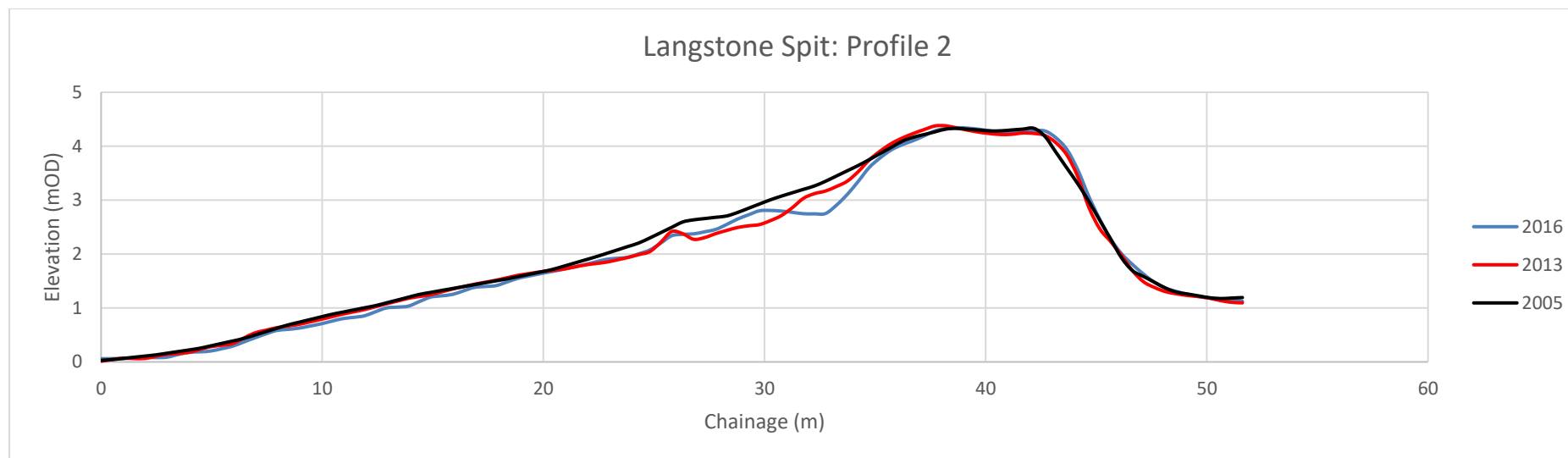


Figure 3.21 Langstone Spit cross-section profile 2

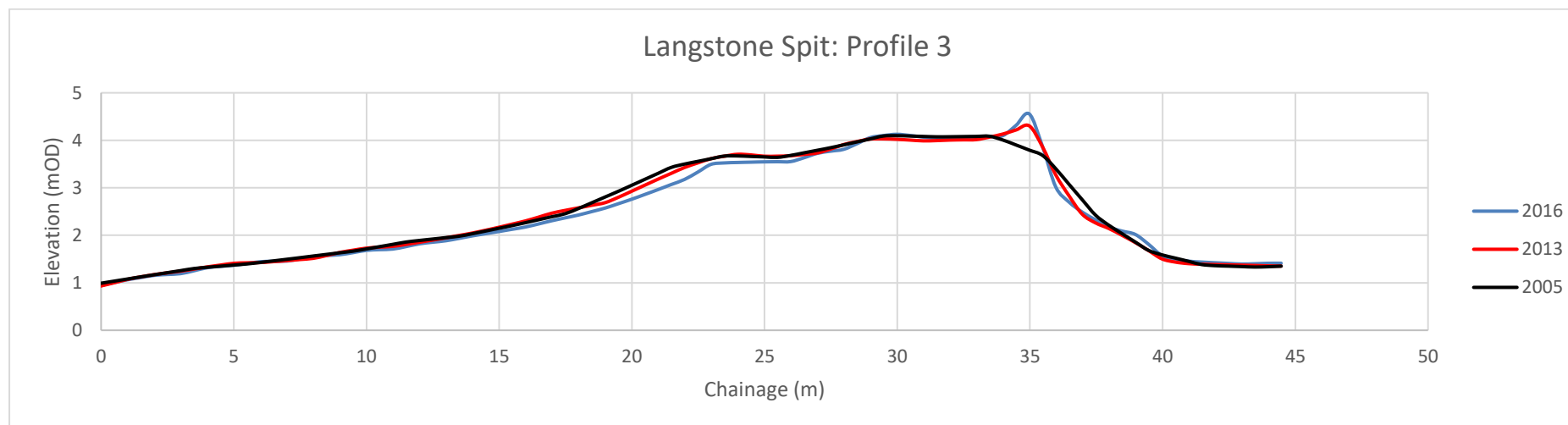


Figure 3.22 Langstone Spit cross-section profile 3

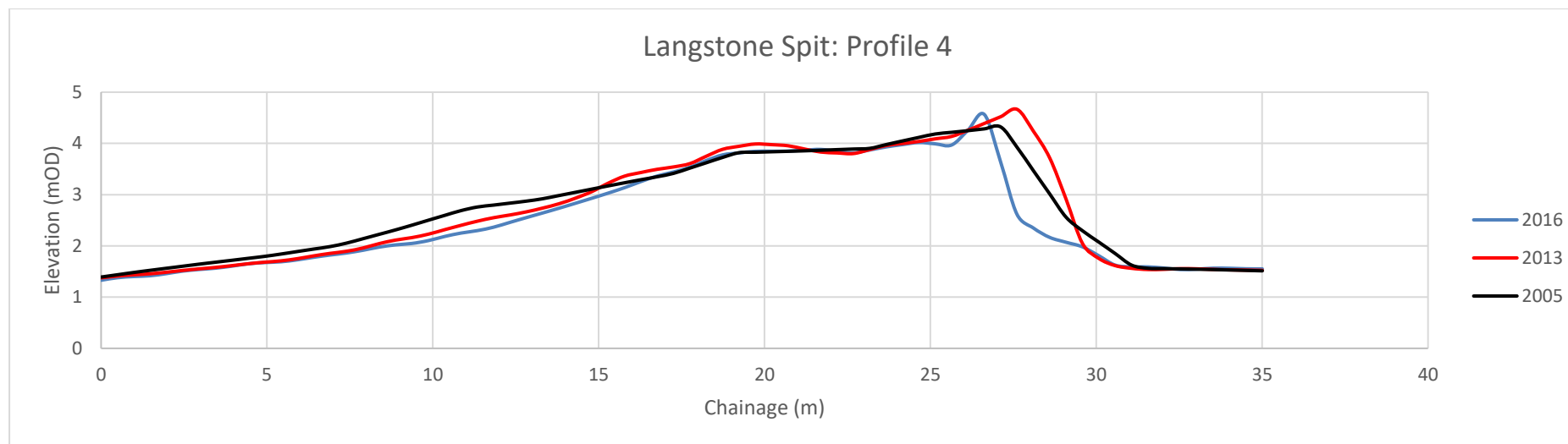


Figure 3.23 Langstone Spit cross-section profile 4

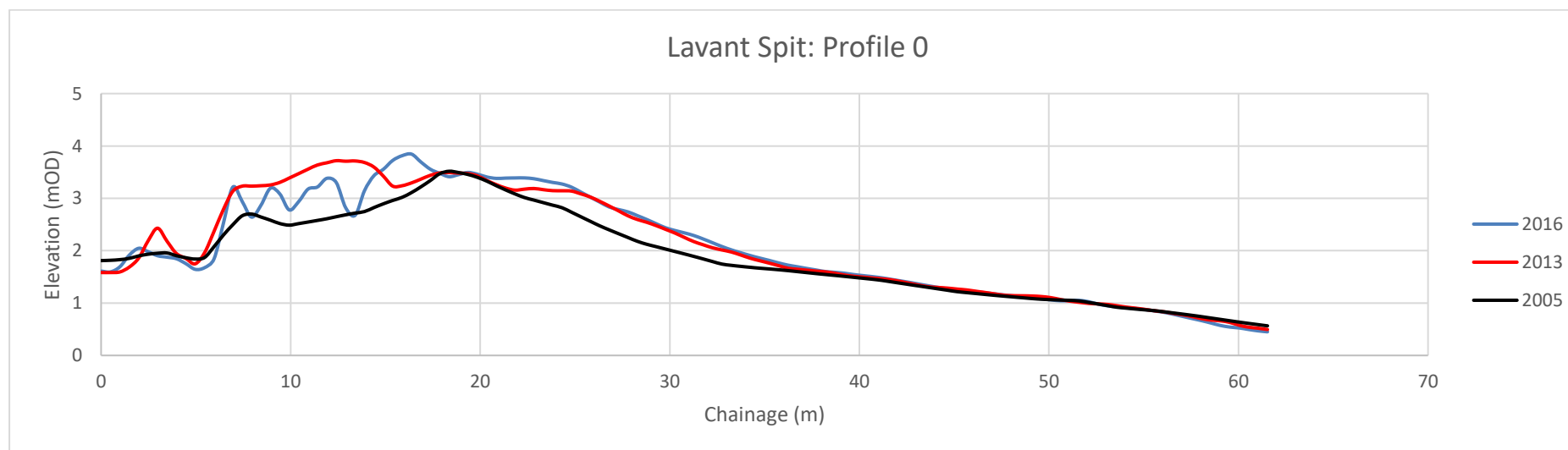


Figure 3.24 Lavant Spit cross-section profile 0

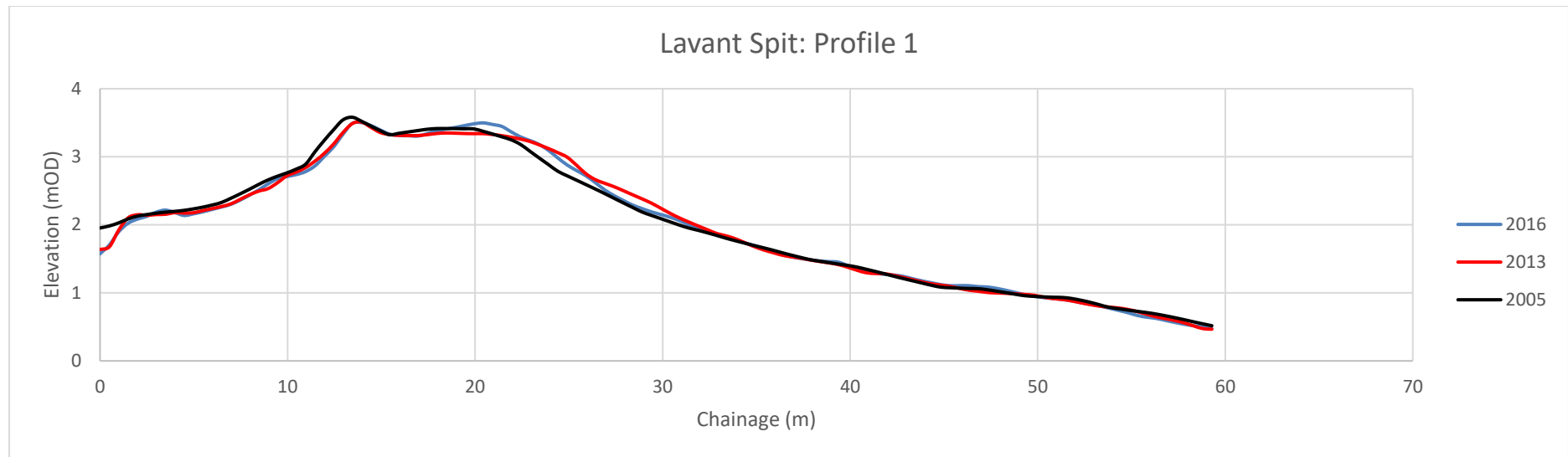


Figure 3.25 Lavant Spit cross-section profile 1

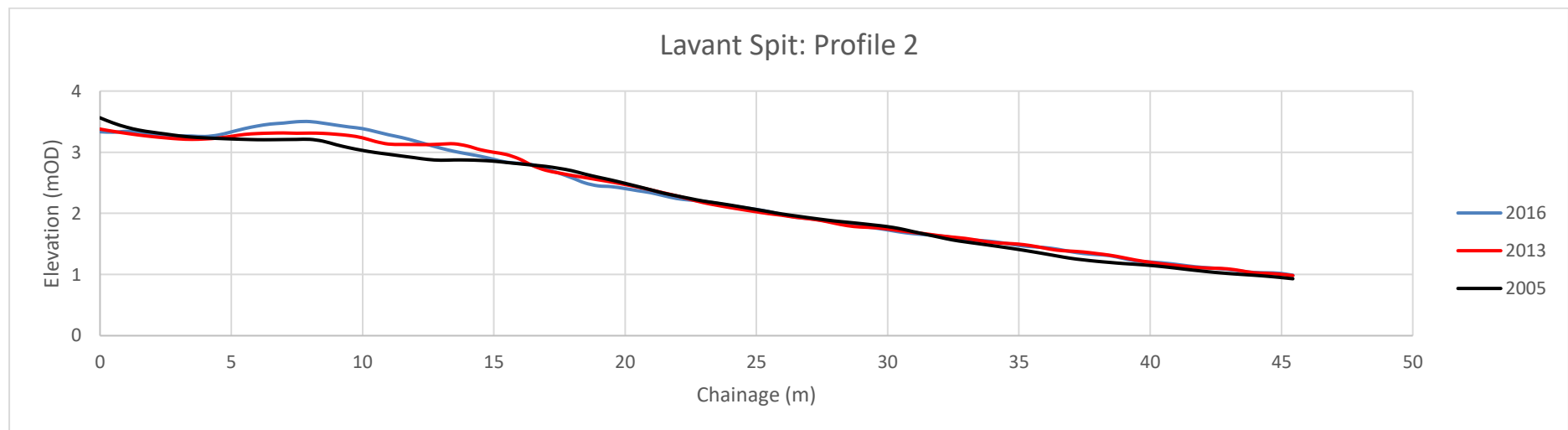


Figure 3.26 Lavant Spit cross-section profile 2

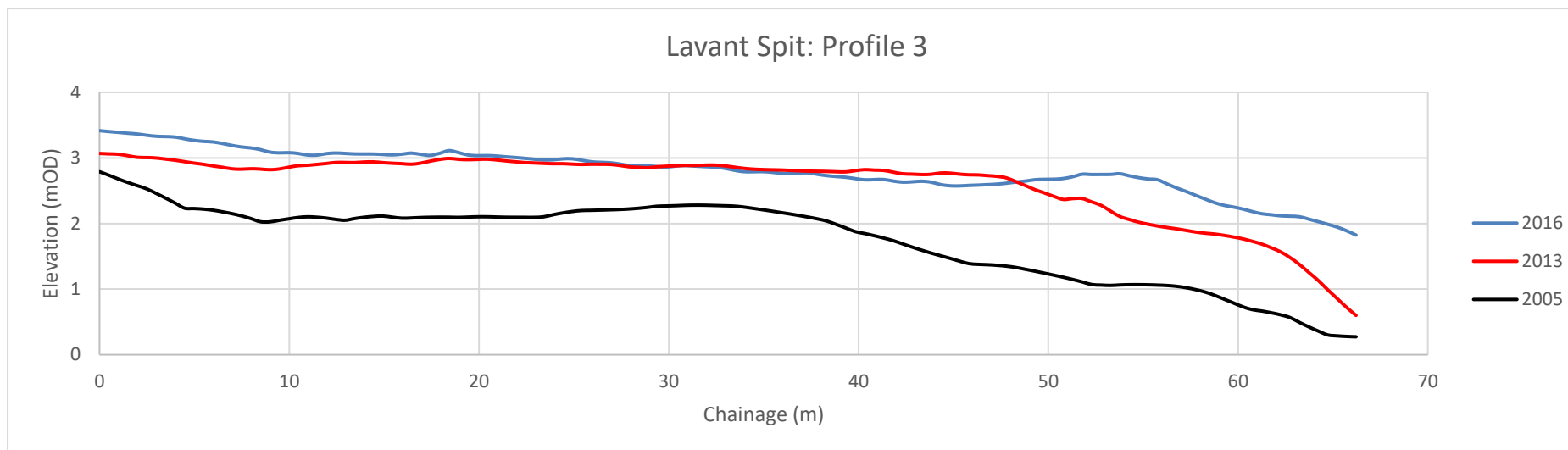


Figure 3.27 Lavant Spit cross-section profile 3

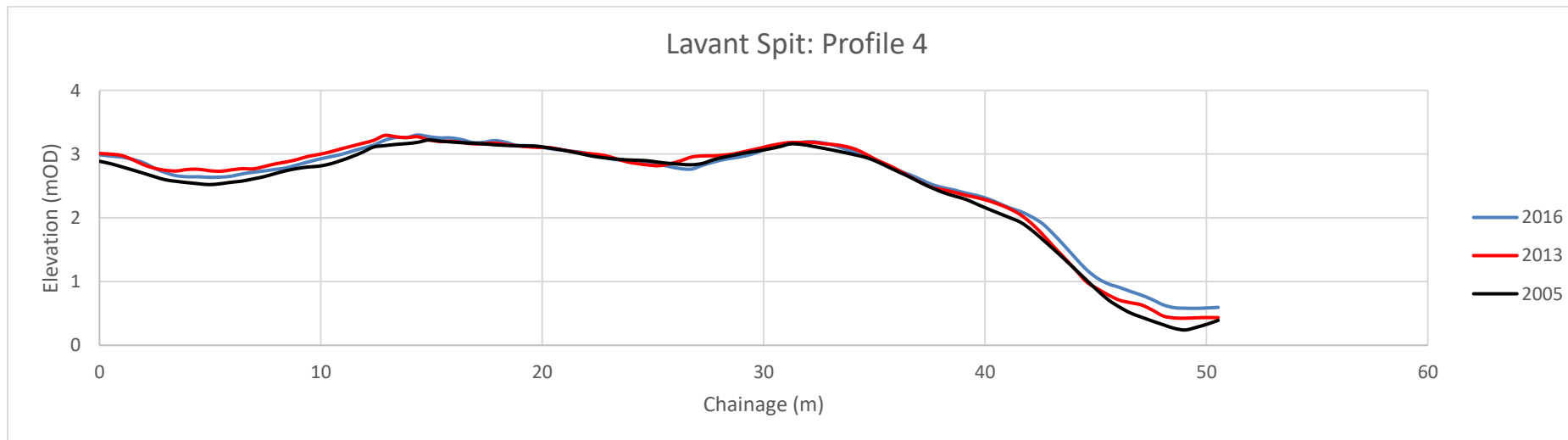


Figure 3.28 Lavant Spit cross-section profile 4

Changes in Mean High Water



Figure 3.29 Changes in mean high water contours

3.7.3 Changes in Spit Position Deduced from Historical Aerial Photography

The spit position has been mapped using the historical aerial photography datasets. This information was then used to calculate rates of movement which have been used to project how the spits may evolve in the future. The results of digitising the Langstone and Lavant spits are shown below in Figure 3.30 and Figure 3.31, respectively. To keep this as objective as possible, the toe of the spit was digitized however in the earlier years (1946 and 1963) it was not possible to identify, therefore the edge of the vegetation was digitized instead. Spot checks were made on the 1946 and 2016 aerials to compare and assess the error, but the error was not considered large enough to significantly affect the results. The georectification error appears to vary from 2 to 5m between these two datasets.

The recent aerial photography (2002 – 2016) shows little change over the Langstone Spit, therefore the years 2002-2013 were excluded from the analysis for the long-term changes. Excluding these still gave a snapshot in time every 20 years. For this area, the lidar data was more useful in determining more recent changes than the aerial photography.

The Lavant spit has increased in volume by 1505m³ at the tip of the spit over the last 20 years and so changes over all the years of data available is shown in Figure 3.31. The channel from the Lavant Stream was also digitised to assess how it has been influencing the spit position in the past and how it may continue to do so in the future (Figure 3.32).

The historical aerial photography that was used to carry out this analysis can be seen in Figure 3.33 to Figure 3.35.

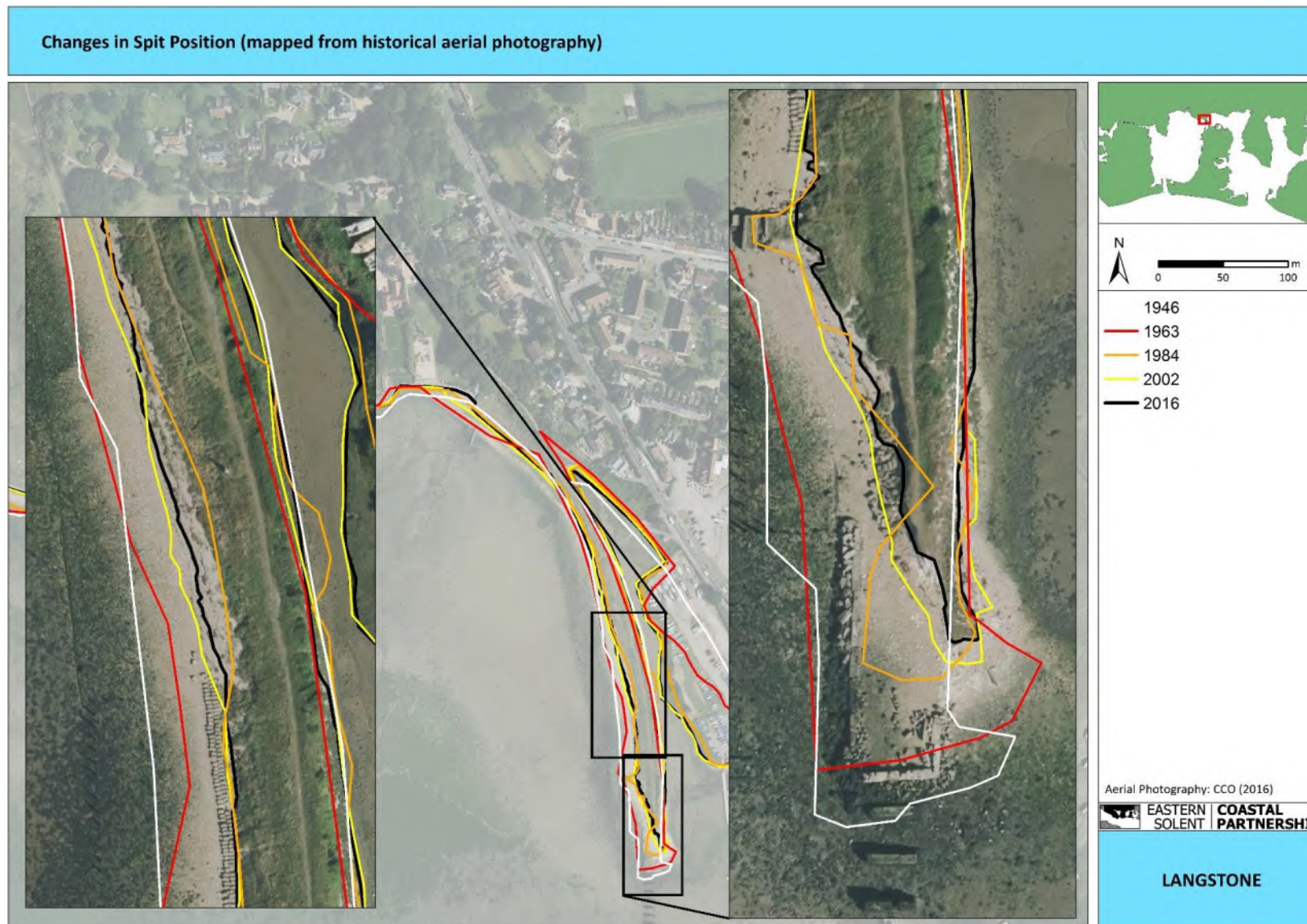


Figure 3.30 Change in spit position as mapped with aerial photography between 1946 and 2016

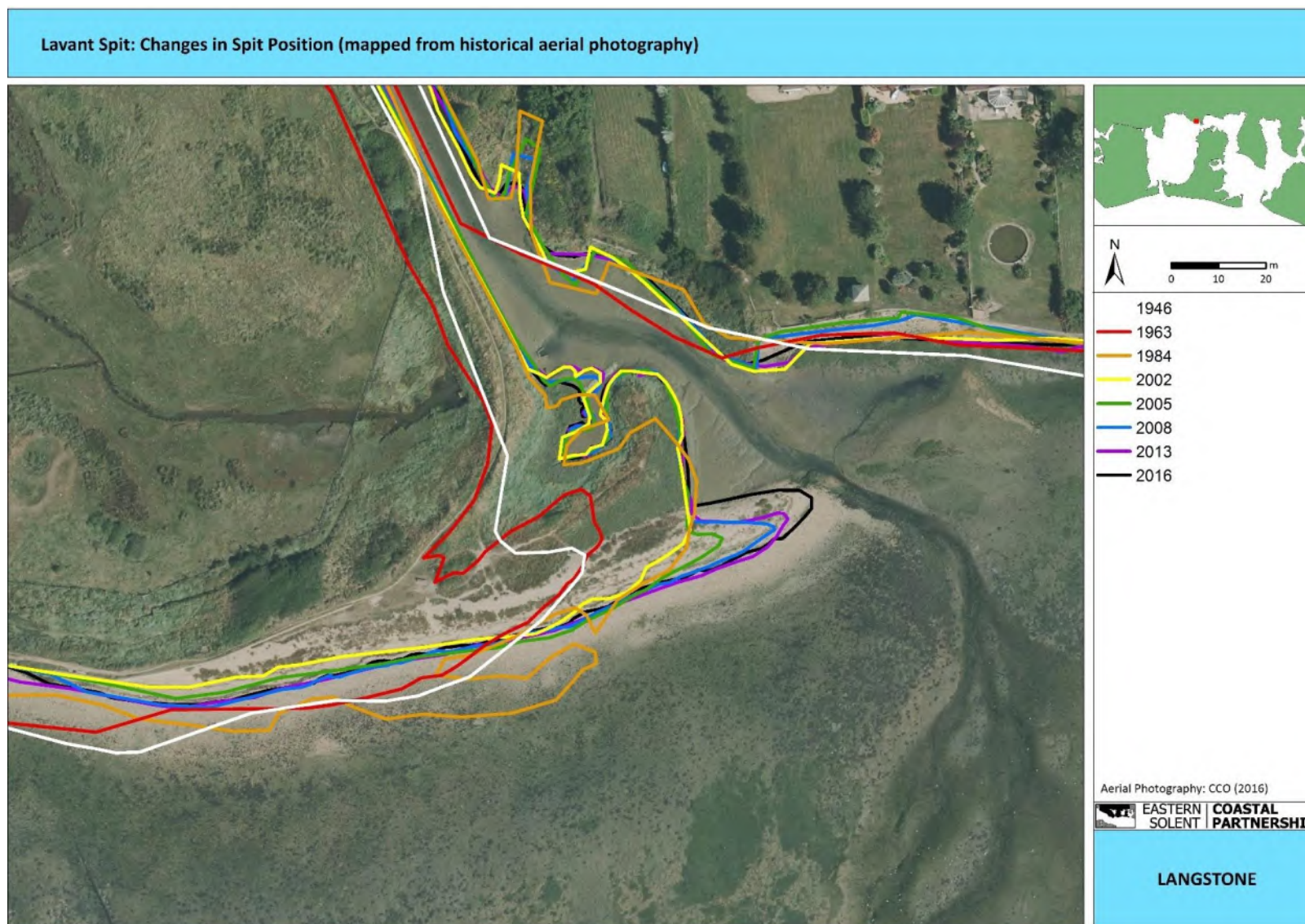


Figure 3.31 Change in spit position as mapped with aerial photography for the Lavant Spit between 1946 and 2016.

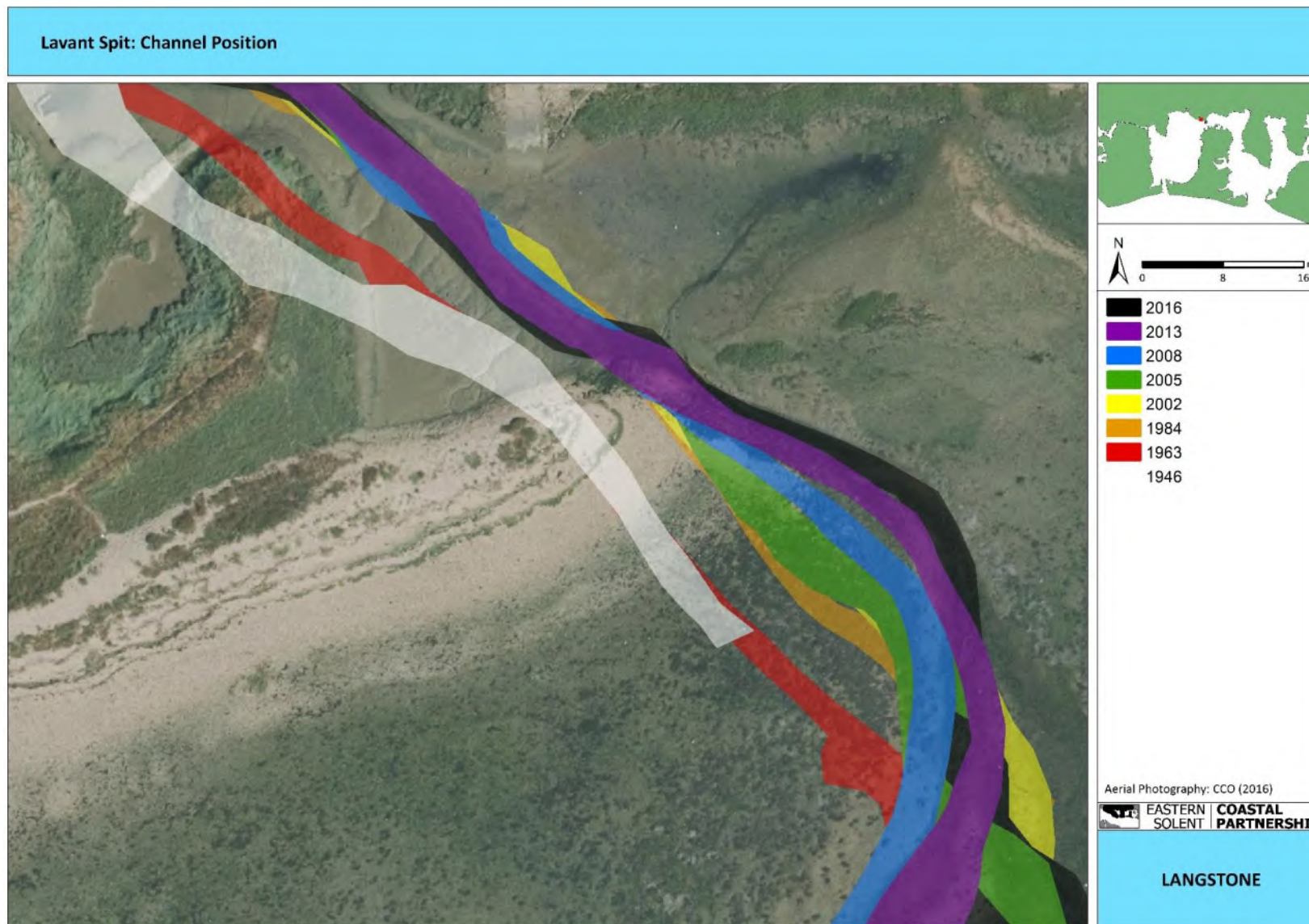


Figure 3.32 The Lavant Stream channel position mapped with aerial photography between 1946 and 2016

Historical Aerial Photography

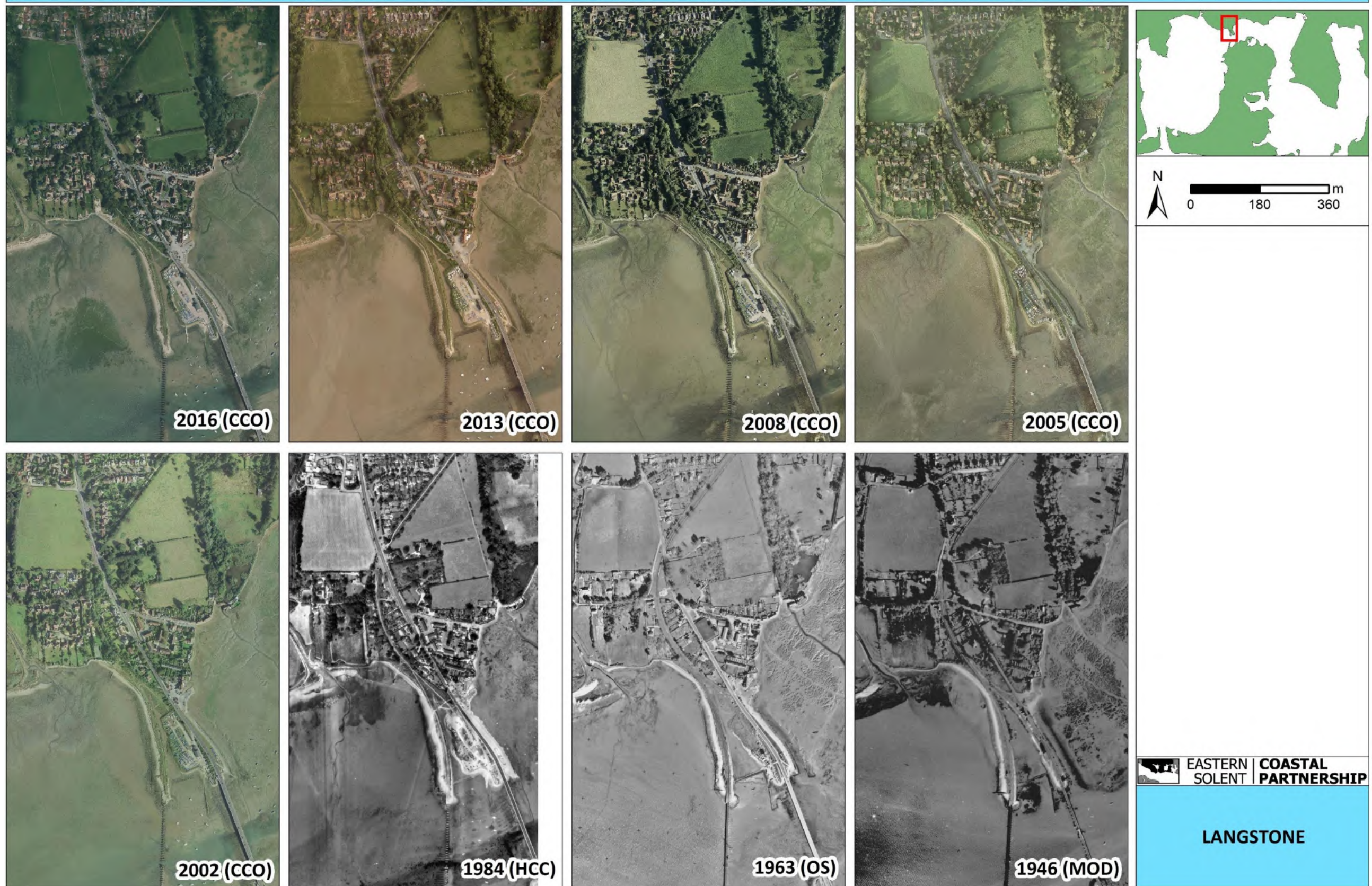


Figure 3.33 Aerial photography for the scheme area between 1946 and 2016 (Copyrights in Table 2.1)

Historical Aerial Photography



Figure 3.34 Aerial photography for the Langstone Spit between 1946 and 2016 (Copyrights in Table 2.1)

Historical Aerial Photography



Figure 3.35 Aerial photography for the Lavant Spit between 1946 and 2016 (Copyrights in Table 2.1)

3.7.4 Rate of Spit Movement and Projections into the Future

The rate of movement of the Langstone and Lavant Spits was primarily determined using the historical aerial photography. As there is variation and error in digitizing, the 1946 and 2016 data was used to give an overall long term change.

For the Langstone Spit, an erosion rate was calculated at each of the profiles shown in Figure 3.17. These varied from 0.05m/yr at the base of the spit to 0.3m/yr at the tip of the spit. An average rate was calculated at 0.2m/yr. These rates were used to project back the front face of the spit for the next 20, 50 and 100 years (Figure 3.36).

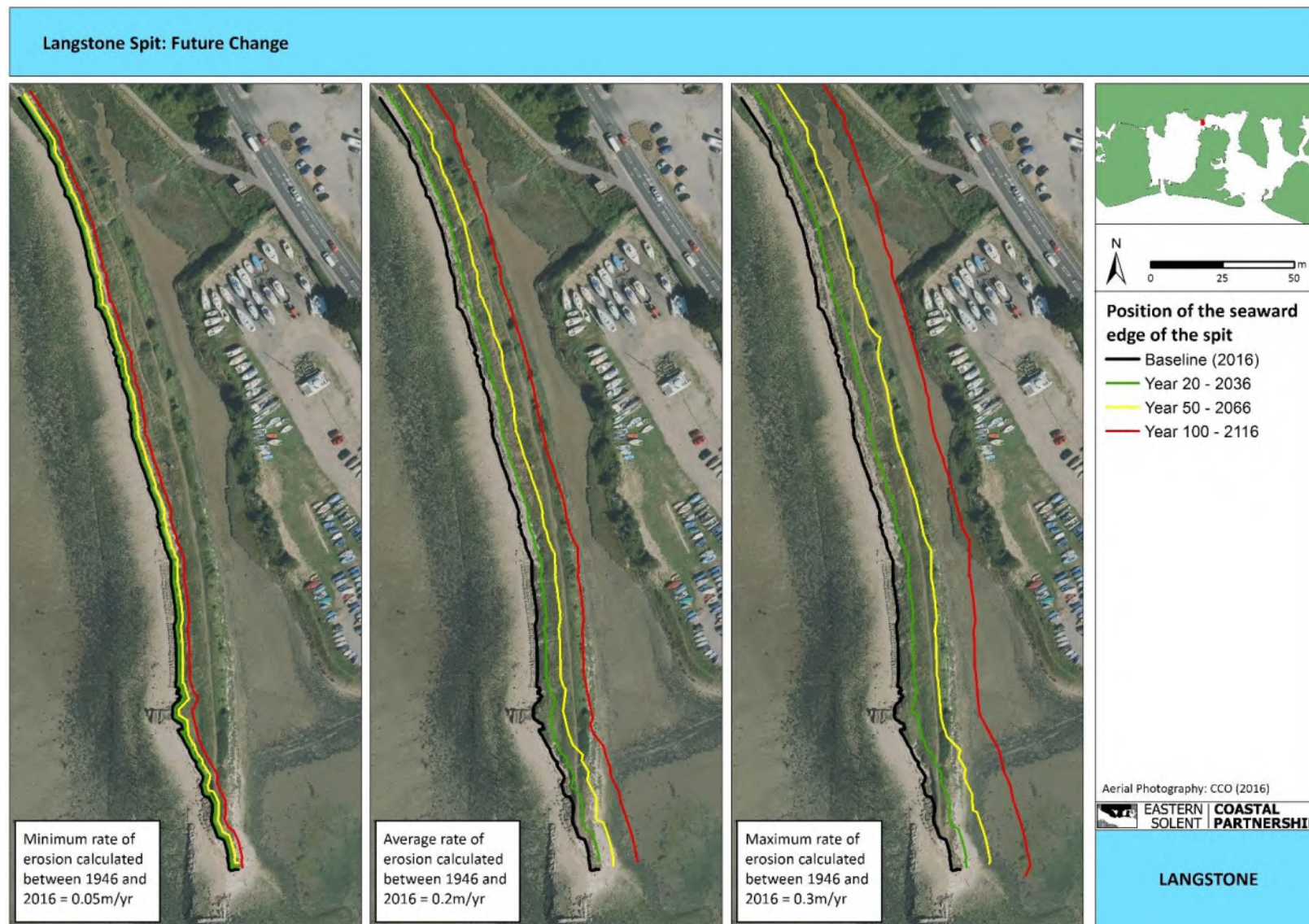


Figure 3.36 Results of the potential future spit positions, using minimum, average and maximum rates of change observed between 1946 and 2016

3.7.5 Volumes Analysis of Langstone and Lavant Spits

A volume analysis over each of the spit was carried out. The volume of each spit was calculated above 0mOD, accounting for the active area of the spit higher than the foreshore. For the Langstone Spit, this did not yield any reliable conclusions (discussed in Section 4.1.2).

This was also undertaken over the Lavant Spit, which has shown a much more significant change over the last 15 years. It was broken down into two areas: the relict spit and the shingle spit (Figure 3.37).

The graph shows the increasing trend in volume for both areas, particularly over Area 2, the shingle spit. The high coefficient of determination shows a strong correlation of the spit volume increasing over time (a value of 1 indicates a perfect fit with a linear trend).

The future of the Lavant Spit is less certain than the Langstone Spit and is dependent on the future combination of sediment supply to the spit and velocity of water exiting the Lavant Stream. The source of sediment feeding the spit is currently unknown and therefore the future of the Lavant Spit is difficult to predict.

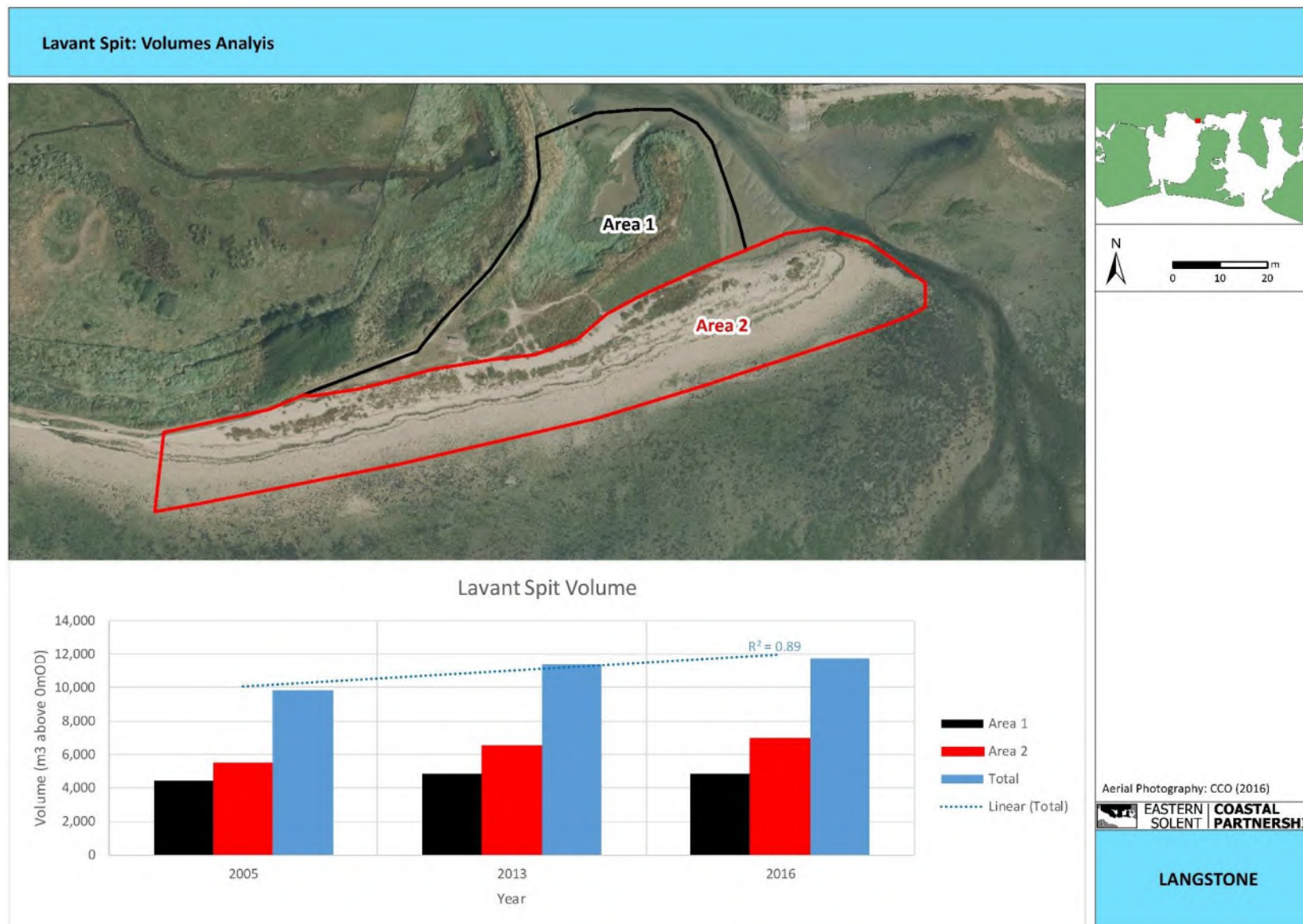


Figure 3.37 Volumes analysis for the Lavant Spit, split into two different areas

4 Discussion

The analysis and interpretation in this discussion draws on the data analysis presented above, in Section 3. The focus is mainly on coastal processes, how this has evolved and what changes may occur in the future.

The difference plots in Figure 3.14 to Figure 3.16 show that, the foreshore around the Langstone Scheme is generally stable and the aerial photography does not show significant infilling or narrowing of the channels in the scheme area. Aerial photography for 2005 and 2016 is available which allows conclusions drawn from the lidar and difference plots to be verified.

The two areas of particular interest are the Langstone and Lavant Spits. A closer look at their changes are discussed below, incorporating findings from the data analysis in Section 3.7 and David Carter's findings (Appendix A).

4.1 Spit Evolution: Langstone

Langstone Spit remains as a feature since the old Hayling railway came out of service. It is close to Langstone Sailing Club, who have noted the erosion of the spit historically and are becoming increasingly concerned of the effect of this erosion as the spit offers some protection against waves. Analysis of historical aerial photography and lidar data to establish how the spit has changed in the past has been used to project into the future to give an indication of how it may erode in the next 20, 50 and 100 years' time.

4.1.1 Historical Evolution

Construction of the Langstone railway began in 1863 and ceased operating in 1963. The bridge has since been dismantled but the abutments across the channel and the embankments at each end are still in place. Carter (2018) states that the development of a natural spit at this location is difficult to explain and seems unlikely.

The difference plot (Figure 3.15) shows that the Langstone Spit has a clear band of erosion along its front face, and accretion along its back edge. This would suggest that the spit is in fact moving, rather than being eroded altogether, but on closer inspection of the difference plot and the 2005/16 aerials, it appears that this change is due to vegetation. This is particularly evident in Profiles 3 and 4 (Figure 3.22 and Figure 3.23) which both spike at the back edge of the spit for the 2013 and 2016 data. Profiles 1 and 2 (Figure 3.20 and Figure 3.21) show the general drop in levels along the front face of the spit well, at approximately 0.25 – 0.5m between 2005 and 2016. The front face erosion was validated using the 2005/16 aerials and also the longer term trend (1946-2016), which indicates that the spit is eroding. The historical aerial photography show that the back edge of the spit is much more stable than the front.

The rate of erosion varies along the length of the spit. In general, the base of the spit is eroding very slowly, compared to the tip of the spit which is showing much more loss of material. This is best illustrated by mapping the spit position using aerial photography between 1946 and 2016 (Figure 3.30). The rates of erosion were calculated at 0.3m/yr (20m total between 1946 and 2016) at the tip of the spit and at 0.05m/yr at the base of the spit (3m total between 1946 and 2016). The changes in MHW over the spit (Figure 3.29) do not show as much change as

the spit positions from aerial photography which suggests that erosion events could be episodic and due to wave action during storms higher up the foreshore on the spit.

4.1.2 Future Evolution

The long-term erosion was calculated by analysing the spit position during 1946 and 2016 (using historic aerial photography) and using the difference to calculate an erosion rate. The erosion rate varies along the spit, so a minimum, average and maximum rate was calculated to give a range of scenarios which will account for some uncertainty. These three rates were used to project into the future and estimate where the front face of the spit position may be in 20, 50 and 100 years' time under a "Do Nothing" scenario (Figure 3.36). With increases in water level, wave height and storminess over the next century, it is more likely that one of the higher rates will be realised.

As can be seen, in 100 years' time for the average and maximum rates of erosion, the projected front face of the spit is behind the existing back face, suggesting that under these circumstances, the spit would have eroded and no longer be present. There is still some uncertainty about where this material ends up, whether it is washed away, or potentially will start to accrete in the area between the spit and the sailing club meaning that the spit effectively moves, rather than being eroded away altogether. A volume analysis over the Langstone Spit was carried out in attempt to answer this, but the indicated change fluctuated, rather than showing a trend either way of increasing or decreasing volume over time, and so with only three datasets, it was inconclusive.

The highest point on the spit currently stands at approximately 4mOD, and the current MHWS is 1.97mOD at Portsmouth. With sea level rise, in 100 years' time, the MHWS is expected to be 2.71mOD (current SLR guidance, EA 2011), so if it not entirely eroded, it is not likely to become a submerged feature during its lifetime.

Further details of the Langstone Spit are available in Appendix A.

4.2 Spit Evolution: Lavant

The Lavant Spit is situated at the mouth of the Lavant Stream. It is a significant feature which must be considered as it likely affords some protection against approaching waves to the properties at Harbourside towards the western end of the scheme. Analysis of historical aerial photography and lidar data was undertaken to establish how the spit has changed in the past how it may change in the future.

4.2.1 Historical Evolution

The overall trend at the Lavant Spit is of accretion – it is growing eastwards becoming longer and wider. The end of the spit has started to divert southwards too (Figure 3.16) which could be due to the channel now keeping its position and diverting accreting material to the south. This may indicate limited future growth to the east. The mean high water (MHW) contours (Figure 3.29) and mapping of the spit over time (Figure 3.31) show that the northern portion of the spit has become a relict and the southern vegetated shingle portion is continuing to grow, although where this material originates from is currently unknown.

The data from Profiles 1 and 2 show the gradual movement of the shoreline and Profile 3 takes a cross section through the shingle spit, highlighting its significant growth over the past 11 years (approximately 50m in length and 1.5-2m in height). Profile 4 shows again that the

relict spit is stable and showing very little movement over the same time period, which is supported by the findings shown in the difference plots and MHW/aerial photography mapping. Prior to this (1946 – 1984), it was moving much more as it was the main mobile section of spit.

The volume analysis complements this, confirming the increase in volume over the spit. The shingle part of the spit (Area 2 in Figure 3.37) has increased in volume by almost 30% since 2005, where Area 1 has only increased in volume by approximately 10%. There is an area of erosion, indicated by the 2005-2016 difference plot immediately west of the Lavant spit, but the volume lost here only accounts for approximately 20% of the volume growth of the spit, so it is likely that there is another source of sediment feed.

4.2.2 Future Evolution

The future of the Lavant Spit is less certain and is dependent on the future combination of sediment supply to the spit and velocity of water exiting the Lavant Stream. The accretion southwards from the spit along the channel edge is an indication that the channel is having a limiting effect on its growth. The channel position has shifted eastwards by about 20m between 1946 and 2016 and 12m between 2002 and 2016 (maximum movement), so although it currently isn't showing signs of blocking, it is moving (Figure 3.32). Carter (2018) states that "for the present it seems a reasonable inference that there is a west to east littoral transport pathway along the updrift beach that is feeding the expansion and distal extension of the Lavant spit". Further discussion on what the feed for this spit may be (supply from updrift, supply from the Lavant Stream, onshore movement) and whether or not it is likely to continue is included in Appendix A.

As the source of material for the spit accretion has not been determined, it is difficult to estimate how much longer the spit will continue to accrete for. The relict spit is now heavily vegetated and the accreting portion also has some areas of vegetated shingle, indicating that the structures are relatively stable. This stability and vegetation is possible due to the low wave energy climate in the area.

The highest point on the relict spit currently stands at approximately 4.5mOD and 4mOD for this shingle portion, and the current MHWS is 1.97mOD at Portsmouth. With sea level rise, in 100 years' time, the MHWS is expected to be 2.71mOD (current SLR guidance, EA 2011), and as this spit is currently accreting, it is not likely to become a submerged feature during its lifetime.

Further details of the Lavant Spit are available in Appendix A.

4.3 Other Areas of the Scheme

Mean High Water contours (Figure 3.29) show that the area around the slipway from Langstone High Street is slowly accreting. This is verified by the aerial photography which shows a greater extent of shingle-type material in more recent years. As before, it is unclear where this material is coming from, however the changes are much more subtle than those at Lavant Spit. The channel at the Lavant Spit is slowly moving eastwards, but there is not a significant change in its channel width. The MHW contours between the Langstone Spit and the Langstone Sailing Club are also moving forward, indicating that this area is silting up.

The extents of mudflats and saltmarsh are also changing. As discussed, saltmarsh has significantly been dying back since the 1940s and there is a possibility that it could completely disappear within the next 15 years.

Other than the changes noted in the above sections, there are no significant areas of erosion or accretion and the Langstone Scheme area is relatively stable.

5 Conclusions and Recommendations

Except for the two spits, there are no significant hotspots of erosion or accretion in the Langstone Scheme area. The mudflat foreshore is generally stable and the channels are not showing significant infilling or narrowing.

It is recommended that further work should be considered, in particular waves and water levels. The wave data is outdated and various sources show different results – it would be beneficial to establish new extremes for the scheme. New sea level rise values are due for release late in 2018 which should be considered in the scheme design once they are available.

The area of saltmarsh in the scheme vicinity has decreased by over 90% between 1946 and 2016. However, the rate of loss does seem to be stabilising, so the predictions made about when all the saltmarsh will disappear may be conservative.

Over the next 100 years, it is likely that a substantial portion of the Langstone Spit will erode. This may leave the Langstone Sailing Club and the northern section of the Langstone Road bridge vulnerable to the effects of the waves and rising sea levels across Langstone Harbour. Although the Lavant Spit is currently accreting and has been since at least the 1940s, the source of material for its feed is unknown and it is more difficult to predict how it will evolve in the future.

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7 Appendix A

Langstone Flood and Coastal Erosion Risk Management Scheme

David Carter - Consultant's Report

The Eastern Solent Coastal Partnership has responsibility for the above scheme and has requested this report as a contribution to: (1) specific knowledge of aspects of the historical development of the frontage, and (2) understanding of physical processes, particularly with respect to uncertainties relating to shoreline sediment supply and transport, and landform development.

1.0 The Wadeway

- 1.1 The historic Wadeway, now obsolescent and negotiable only with difficulty at extreme low water, is a protected right of way across the tidal channel that separates the mainland from the north shore of Hayling Island. Consisting of a mix of roughly dressed stone and rubble overlying compacted gravel, it provided the only means of communication for pedestrians and horse-drawn traffic until the building of a bridge in 1824. Approximately 1.1 km in length, it trends initially south-east from the Ship Inn at Langstone and then re-orientates south-south west beyond its mid point. For most of its length it is little more than half a metre in width, but expands to twice that where it crosses the western end of a shingle bank. This feature is probably natural in origin and influenced the change in alignment; it is referred to as “The Hard” on nineteenth century Admiralty navigation charts. Due to lack of use and therefore maintenance since the early nineteenth century, the Wadeway is today mostly obscured by inter-tidal mud and loose gravel. It is dissected by several shallow channels and is breached around its central area by a deeper depression. This originally trench shaped feature, now partially infilled with estuarine clay and silt, is the so-called New Cut that was created in 1820 or 1821 to accommodate barges using the projected Arundel to Portsmouth canal. This provided a navigation channel for shallow draught vessels passing through Bridge Lake (as it was later named) and Sweare Deep connecting Portsmouth and Chichester Harbours (Vine, 1970) The canal was formally opened in 1823. The New Cut bisected the Wadeway, effectively preventing its further use except during the short period of extreme low water by those seeking to avoid payment of tolls on the new bridge. It is very rarely used today, and then only recreationally.
- 1.2 The first known map (in reality a chart) to indicate and name the Wadeway dates to 1716, with its approximate route shown on several later eighteenth century maps. It is accurately portrayed on the first edition Ordnance Survey 1 inch to 1 mile map published in 1815; the Langstone and Hayling shorelines are thought to have been surveyed for this map in about 1802. It appears on all subsequent O.S. maps at scales between 1:10,000 and 1: 50,000.

Recent research (Satchell, 2010, 2016) has established that the Wadeway was constructed between 1260 and 1420 AD by cutting through a metre or so of estuarine clay and silt down to a compacted clay horizon. This provided a firm foundation on which were laid several layers of aggregate and a superficial cover of flint rubble and rather crudely shaped blocks of stone. This material (of unknown provenance) was secured on both sides by closely spaced timber posts, between which were laid wood planks. Palaeo-environmental analysis of the molluscan and pollen content of the estuarine sediments together with radiocarbon dating of wood and other organic samples provide a chronostratigraphic time frame for the creation of the Wadeway. The estuarine sediments accumulated between 1030 and 1220AD indicating that the tidal channel between Hayling Island and the mainland existed by at least late Saxon times. The aggregate at the base of the Wadeway is present in two distinct layers, the lower unit dating to between 1260 and 1390 and the overlying unit to the period 1390 to 1420. It therefore appears that it was built in phases over an extended period, probably as a co-ordinated effort by local landowners. It may be that construction work was interrupted by inundation by one or more well documented storm surges, several of which caused substantial land losses along the open and estuarine coasts of southern England between 1236 and 1421. Flood and erosion events along the Hayling shoreline are recorded by Longcroft (1857), Thomas (1961) and Tweed(1990); the several re-entrants along the eastern shoreline of Hayling Island may be a permanent legacy of one or more surge events. In addition, during the fourteenth century there were several episodes of high human mortality from the Plague, resulting in severe labour shortages that prolonged work on the Wadeway.

- 1.3 Morley (1988;2016) has speculated that there was an earlier Wadeway located further east, perhaps created during the middle Roman period (2nd to 3rd centuries AD). There is considerable archaeological evidence for Roman settlement in both north Hayling and the Langstone areas. It may have followed a low isthmus that was progressively eroded and inundated in succeeding centuries by a combination of sea-level rise and first order tidal creek headcuts. By the eleventh century, and possibly earlier, it was no longer useable and the present Wadeway was constructed to replace it. If this could be confirmed the implication is that the final separation of Hayling Island from the mainland by the elimination of the divide between Sweare Deep and Bridge Lake might be as recent as the period between the fourth and tenth centuries AD. This is, however, difficult to relate to the late Holocene environmental history of Langstone Harbour proposed by Allen and Gardner (2000) and Arch-Manche (2015). This latter research suggests that tidal conditions were established in the north-west area of the harbour by middle to late Bronze Age times. These issues require clarification from additional chronostratigraphic data, and are outside the remit of this report.

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2.0 Havant to Hayling Island Railway Bridge; The “ Langstone Spit “

- 2.1 Following two abortive proposals the Hayling Railway Company, formed in 1860, was granted by Act of Parliament the right to build a steam locomotive railway from Havant to south Hayling Island. Construction started in 1863 with the track between Havant station and Langstone Wharf completed in late 1864. During the following year a wooden bridge supported by concrete encased piers was built across the tidal channel (now named Bridge Lake) between the mainland and the north shore of Hayling Island. At this stage it was planned to extend the railway southwards on an embankment along the western boundary of reclaimed mudflats and saltmarsh seawards of the north-west shoreline of Hayling. A lease for reclamation had been negotiated in 1863. This plan was abandoned after 160m of the embankment had been constructed, due to its partial collapse during the winter of 1865. The cause of this failure was apparently undermining of the foundations by “tidal scour” and wave abrasion, but inadequate design was probably an additional factor. A route close to the western shoreline of Hayling Island was chosen as a viable alternative (now the Hayling Billy pedestrian and cycle path) and was completed to its terminus at South Hayling station in 1867. The central part of the bridge included a section that could be

swung to one side to allow shipping to pass through. From 1867 until its closure in November 1963 the railway operated continuously, under a succession of ownerships. Much of the structure above the piers (which survive to the present day) was demolished in stages between 1966 and the early 1980s. Some 150m of the embankment connecting the line to the Langstone side of the bridge has been removed in the interests of public safety, although what remains of the bridge is accessible.

2.2 There are no available details on the materials used for the construction of the embankments immediately adjacent to the bridge nor of the sub-tidal foundations of the bridge itself. The successive first editions of the 1’’:1 mile Ordnance Survey map published up to the time when the bridge was built do not unambiguously indicate the presence of a gravel bank or similar “ hard” oriented approximately at right angles to the shoreline west of Langstone Quay that might have provided a firm foundation for the bridge piles and piers. Its alignment across Bridge Lake would appear to have been determined by economy, ie the shortest route connecting to the proposed embankment on the Hayling side. However, where the surviving railway line embankments adjacent to either end of the former bridge have partially collapsed it is currently possible to see crudely stratified layers of both coarse and fine gravel, large blocks of chalk and more finely divided chalk fragments. Some of this material litters the adjacent beaches and foreshores. Collapse is probably mostly due to deliberate regrading of the embankment slopes, but wave abrasion may be an additional contributory process of degradation. This evidence does not extend to the foundations of the embankment, but there is a strong possibility that a basal layer of coarse aggregate was laid as a base for the material used in their elevation. Throughout the nineteenth century, and possibly during the late eighteenth century, Langstone was a small port where cargoes of gravel, crushed road metal and coal were unloaded and stored in the vicinity of the Quay. Aggregate would therefore have been readily available to the railway building contractors as an inexpensive foundation and fill material. Aggregate was also discharged at nearby Langstone Mill and Bedhampton Quays, although it is unknown if this was the case at the time when the railway was being built.

2.3 Along the north-west Hayling shoreline several interconnecting enclosed oyster beds were created (or reconstructed) in the 1870s and early 1880s after the railway had been completed. These were later abandoned for commercial reasons and the site became derelict, and thereafter used in part as a waste dump . This use encroached onto land vacated by the railway after 1963, and continued into the mid 1970s. As part of the reclamation of this site for conversion to a Local Nature Reserve between 1990 and 1995, several trial boreholes were sunk. Some of these encountered what is described as “clean” gravel at depth, which might provide further evidence of the material used in preparing the foundations of the railway line. (www.haylingbillyheritage.org.uk/the-oyster-beds). This groundwork was undertaken by a partnership of Havant Borough Council and Hampshire County Council; these borehole logs may have been archived and available for inspection.

2.4 The gravel beach that has accumulated along the western boundary of the Langstone “Spit” is likely to have a composite origin. Some of the material has come from railway embankment exposure (especially evident along its southern sector, closest

to the former bridge), most of the remainder transported by onshore waves. Refracted waves have probably moved material by weak littoral drift along this sector, as suggested by patterns of particle sorting. The source of sediment feeding onshore transport would be the same as for the Lavant spit (refer to next section of this report for a more detailed discussion.) An additional artificial input might be aggregate used to build foundations for a pile supported wharf built in 1881/2 to service a short lived train ferry that operated between Langstone and the Isle of Wight.

- 2.5** Analysis by Last and Cope (2018) reveals that the beach along the western perimeter of the old railway embankment has moved westwards since 1946, at an average retreat rate of 0.2m.sec-1. This is deduced from the migration of the position of mean high water in the same direction, suggesting that it is due to beach narrowing and steepening over this period. Profile form has been steady, except at the “distal” end, whilst there has been an overall, if small, increase in both elevation and volume. This net gain could simply be a product of the incidence of higher energy waves directing sediment feed shorewards (refer to the following discussion of the Lavant Spit.) The balance of probability is that the morphodynamic trends of recent years will continue.
- 2.6** Accretion accounts for changes in the position of mean high water along the protected eastern boundary of the railway embankment. This is fine grain material, some of which has been released due to almost total extinction of salt marsh in this area of the harbour since the 1950s. Griffiths (2016) states that between 8 to 9,000 cubic metres of “mud” was piped to this site when the foundations of the new road bridge were excavated in 1955. There has also been dredging of the main navigation channels in the harbour; the approach channel to Langstone was regularly dredged between the 1870s and 1914 (Portsmouth Polytechnic, 1976) Might this also be a very localised source of silt and clay that settled out after initial disturbance?
- 2.7** As a final point, the development of a natural spit at this location is difficult to explain, and seems unlikely. There might have been a pre-existing gravel “hard”, but this is not apparent from the cartographic and documentary evidence. Only a borehole survey can clarify this question.

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3.0 Lavant Spit

- 3.1 There are two distinct spits that have extended eastwards across the mouth of the Lavant stream from the beach west to Southmoor Lane, which has accumulated in front of a low seawall and gabion defences. A seaward accretion structure extends for approximately 180m beyond its proximal attachment to this beach, trending at about 20 degrees east-north-east of the orientation of the latter. Much of its crest and landward slope support shingle tolerant vegetation, but its lobate shaped distal (terminal) sector is only partially stabilised by plant cover. A shallow, narrow tidal channel re-entrant separates this well-defined feature from an inner, shorter spit with proximal and distal sectors of different alignments. The latter has the characteristic of a recurve, diagnostic of spits modelled by secondary refracted breaking waves. This feature is apparently static, stabilised by a scrub and grass sward, and protected from open coast wave processes.
- 3.2 The sediment composition of the outer spit is dominated by mixed coarse to medium flint gravel; the largest clasts have long axes between 6 and 10 cms. Sampling by Bellew (1990) concluded that gravel accounted for 80% of the material, with 17% sand and 3% clay. (Samples were obtained from sites that are now located in the proximal sector, but at that time were close to the distal area.) The seaward slope (beach face) of the spit is of similar but less well sorted composition; median clast size was observed on a recent field visit to be marginally less close to the break of slope with the adjacent foreshore. The upper beach slope is apparently stable at about 10 degrees, declining to between 3 to 7 degrees seawards, although this change of gradient has no immediately evident relationship with grain size distribution or sorting. The wide foreshore has a gradient of less than one half a degree and consists of a patchy but dense distribution of coarse clastic material overlying a muddy (clay and silt) substrate. Much of it is colonised by algae, except for areas dissected by shallow shore parallel channels. Saltmarsh would have been present up to the mid twentieth century, but has been lost entirely as a result of the rapid decline of *Spartina anglica* in Langstone Harbour since then (Haynes and Coulson(1982); Baily and Pearson (2007); Cope et al (2008).
- 3.3 Analysis of the morphology of the outer spit (Last and Cope, 2018) reveals that its volume has progressively increased during the most recent 35 years (30% since 2005). It has also extended eastwards and gained elevation over the same period, with nearly 50m of distal growth between 2005 and 2016. Serial air photo cover back to 1946 indicates earlier eastward growth, but it was not until the late 1970s or early 1980s that the inner spit, until then a mobile feature, was left morphodynamically inactive by the expansion of its successor. It is difficult to interpret the evidence, and suggest reasons, for this hiatus in spit development at the mouth of the Lavant. It is likely to involve an alteration in the local sediment budget and/or may indicate

episodic sediment supply. For the present it seems a reasonable inference that there is a west to east littoral transport pathway along the updrift beach that is feeding the expansion and distal extension of the Lavant spit. The updrift beach west to the inlet at Brockhampton provides a sediment store of clastic material similar to that being added to the spit. Presumably it is being moved by refracted oblique breaking waves. However, this beach has been eroding over a longer term period as indicated by the landward movement of the position of mean high water (Last and Cope, 2018) This may only indicate that the beach has narrowed and steepened in response to ongoing sea-level rise and increased exposure resulting from the loss of inter-tidal saltmarsh. Storage volume may not have diminished. Thus it is a probability that lateral growth will continue into the future, accompanied by the eastward migration of the inter-tidal channel that carries discharge from the Lavant stream. Whether it will also continue to increase in elevation cannot be predicted.

- 3.4 The Coastal Sediment Transport Study (Carter, et al, 2004, updated 2012) fails to indicate longshore transport along the north-west shoreline of Langstone Harbour. This is an omission, as the indirect evidence from the Lavant spit is indicative, if not definitive. However, this report was unable to identify net littoral transport pathways elsewhere along the northern shorelines of Langstone, Portsmouth and Chichester Harbours.
- 3.5 Whilst a lateral transport feed to the Lavant spit seems a reasonable deduction (albeit a conditional one given the absence of supporting experimental field data), a critical question arising is the provenance of the dominant coarse as an inexpensive foundation and fill material clastic sediment. Where ultimately has it come from, and how has it been transported to the Langstone shoreline? This material is present in quantity on other beaches and foreshores elsewhere in Langstone and adjacent harbours. Its only likely source is Coombe Rock, a late Quaternary drift deposit of periglacial origin that occupies much of the coastal plain of south-east Hampshire and West Sussex. (Mottershead, 1977; Daley and Carter, 1989). It is composed of angular and sub-angular flint clasts in a clay matrix; the clasts are similar in shape and size to those on the Lavant spit and updrift beach. Many are unworn, suggesting that they have been released from Coombe Rock that formed low gradient fans and which extended some distance seawards of the modern harbour coastline. As a poorly consolidated deposit it was readily eroded, with its clay content lost to suspended transport, as sea-level rose during the Holocene and an ancestral form of Langstone Harbour was entrenched by ravine incision (Allen and Gardner, 2000). Erosion and low cliff recession ceased with the building of clay bunds enclosing inter-tidal land claim in the early nineteenth century and the later building of defences.
- 3.6 This foreshore store of coarse clastic material is substantial. How has a fraction of it been transported onto the beach and spit under discussion (and other harbour beaches)? Computed significant wave heights incident along the shoreline in north-west Langstone Harbour (Last and Cope, 2018) are well below those that entrain clasts of the sizes that occur there. This is conventionally regarded as a low energy shoreline, with weak tidal currents. The loss of inter-tidal saltmarsh has increased its exposure, but not sufficiently to account for the transport of material of observed calibre. Waves incident on this shoreline would presumably be constrained by the limited fetch distances within the harbour, which saltmarsh loss would only increase

marginally. It is therefore difficult to avoid the conclusion that the occurrence of high energy waves generated and propagated by storm surges has been disregarded, or at least seriously underestimated. A surge occurring during a period of peak high tide, when the foreshore is submerged between 4 to 6 hours, might create conditions that could mobilise offshore to onshore transport of large clastic debris. Erosion resulting from higher energy waves along the northern shorelines of the islands in the north-east of Langstone harbour between 1997 and 2000 are described in Allen and Gardner(2000). The construction of a so-called storm beach along the foundations of the railway embankment adjacent to the oyster beds during a surge event on 10/02/1997 is described in an account on the Hayling Billy heritage web site (www.haylingbillyheritage.org/the-oyster-beds.) Is this exceptional, or might we presume a long sequence of random high energy events that has produced a pulsed supply of coarse clastic beach sediment ? If so, it might have had a cumulative effect, ie material once gained would not be moved offshore, but perhaps longshore.

- 3.7 The possibility that harbour beaches have been partly constructed by human agency cannot be totally discounted, but there is no documentary or other supporting evidence. The enclosures made for land claim were clay banks, using spoil from co-adjacent mudflats.

- 3.8 Discharge from the River Lavant is a further possibility, as coarse flint bedload occupies the channel downstream to the mouth. However, air photo and lidar fails to show any convincing evidence of a sub-tidal delta. This potential source has therefore been discounted.

- 3.9 Most of the arguments in this review are provisional, indeed some of them are speculative. Further understanding would be served by the availability of field data on sediment characteristics and monitored wave heights and steepness. A short deployment of sediment tracing would be very useful in resolving the question of longshore transport- the rate at which it operates and the effects, if any, of wave abrasion on particle shape and size, sorting and other distribution criteria both cross and long-shore. The difficult question of whether longshore and offshore to onshore (?) sediment supply has been and will in the future be “pulsed” or episodic needs to be addressed.

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