EASTERN SOLENT | COASTAL PARTNERSHIP

CAKEHAM MANOR ESTATE

Coastal Process Analysis 2015

Monitoring Report

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1. INTRODUCTION

This coastal process report has been prepared by the Eastern Solent Coastal Partnership on behalf of Cakeham Manor Estate, summarising evolution of the coastline and the data available for monitoring coastal change. The report explores whether any additional data collection is required for;

- the western end of the frontage to establish *if and when* the coastline switches from accretion to erosion, according to Fitzgerald's (2012) theory
- the central and eastern section of the frontage, which are generally more vulnerable to erosion (Figure 1.1 and 1.2).

1.1 THE SITE

The section of coastline to the east of the Chichester Harbour inlet, West Sussex is extremely dynamic in nature given the strong tidal currents, alignment to the dominant south-south-westerly wave approach and mixture of sand and shingle beaches. The area of interest is the Cakeham Manor Estate frontage, situated between West Wittering and East Wittering, both of which have distinct sediment types and coastal processes in operation (Figure 1.1 and 1.2).

Figure 1.1: Oblique aerial photograph of Cakeham, looking towards East Head Spit and Hayling Island © Cope, 2013

The report presents the historical evolution of the site, with a focus on the last 12 years of data and records collected through the South-east Regional Coastal Monitoring Programme (www.channelcoast.org) and Chichester District Council, respectively. Recommendations for future monitoring and report writing are summarised.

Figure 1.2: Photograph location map of Cakeham Manor Estate

1.2 HISTORICAL EVOLUTION

The West Wittering and west Cakeham frontage is adjacent to the Chichester Harbour ebb-delta and therefore has a wide sandy foreshore made up of onshore wave-driven sand bars and sand dunes. The area is very much dominated by onshore wind-blown sand and strong tidal currents. The east Cakeham and East Wittering frontage is comprised of a gravel beach with a lower sandy foreshore, dominated by longshore drift from east to west (Figure 1.2 and 1.3). The central section of the Cakeham frontage is situated at the inter-change between the two, composed of a wide sandy foreshore with a mixed sand and gravel upper beach, backed by low cliffs (Figure 1.2).

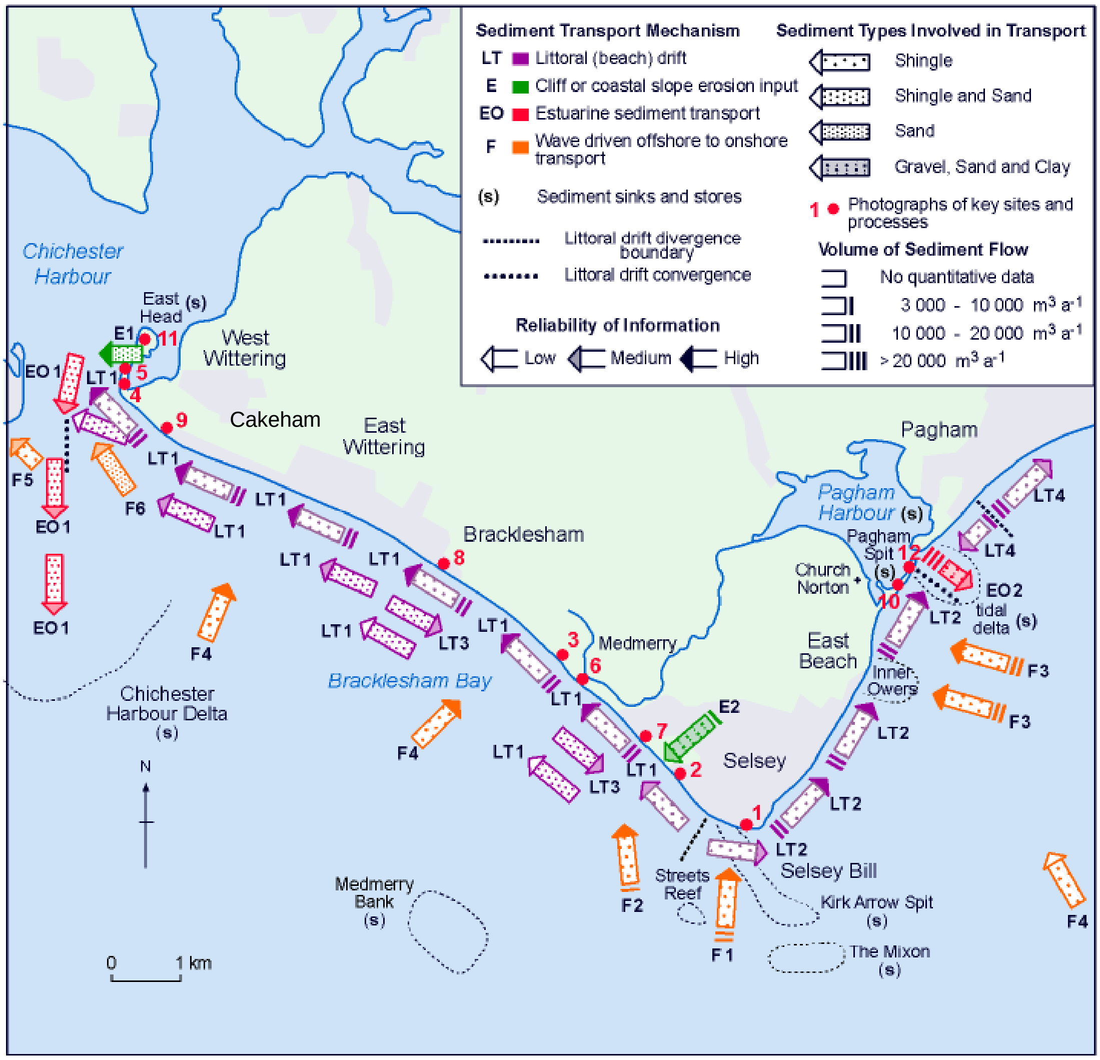


Figure 1.3: East Head Spit to Pagham, West Sussex: Sediment Transport (Carter *et al.,* 2004)

Over time, East Head spit has accreted a large volume of sand and has pivoted at The Hinge from a swash-aligned to a drift-aligned feature (ABP, 2001). At the same time, the sand has accumulated at West Wittering and west Cakeham, forming prograding sand dune features which act as a natural sea defence to the land and properties behind (Figure 1.4 and 1.5; Figures 8.1 and 8.2 in Appendix A; Figure 2.7 in Section 2.2.1).

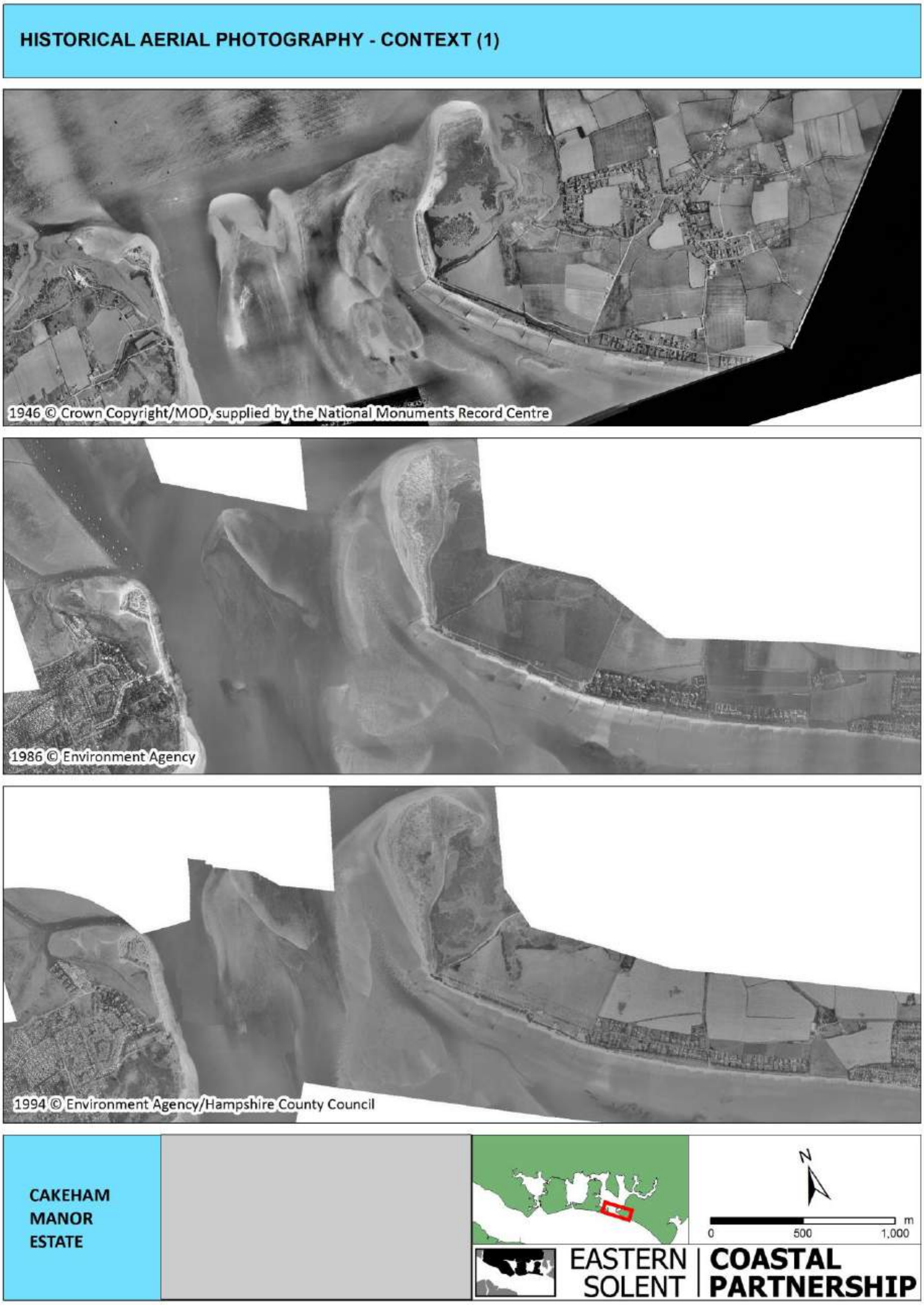


Figure 1.4: Cakeham wider area photography comparison (1946 - 1994)

Figure 1.5: Cakeham wider area photography comparison (2001 - 2013)

Accretion and erosion cycles of the sand dunes and sandy foreshore at west Cakeham are very much linked into the wider Chichester Harbour ebb delta system, whilst accretion and erosion of the gravel beach at east Cakeham is determined more by longshore drift with some onshore feed.

Cakeham Manor Estate is interested in monitoring these cycles to understand when coastal management intervention may be necessary. This is particularly true following the 2013/2014 storms which eroded parts of the frontage, and a recent report by Fitzgerald (2012) outlining his theory on the cyclical nature of the sand component of the Chichester Harbour system.

1.3 FITZGERALD'S THEORY (2012)

Fitzgerald's (2012) theory suggests that sediment is circulated in a counter-clockwise direction on the east of the Chichester Harbour inlet (Figure 1.6) and that the beaches experience repeated cycles of accretion and erosion relating to the 18.6 year tidal nodal cycle. Fitzgerald (2012) notes that accretionary phases last for 5-10 years, following a period of low tidal range. With the recent accretionary phase believed to have commenced in 2005 (Fitzgerald, 2012), Cakeham Manor Estate are concerned a period of erosion could commence soon (see Appendix B for additional detail).

Additional evidence is required to prove this theory and Fitzgerald (2012) notes that these predictions are cautious forecasts.

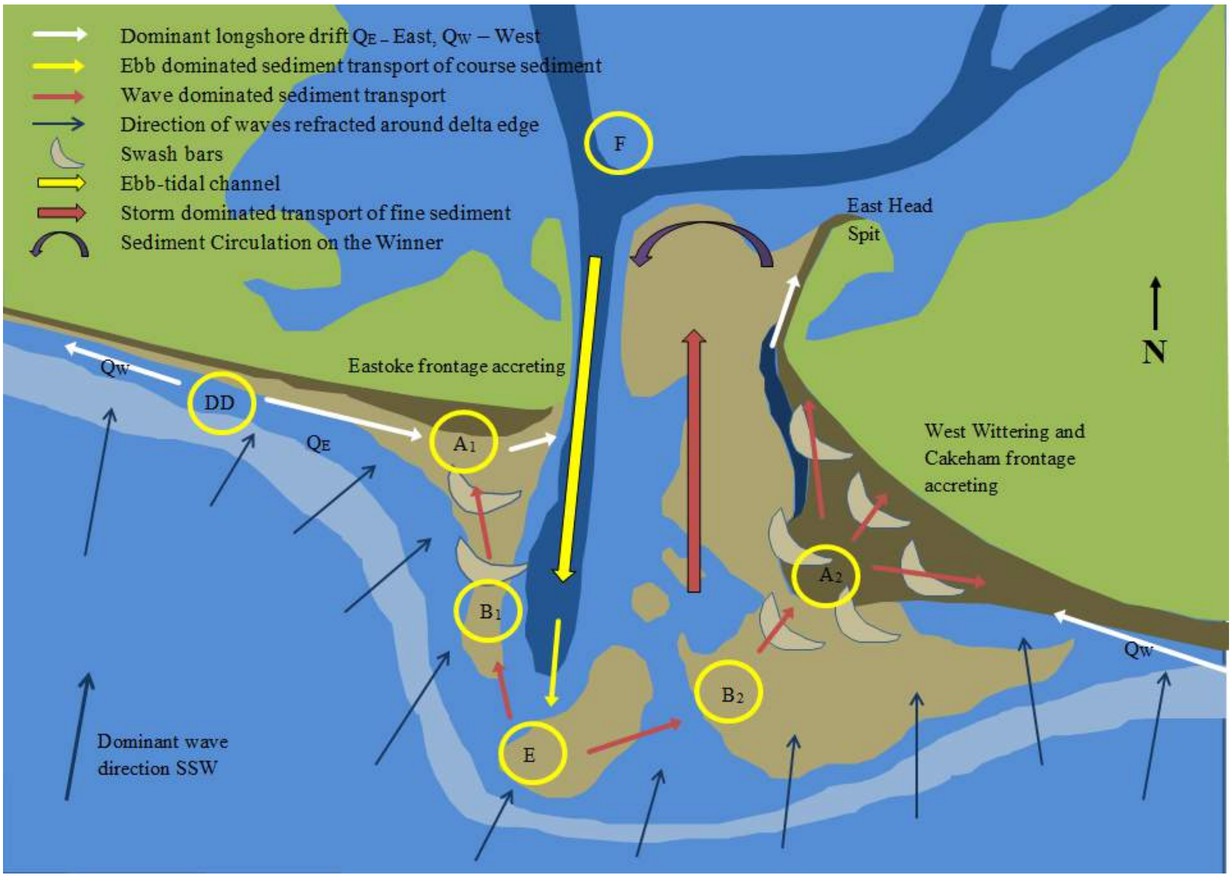


Figure 1.6: Stable inlet conceptual model showing dominant longshore transport & wave dominated transport (Fitzgerald, 2012)

2. DECADAL EVOLUTION

Following establishment of the South-east Regional Coastal Monitoring Programme (www.channelcoast.org) in 2002, it is now possible to analyse coastal change with more certainty. Given the 12 years of data available, longer term trends, rather than seasonal fluctuations can be determined.

When analysing beach volume change and cliff erosion, it is important to also consider the offshore conditions as well as any coastal management practices. This section presents the following:

2.1 Offshore conditions

2.2 Beach change

2.3 Beach management practices

2.1 OFFSHORE CONDITIONS

The Hayling Island and Bracklesham Bay directional wave buoys are located within close proximity to Cakeham and were deployed in ~10mCD water depth in 2003 and 2008 respectively, as part of the South-east Regional Coastal Monitoring Programme (Figure 2.1).

Figure 2.1: Position of wave buoys

The wave buoys show a difference in dominant wave direction between the two locations. The Hayling Island buoy has a predominant south-south-west wave approach (Figure 2.2), whilst the Bracklesham Bay buoy has a more predominant south-west approach (Figure 2.3). Wave energy from the west is low because of the sheltering effect of the Isle of Wight (Bray, 2010).

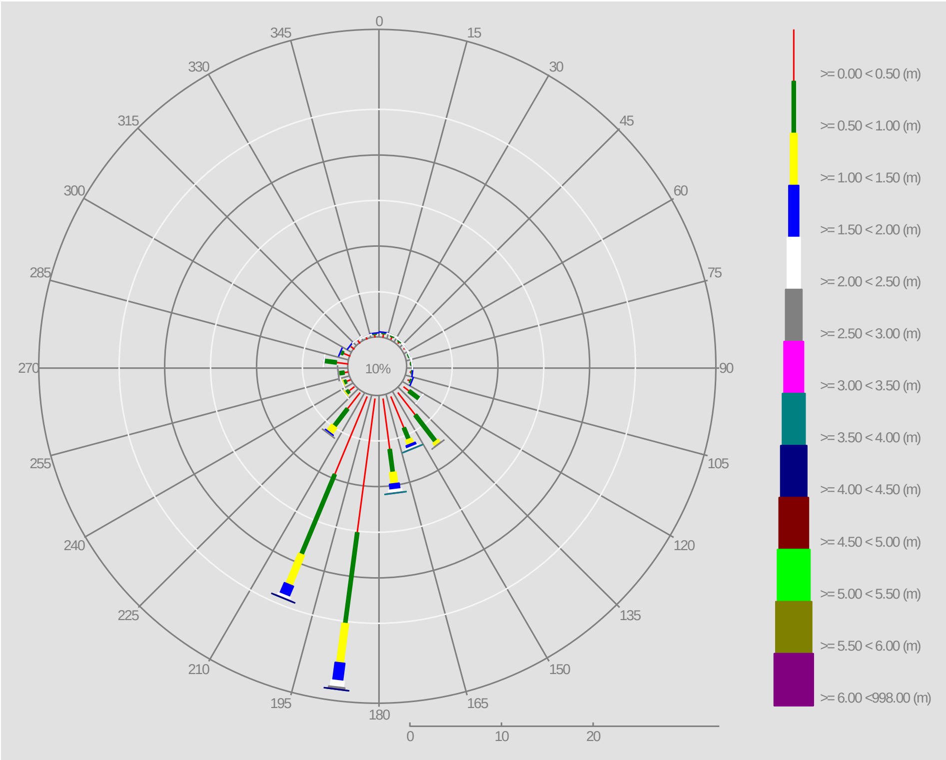


Figure 2.2: Offshore significant wave height - 2003 to 2014 at Hayling Island wave buoy (Mylroie and Evans, 2014)

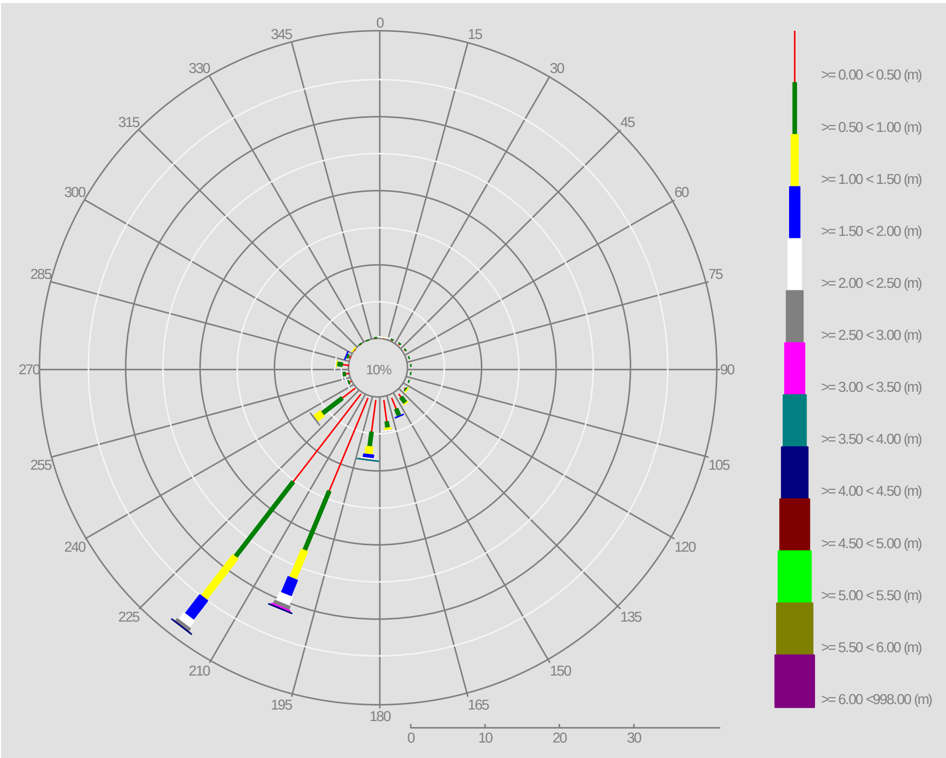


Figure 2.3: Offshore significant wave height - 2008 to 2014 at Bracklesham Bay wave buoy (Mylroie and Evans, 2014)

Table 2.1 and 2.2 present the maximum wave height per year for the Hayling Island and Bracklesham Bay wave buoy respectively.

Table 2.1: Annual wave statistics - Hayling Island wave buoy (Mylroie and Evans, 2014)

Year	Annual Maximum H_s	
	Date	A_{max} (m)
2003	29-Nov-2003 10:00	2.68
2004	08-Jan-2004 10:30	3.64
2005	02-Dec-2005 17:00	3.53
2006	03-Dec-2006 08:00	3.42
2007	18-Jan-2007 13:00	3.58
2008	10-Mar-2008 08:00	3.79
2009	14-Nov-2009 13:30	3.36
2010	11-Nov-2010 08:30	3.25
2011	13-Dec-2011 01:00	3.77
2012	03-Jan-2012 08:30	3.32
2013	28-Oct-2013 06:00	3.73
2014	05-Feb-2014 14:30	4.13

Table 2.2: Annual wave statistics - Bracklesham Bay wave buoy (Mylroie and Evans, 2014)

Year	Annual Maximum H_s	
	Date	A_{max} (m)
2008	09-Nov-2008 23:00	3.28
2009	23-Nov-2009 13:00	3.83
2010	31-Mar-2010 09:30	3.46
2011	13-Dec-2011 00:00	3.64^{+}
2012	03-Jan-2012 09:00	3.67
2013	24-Dec-2013 02:00	4.13
2014	15-Feb-2014 00:00	4.47

Both tables show 2014 as being the year with the highest wave heights since the buoys were deployed. Bradbury and Mason (2014) note that the storm on the 5th February 2014 recorded as 4.13 m by the Hayling buoy (Table 2.1) had a return period of 1:50 years, whilst the storm on the 15th February 2014, recorded by the Bracklesham buoy (Table 2.2) had a return period of 1:20 years.

The following storm charts show that the winter of 2013/2014 was the stormiest season on record since the buoys were deployed. Not only were there many more storms during this winter but they were larger than previous years (Bradbury and Mason, 2014).

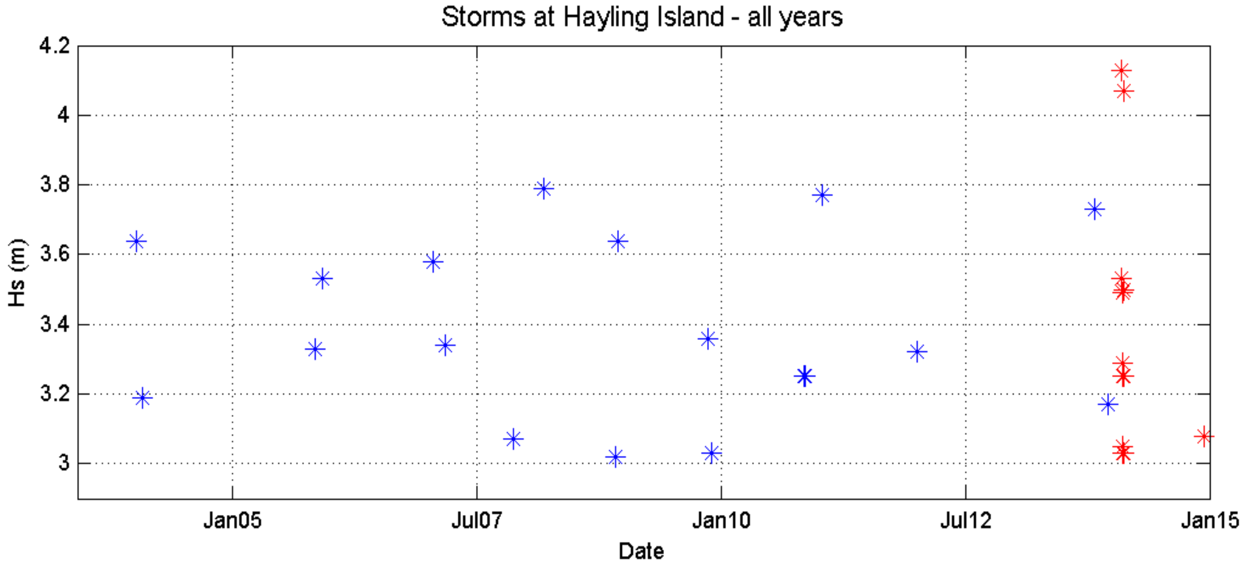


Figure 2.4: Storms affecting Hayling Island between 2003 and 2014. 2014 storms are shown in red (Mylroie and Evans, 2014).

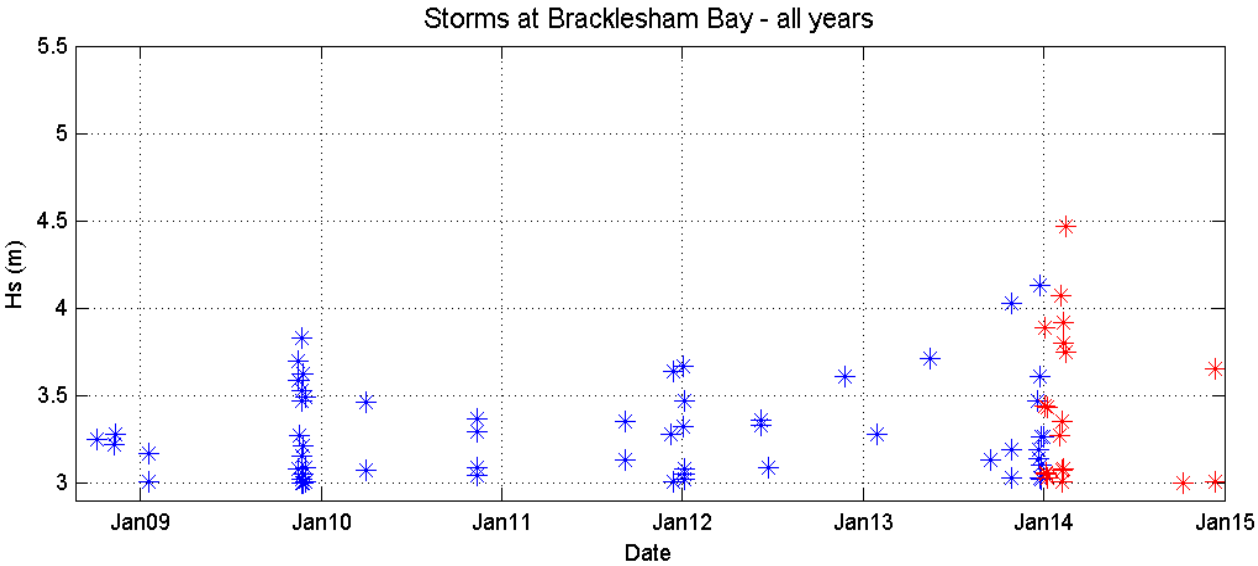


Figure 2.5: Storms affecting Bracklesham Bay between 2008 and 2014. 2014 storms are shown in red (Mylroie and Evans, 2014)

The tidal conditions for Chichester Harbour entrance are shown in Table 2.3.

Table 2.3: Tidal conditions for Chichester Harbour (Entrance), 2015

Tide Condition	Level (mCD)	Level (mOD)
LAT	+0.2	-2.54
MLWS	+0.9	-1.84
MLWN	+1.9	-0.84
MSL	+2.9	0.16
MHWN	+4.0	1.26
MHWS	+4.9	2.16
HAT	+5.3	2.56

Figure 2.6 presents mapping of the seabed sediment type offshore of Cakeham. The majority is sand with a coarse sediment bank to the east, in front of East Wittering (Evans and Colenutt, 2015).

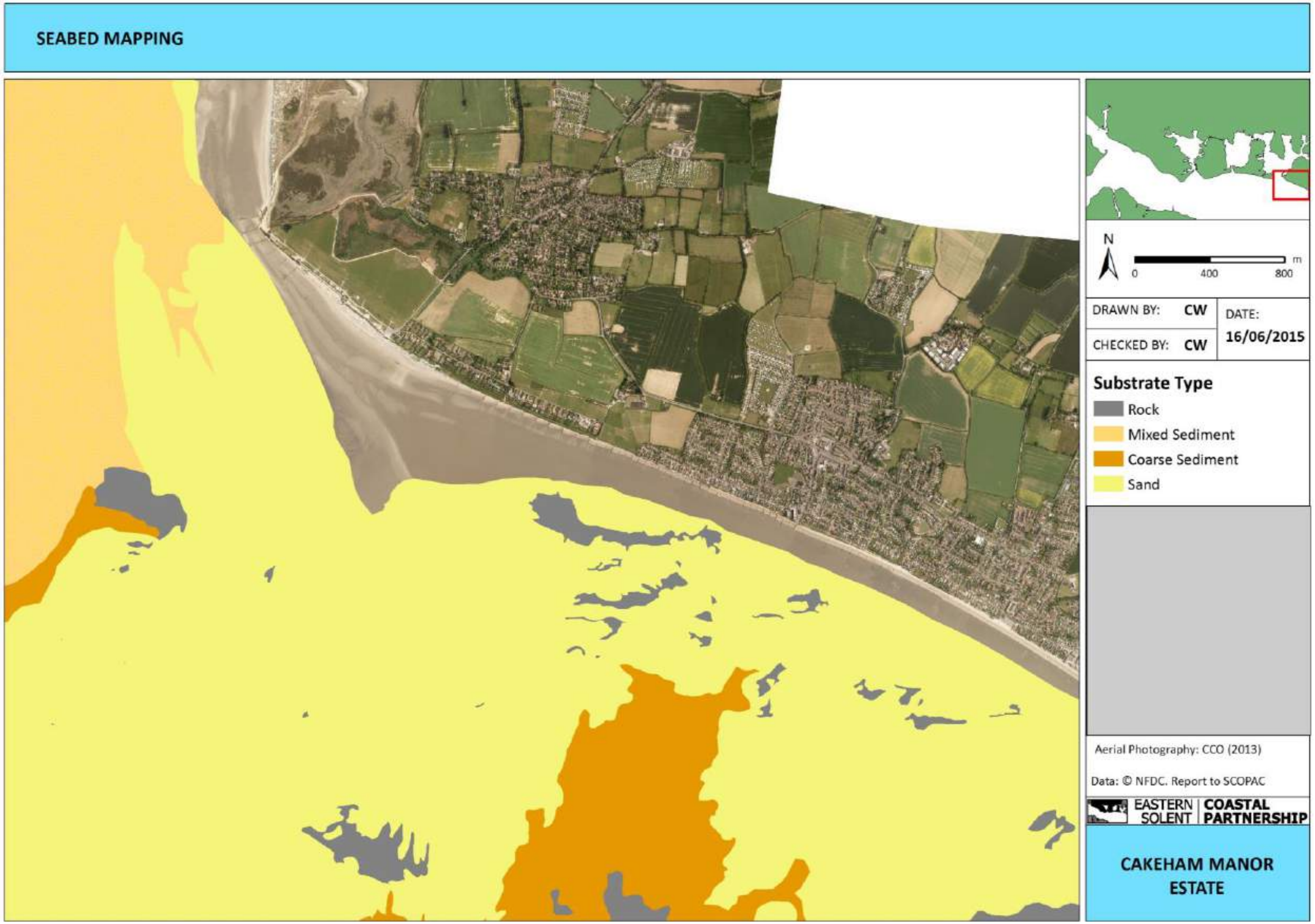


Figure 2.6: Sediment type offshore of Cakeham frontage, 2014 (Evans and Colenutt, 2015)

2.2 BEACH CHANGE

The following section analyses data from the South-east Regional Coastal Monitoring Programme to show:

2.2.1 Beach sediment type

2.2.2 Profile cross-section area change

2.2.3 Topographic difference plots

2.2.1 BEACH SEDIMENT TYPE

Beach sediment type changes were mapped from aerial photography flown in 2001, 2008 and 2013 (Figure 2.7). Sediment types identified include *gravel, gravel and sand, sand* and *sand dunes*.

The *sand dunes* (mapped in green) have accreted to the east since the 2001 mapping. There appears to be an area (circled in red) which switches between *sand* and mixed *gravel and sand* as the *gravel* travels west and the *sand* progrades east. The *gravel* portion of the beach (grey) appears to be more dominated by mixed *gravel and sand* in 2013 compared to other years.

Figure 2.7: Change in position of sediment type (2001 - 2013)

2.2.2 PROFILE CROSS-SECTION AREA CHANGE

The profile lines represent annual change on the beach at the position shown by the lines. The surveys are carried out using kinematic GPS by surveyors on the beach, with an accuracy of ±2cm. The lines represent accretion (blue) and erosion (red), and display actual change in m^2.

The difference in profile cross-sectional area is presented, showing change annually between 2003 and 2014 (Figures 2.8 – 2.11). Additional information on interpretation of the profiles is presented in Appendix C; when analysing, "actual change," the results are dependent on the length of the profile line surveyed.

2.2.3 TOPOGRAPHIC DIFFERENCE PLOTS

In order to show change in beach levels across the whole beach, 'difference plots' were created by subtracting one survey from another in GIS. A decrease in beach elevation is shown in red and an increase in beach elevation is shown in blue. The extent of the difference plots is depicted with a yellow boundary. Topographic beach data was used where possible with an accuracy of ±2cm; otherwise lidar data was included, which has a vertical accuracy of ±15cm.

The following difference plots were created:

2003-2008: Figure 2.12 shows the first 5 years of change

2008-2012: Figure 2.13 shows the latter 5 years of change

2012-2013: Figure 2.14 shows change before the major 2013/2014 storms[1]

2013-2015: Figure 2.15 shows change after the major 2013/2014 storms[1]

2003-2012: Figure 2.16 shows long term change before the 2013/2014 storms

2003-2015: Figure 2.17 shows long term change after the 2013/2014 storms[1]

[1] 2013 and 2015 lidar data (© Environment Agency) still to be quality checked. Outputs to be used with caution until data is signed off in Autumn 2015

Figure 2.8: Annual beach change (2003-2005)

Figure 2.9: Annual beach change (2005-2008)

Figure 2.10: Annual beach change (2008-2011)

Figure 2.11: Annual beach change (2011-2014)

Figure 2.12: Topographic difference plot (2003-2008)

Figure 2.13: Topographic difference plot (2008-2012)

Figure 2.14: Topographic difference plot (2012-2013)

Figure 2.15: Topographic difference plot (2013-2015)

Figure 2.16: Topographic difference plot (2003-2012)

Figure 2.17: Topographic difference plot (2003-2015)

2.3 BEACH MANAGEMENT PRACTICES

It is important to understand both natural and man-made sediment movement, therefore beach recycling and replenishment volumes are presented in Table 2.4 and Figure 2.18.

Table 2.4: Beach management since 2000 between East Head and Bracklesham

Location	Year	Activity	Volume
East Head Spit	2005	Extraction	13,000
	2009		10,200
East Head Spit Hinge	2005	Deposition	13,000
	2009		10,200
West Witterings – behind beach huts *	2000	Extraction	600
	2001		600
	2002		600
	2003		600
	2004		600
	2005		600
	2006		600
	2007		600
	2008		600
	2009		600
	2010		600
	2011		600
	2012		600
West Witterings – in front of beach huts	2000	Deposition	600
	2001		600
	2002		600
	2003		600
	2004		600
	2005		600
	2006		600
	2007		600
	2008		600
	2009		600
	2010		600
	2011		600
	2012		600
Shore Road & E. Bracklesham Development	Winter 2013/2014	Extraction	8,000
West of Shore Road (8 groyne bays)	Winter 2013/2014	Deposition	8,000
East of Joliffe Road (3 groyne bays)	Winter 2014/2015	Deposition (replenishment)	3,900
West of Joliffe Road (5 groyne bays)	Winter 2014/2015		7,800

NOTE*: the extraction and deposition around the beach huts at the Witterings isn't actual recycling. The sediment which is moved from behind the beach huts to the front is wind-blown sand. The sand is blown behind the beach huts over the winter and is then removed and placed back on the beach during March every year.

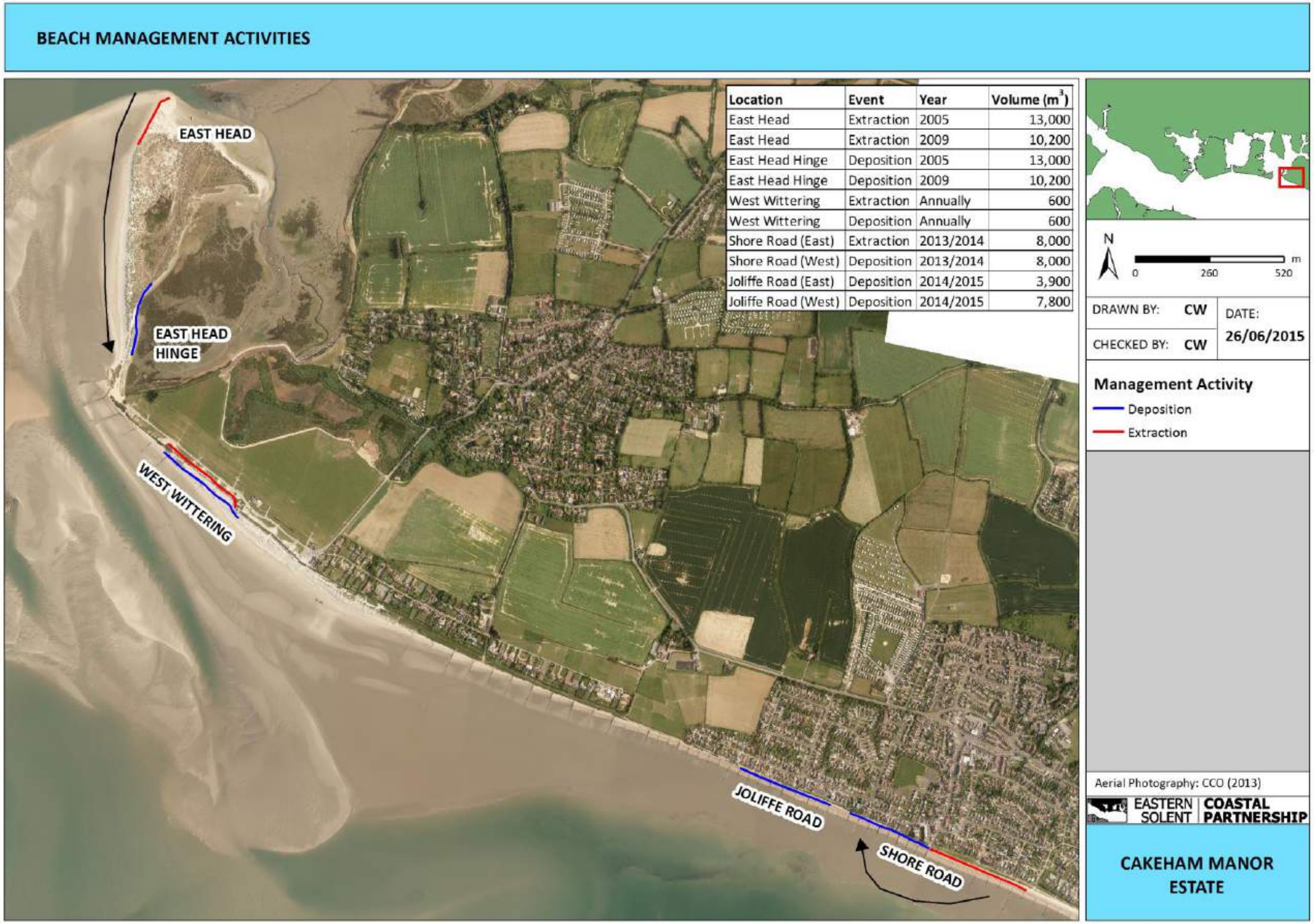
Following the 2013/2014 storms, David Lowsley of Chichester District Council (personal communication, 2015), reports that;

2013-2014: 8000m^3 gravel was extracted from in front of the east Bracklesham development, and deposited directly to the west of Shore Road. This recycling event filled 8 groyne bays after the storms.

2014-2015: 11,000m^3 of pure gravel was imported and deposited around Joliffe Road; 3 groyne bays to the east and 5 groyne bays to the west. The bays were filled with a crest width of approximately 5m, and a height of ~5mOD. As the winter of 2014/2015 had a relatively low storm frequency and magnitude, the gravel has remained and not moved alongshore.

According to the historical aerial photography, Cakeham Manor Estate has had timber groynes in place since at least 1946, to slow the rate of gravel transport from east to west. The groynes at west Cakeham are now covered with sand, illustrating the movement of sand from west to east.

Recently, Cakeham Manor Estate has been trapping the excess sand at west Cakeham to assist the natural process of building sand dunes. In turn, the sand dunes act as a natural sea defence, protecting the properties behind.



Location	Event	Year	Volume (m^3)
East Head	Extraction	2005	13,000
East Head	Extraction	2009	10,200
East Head Hinge	Deposition	2005	13,000
East Head Hinge	Deposition	2009	10,200
West Wittering	Extraction	Annually	600
West Wittering	Deposition	Annually	600
Shore Road (East)	Extraction	2013/2014	8,000
Shore Road (West)	Deposition	2013/2014	8,000
Joliffe Road (East)	Deposition	2014/2015	3,900
Joliffe Road (West)	Deposition	2014/2015	7,800

Figure 2.18: Beach Management Activities around the Cakeham area

3. DISCUSSION

Beach change prior to 2012

According to the 2003 – 2012 difference plot (Figure 2.16), there was a general trend of accretion for the Cakeham frontage, with lowering of the central Cakeham section for the mixed gravel and sand upper beach.

Beach change since 2012

According to the 2012 – 2013 and 2013 – 2015 difference plots (Figures 2.14 and 2.15), as well as the 2012 – 2013 and 2013 – 2014 profile line maps (Figure 2.11), there does appear to be a more general trend of erosion, particularly for central and east Cakeham and the sandy foreshore at west Cakeham. A difference plot of the wider area was produced to investigate this further, highlighting foreshore lowering at West Wittering between 2013 – 2015 (Figure 3.1). This erosion correlates with an increase in storm frequency and intensity (Figures 2.4 and 2.5) and annual maximum wave height since 2012 (Table 2.2).

Still, the 2003 – 2015 long-term difference plot (Figure 2.17) shows the continued accretion of sand on the upper and lower beach for west Cakeham, as well as an increase in sand on the lower foreshore for central Cakeham, supporting earlier interpretation by Bray (2007; 2010) of onshore migration of swash bars of sand from the Chichester Harbour ebb tidal delta.

West Cakeham

The longer term difference plots clearly show the accretion of sand at west Cakeham between 2003 – 2015 (Figure 2.17). The profile line maps support this in general, although seasonal erosion is noted for 2005-2006, 2010-2011, 2011-2012, 2012-2013 and 2013-2014. According to Figure 2.5, the winter of 2009/10, 2011/2012 and 2013/2014 had a high cluster of storms.

Central Cakeham

Central Cakeham is the interchange between sand and gravel and over the longer term, the difference plots show erosion of the upper beach between 2003 - 2012 and 2003 – 2015 (Figure 2.16 and Figure 2.17), with accretion of sand on the foreshore. The profile line maps show mixed accretion and erosion with a higher degree of seasonal erosion for 2005-2006, 2010-2011, 2012-2013 and 2013-2014. There is a hotspot of erosion at the end of Berry Barn Lane, highlighted since the 2013/2014 storms in the 2003 – 2015 difference plot (Figure 2.17).

East Cakeham

East Cakeham is dominated by an upper gravel beach and lower sandy foreshore. Prior to the 2013/2014 storms, the gravel beach and sandy foreshore were showing net accretion (Figure 2.16). The longer term trend since the 2013/2014 storms continues to be beach accretion, although a hotspot of erosion is noted for the gravel beach and sandy foreshore along the footpath backed by fields (Figure 2.17). The profile line maps show mixed accretion and erosion with a higher degree of seasonal erosion for 2008-2009, 2010-2011, 2012-2013 and 2013-2014.

Following analysis of the difference plots and profile line maps, two hotspots of erosion have been identified for central and east Cakeham (Figure 3.2). According to the Environment Agency flood zones, the hinterland is not at risk of flooding under a, “no defences” scenario (Figure 11.1).

Figure 3.1: Difference plot of wider area around Cakeham Manor Estate: 2013 - 2015

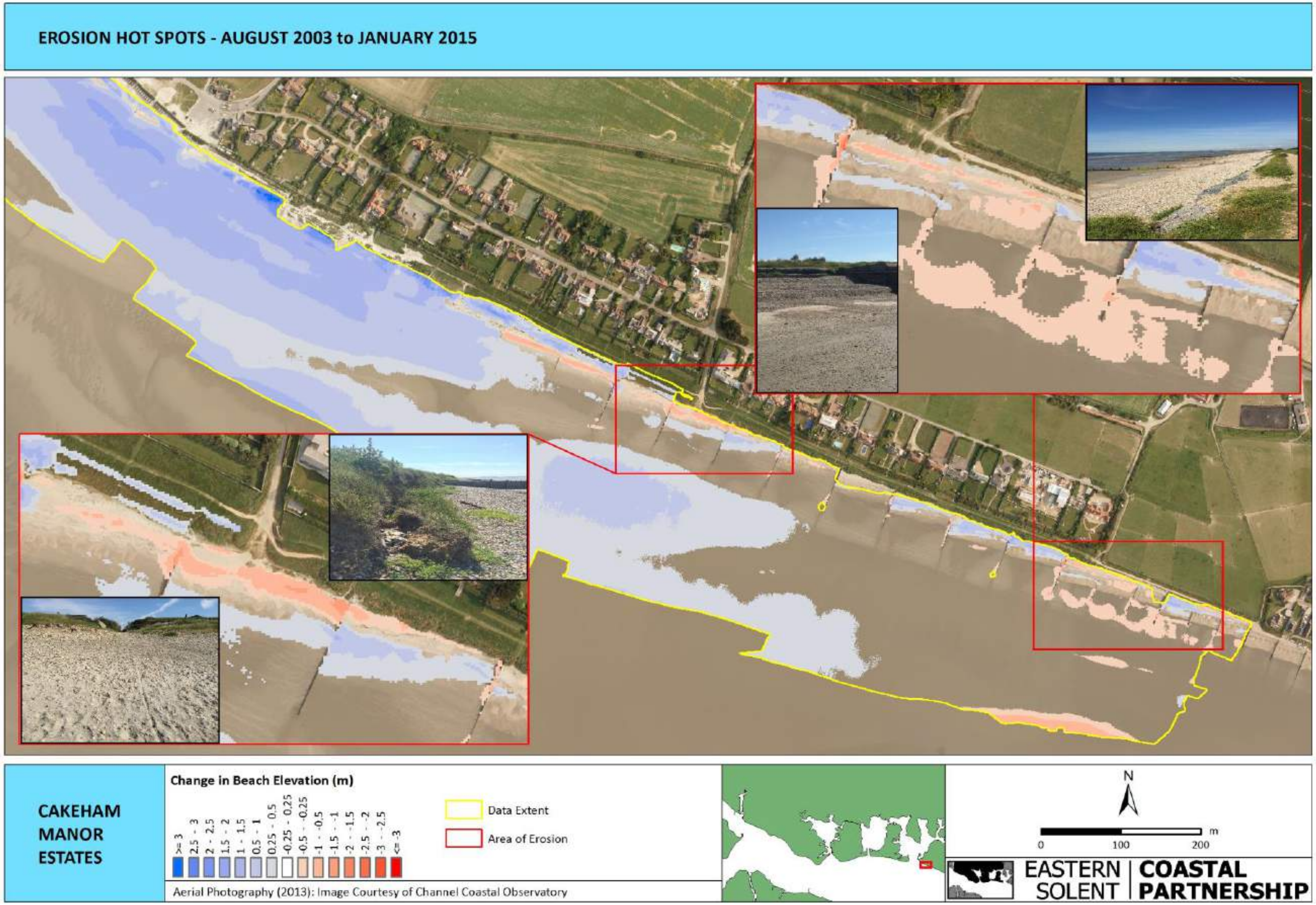


Figure 3.2: Main erosion hot spots identified from survey data (2003 – 2015)

4. MONITORING RECOMMENDATIONS

It is recommended that an annual report is produced to identify any changes to the sand dune section and lower foreshore to the west of Cakeham and the low cliffs and gravel section to the east. Currently, lidar data is captured for the frontage on an annual basis as part of the South-east Regional Coastal Monitoring Programme. This data can be worked up to produce annual difference plots, highlighting any hotspots of erosion or accretion.

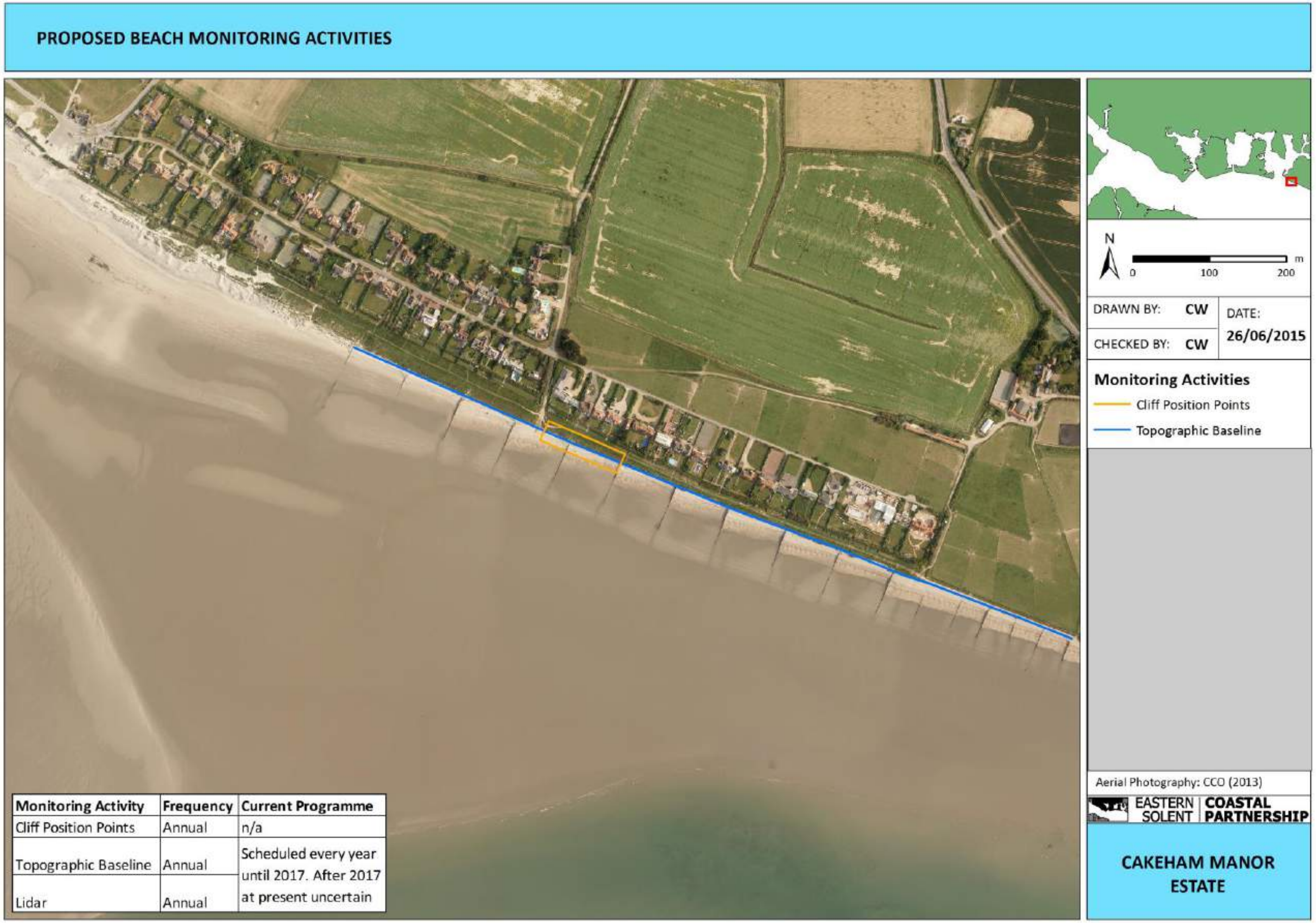
Additional monitoring is recommended for the low cliffed section depicted in Figure 4.1. This would involve surveying points at the top of the cliff and at the base of the cliff on an annual basis (Figure 4.2). Increased survey frequency may be required if the erosion rate escalates. It is also recommended that Cakeham Manor Estate take photos of the hotpots of erosion identified in Figure 3.2 on an annual basis, as well as the low cliffs and the West Cakeham section.

Figure 4.1: Low cliffed section at Cakeham (© Uwe Dornbusch, July 2014)

The survey schedule for the current 5 year phase (2012 – 2016) of the South-east Regional Coastal Monitoring Programme is presented in Table 4.1. The next 5 year phase of monitoring (2017 – 2021) is yet to be formally approved; therefore there is no certainty over future survey coverage and frequency. It is recommended that topographic baseline surveys are undertaken for the blue line depicted on Figure 4.1 for any years when lidar or topographic surveys are not collected as part of the next 5 year programme.

Table 4.1: Survey schedule for the South-east Regional Coastal Monitoring Programme at Cakeham Manor Estates

Survey Type	Frequency	Next Scheduled
Lidar	Annually	2016
Topographic Baseline	Annually	August 2015
Topographic Profiles	6 monthly	October 2015
Hydrographic Baseline	Annually	June 2015
Aerial Photography	5 yearly	2018



Monitoring Activity	Frequency	Current Programme
Cliff Position Points	Annual	n/a
Topographic Baseline	Annual	Scheduled every year until 2017. After 2017 at present uncertain
Lidar	Annual	

Figure 4.2: Proposed future beach monitoring for Cakeham Manor Estate

5. CONCLUSIONS

The year 2014 was the stormiest both in frequency and magnitude, since the Hayling Island and Bracklesham Bay wave buoys were deployed in 2003 and 2008 respectively (Bradbury and Mason, 2014) (Section 2.1). The difference plots indicate that the erosion experienced along the Cakeham frontage during this time was probably a direct response to these stormy conditions. Still, given the foreshore lowering at West Wittering since the 2013/2014 storms and the two hotspots of erosion identified at the end of Berry Barn Lane and the section of coastline at east Cakeham, it is recommended that this report be revised on an annual basis. This will identify how these areas are recovering since the storms and provide additional evidence to support or disprove Fitzgerald's (2012) theory for West Cakeham.

It is recommended that an annual report be produced in summer 2016 using the South-east Regional Monitoring Programme lidar data, which is captured on an annual basis for the current 5 year phase of the programme. The future funding and monitoring schedule is still to be approved for the next 5 year phase of the programme commencing in 2017. Once the outcome is known, Cakeham Manor Estate will be in a better position to decide whether additional beach monitoring is required.

This report does recommend however, that additional monitoring is collected for the low cliffs (Section 4), and that photographs of the frontage are taken from the same point on an annual basis.

6. REFERENCES

ABP, 2001a. *Geomorphological Analysis of East Head and Chichester Harbour*. ABP Research & Consultancy Ltd, Report no. R.893.

Bradbury, A.P., and Mason, T.E. (2014) *Review of south coast beach response to wave conditions in the winter of 2013-2014.* Southeast Regional Coastal Monitoring Programme.

Bray, M. (2007) *East Head, West Wittering and Cakeham: Interpretation of beach changes 2003-06*. Draft Report to: Chichester District Council and East Head Coastal Issues Advisory Group

Bray, M. (2010) *East Head, West Wittering and Cakeham: Interpretation of beach changes 2004-09*. Draft Report to: Chichester District Council and East Head Coastal Issues Advisory Group

Evans, J., & Colenutt, A. (2015) *Seabed Mapping: Selsey to Eastoke. SCOPAC East Solent Seabed Mapping.* New Forest District Council report to SCOPAC

Fitzgerald, R. (2012) *Dynamics of an Ebb-Tidal Delta & Adjacent Beaches: Chichester Tidal Inlet*. Master's Thesis, University of Sussex

Mylroie, P., & Evans, E. (2014) *Annual Survey Report 2014: Selsey Bill to Southampton Water*. Southeast Strategic Regional Coastal Monitoring Programme

Carter, D., Bray, M. & Hooke, J. (2004) *SCOPAC Sediment Transport Study.* Department of Geography, University of Portsmouth. Report to SCOPAC, hosted on: www.scopac.org.uk/sediment-transport.htm

7. ACKNOWLEDGEMENTS

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8. APPENDIX A: Historic Aerial Photography

The following Figures 8.1 and 8.2 show historical aerial photography for the Cakeham frontage with the 2013 Mean Low Water contour overlaid.

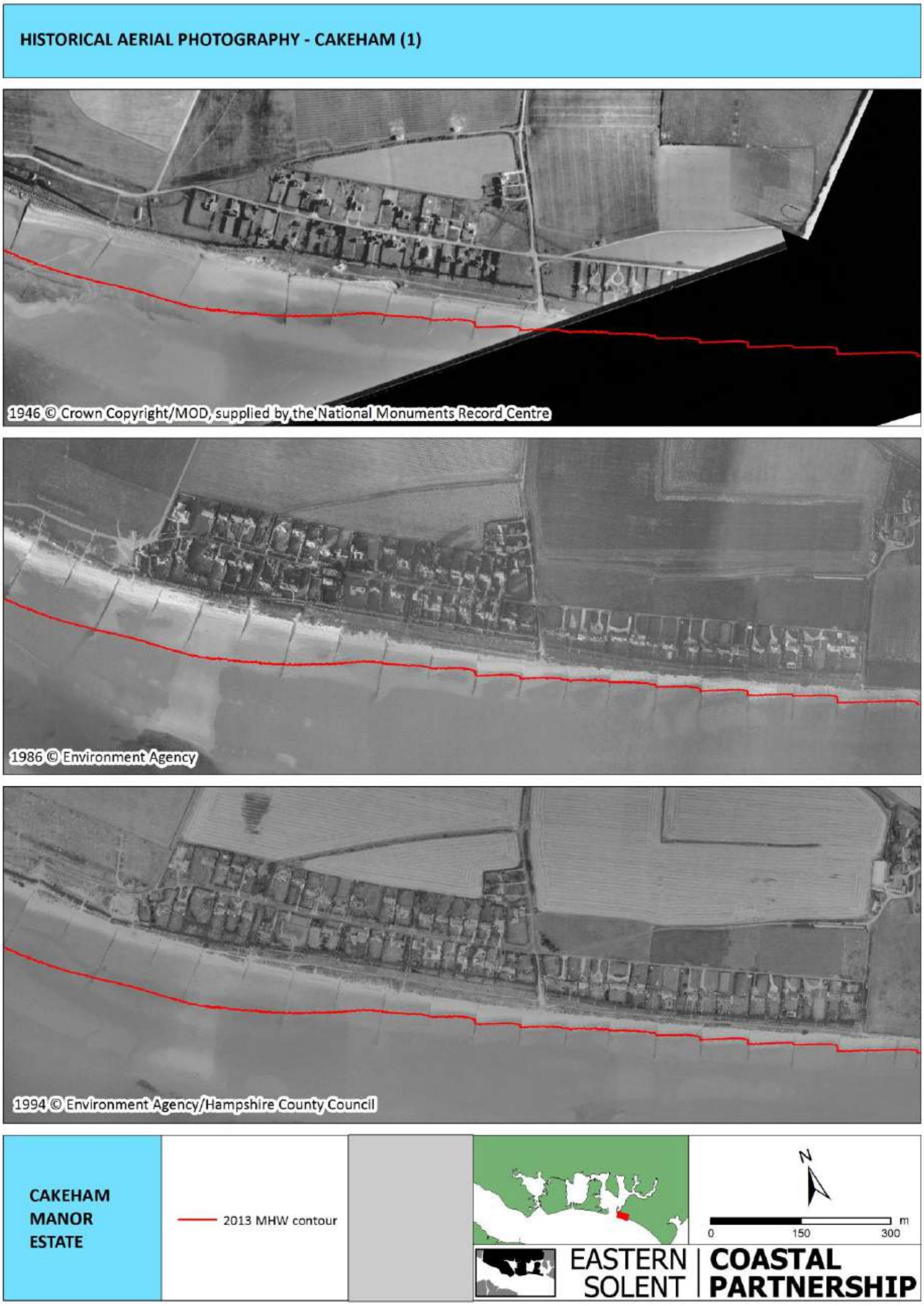

Figure 8.1: Cakeham frontage photography comparison (1946 - 1994)

Figure 8.2: Cakeham frontage photography comparison (2001 - 2013)

9. APPENDIX B: Fitzgerald's (2012) Theory

The following presents Fitzgerald's (2012) theory:

"Abstract: This paper describes an investigation into the volumetric growth of beaches adjacent to the Chichester Tidal Inlet. It uses a multi-faceted approach to synthesise the inlet system's historical evolution and behaviour, its contemporary sediment budgets and geomorphology, and the influence of controls and the forcing environment. The results suggest that sediment is circulated in a counter-clockwise direction on the east of the inlet and that the beaches here experience repeated cycles of growth and decay relating to the cyclic formation and onshore migration of swash bars on the marginal shoal of the ebb-delta. Accretion during the current growth phase, which began in 2005 and is calculated to involve 150,000 $m^3 a^{-1}$ of sediment welding to the foreshore, has significantly slowed with erosion predicted to recommence. Modelling suggests that conditions are most conducive to beach accretion following peaks in low tidal range when they coincide with periods of exceptional swell wave activity and sediment availability. Growth phases are likely to last 5-10 years and involve upward of 600,000 m^3 of sediment. Conditions are most conducive to periods of decay following peaks in high tidal range, with coastal erosion and flooding most likely when they coincide with exceptional storm wave activity and sediment deficiency. Despite the complexity of the system's behaviour and the significant uncertainty regarding the predictions, based on the 18.6 year tidal nodal cycle the study cautiously forecasts that potential for erosion is greatest following the 2017, 2035, 2054, 2072 and 2091 peaks in tidal range. During these periods the estuary's tidal prism is enhanced by as much as 11% maximising the ebb-jet's capacity to oppose wave energy's attempts to return shoreward delta sand and starve the frontages adjacent to the inlet. This study demonstrates how an approach that considers coastal setting, geomorphological change, sediment budgets, controls and forcing at a variety of temporal scales can be used to enhance coastal management plans and in general the interpretation of tidal inlets."

10. APPENDIX C: Topographic Profile Lines

The following provides additional information on the interpretation of the profile lines at Cakeham:

Points are recorded along the profile lines every 5m, or wherever there is a change in slope (e.g. beach berms, beach toe). All lines on the maps are shown to be the same length; however this is not the extent of the surveyed line. Some lines are longer than others, and this needs to be taken in to account when considering the beach change. Between the Cakeham Manor Estate frontage and East Head spit the profile lines surveyed are very long. Therefore any large changes in the cross-sectional area over the line will be relatively small when spread along the full length of the line. If these cross-sectional areas are converted to percentages then the change will be very small along the lines.

11. APPENDIX D: Environment Agency Flood Zones

Figure 11.1: Environment Agency flood zones 2 and 3 under a, "no defences" scenario


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