Halcrow
A CH2M HILL COMPANY

Cell 1 Regional Coastal Monitoring Programme
Analytical Report 1: 'Full Measures' Survey 2011

Redcar and Cleveland Borough Council
Final Report

October 2012

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Abbreviations and Acronyms

Acronym / Abbreviation	Definition
AONB	Area of Outstanding Natural Beauty
DGM	Digital Ground Model
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWS	Mean Low Water Neap
MLWS	Mean Low Water Spring
m	metres
ODN	Ordnance Datum Newlyn

Water Levels Used in Interpretation of Changes

Water Level Parameter	Water Level (m AOD) Hartlepool Headland to Saltburn Scar	Skinningrove	Hummersea Scar to Sandsend Ness	Sandsend Ness to Saltwick Nab
HAT	3.25	3.18	3.15	3.10
MHWS	2.65	2.68	2.65	2.60
MLWS	-1.95	-2.13	-2.15	-2.20

Water Level Parameter	Water Level (m AOD) Saltwick Nab to Hundale Point	Hundale Point to White Nab	White Nab to Filey Brigg	Filey Brigg to Flamborough Head
HAT	3.10	3.05	3.05	3.10
MHWS	2.60	2.45	2.45	2.50
MLWS	-2.20	-2.35	-2.35	-2.30

Source: *River Tyne to Flamborough Head Shoreline Management Plan 2*. Royal Haskoning, February 2007.

Glossary of Terms

Term	Definition
Beach nourishment	Artificial process of replenishing a beach with material from another source.
Berm crest	Ridge of sand or gravel deposited by wave action on the shore just above the normal high water mark.
Breaker zone	Area in the sea where the waves break.
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by the fixing of the high water mark, e.g. a sea wall.
Downdrift	Direction of alongshore movement of beach materials.
Ebb-tide	The falling tide, part of the tidal cycle between high water and the next low water.
Fetch	Length of water over which a given wind has blown that determines the size of the waves produced.
Flood-tide	Rising tide, part of the tidal cycle between low water and the next high water.
Foreshore	Zone between the high water and low water marks, also known as the intertidal zone.
Geomorphology	The branch of physical geography/geology which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.
Groyne	Shore protection structure built perpendicular to the shore; designed to trap sediment.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean Sea Level (MSL)	Average height of the sea surface over a 19-year period.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm.
Swell	Waves that have travelled out of the area in which they were generated.
Tidal prism	The volume of water within the estuary between the level of high and low tide, typically taken for mean spring tides.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Updrift	Direction opposite to the predominant movement of longshore transport.
Wave direction	Direction from which a wave approaches.
Wave refraction	Process by which the direction of approach of a wave changes as it moves into shallow water.

Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the north east coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. This coastline is often referred to as 'Coastal Sediment Cell 1' in England and Wales (Figure 1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing salt marshes, hard rock cliffs that are mantled with glacial sediment to varying thicknesses, softer rock cliffs and extensive landslide complexes.

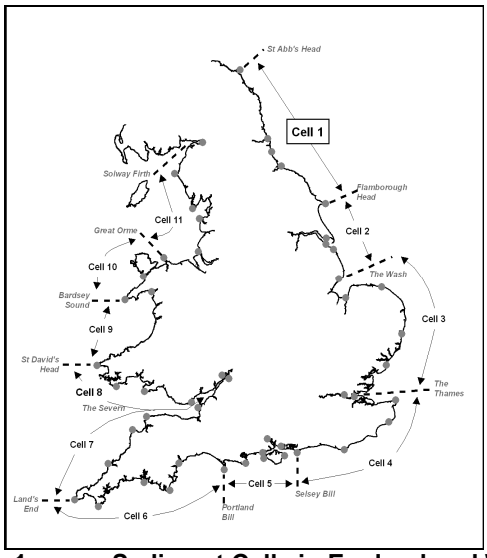


Figure 1 Sediment Cells in England and Wales

The work commenced with a three-year monitoring programme in September 2008 that was managed by Scarborough Borough Council on behalf of the North East Coastal Group. This initial phase has been followed by a five-year programme of work, which started in October 2011. The work is funded by the Environment Agency, working in partnership with the following organisations:

The original three year programme of work was undertaken as a partnership between Royal Haskoning, Halcrow and Academy Geomatics. For the current five year programme of work the data collection associated with beach profiles, topographic surveys and cliff top surveys is being undertaken by Academy Geomatics. The analysis and reporting for the programme is being undertaken by Halcrow.

The main elements of the Cell 1 Regional Coastal Monitoring Programme involve:

- beach profile surveys
- topographic surveys
- cliff top recession surveys
- real-time wave data collection
- bathymetric and sea bed characterisation surveys
- aerial photography
- walk-over surveys

The beach profile surveys, topographic surveys and cliff top recession surveys are undertaken as a 'Full Measures' survey in autumn/early winter every year. Some of these surveys are then repeated the following spring as part of a 'Partial Measures' survey.

Each year, an Analytical Report is produced for each individual authority, providing a detailed analysis and interpretation of the 'Full Measures' surveys.

This is followed by a brief Update Report for each individual authority, providing ongoing findings from the 'Partial Measures' surveys.

Annually, a Cell 1 Overview Report is also produced. This provides a region-wide summary of the main findings relating to trends and interactions along the entire Cell 1 frontage.

To date the following reports have been produced:

Table 1 Analytical, Update and Overview Reports Produced to Date

Year		Full Measures		Partial Measures		Cell 1 Overview Report
		Survey	Analytical Report	Survey	Update Report	
1	2008/09	Sep-Dec 08	May 09	Mar-May 09		-
2	2009/10	Sep-Dec 09	Mar 10	Feb-Mar 10	Jul 10	-
3	2010/11	Aug-Nov 10	Feb 11	Feb-Apr 11	Aug 11	Sep 11
4	2011/12	Sep-Oct 11 *	Oct 12			

* The present report is **Analytical Report 4** and provides an analysis of the 2011 Full Measures survey for Redcar and Cleveland Borough Council's frontage.

In addition, separate reports are produced for other elements of the programme as and when specific components are undertaken, such as wave data collection, bathymetric and sea bed sediment data collection, aerial photography, and walk-over visual inspections.

For purposes of analysis, the Cell 1 frontage has been split into the sub-sections listed in the Table 2.

Table 2 Sub-divisions of the Cell 1 Coastline

Authority	Zone
Northumberland County Council	Spittal A
	Spittal B
	Goswick Sands
	Holy Island
	Bamburgh
	Beadnell Village
	Beadnell Bay
	Embelton Bay
	Boulmer
	Alnmouth Bay
	High Hauxley and Druridge Bay
	Lynemouth Bay
	Newbiggin Bay
	Cambois Bay
	Blyth South Beach
North Tyneside Council	Whitley Sands
	Cullercoats Bay
	Tynemouth Long Sands
	King Edward's Bay
South Tyneside Council	Littehaven Beach
	Herd Sands
	Trow Quarry (incl. Frenchman's Bay)
	Marsden Bay
Sunderland Council	Whitburn Bay
	Harbour and Docks
	Hendon to Ryhope (incl. Halliwell Banks)
Durham County Council	Featherbed Rocks
	Seaham
	Blast Beach
	Hawthorn Hive
	Blackhall Colliery
Hartlepool Borough Council	North Sands
	Headland
	Middleton
	Hartlepool Bay
Redcar & Cleveland Borough Council	Coatham Sands
	Redcar Sands
	Marske Sands
	Saltburn Sands
	Cattersty Sands (Skinningrove)
Scarborough Borough Council	Staithes
	Runswick Bay
	Sandsend Beach, Upgang Beach and Whitby Sands
	Robin Hood's Bay
	Scarborough North Bay
	Scarborough South Bay
	Cayton Bay
	Filey Bay

1. Introduction

1.1 Study Area

Redcar & Cleveland Borough Council's frontage extends from the South Gare breakwater at the mouth of the River Tees to Cowbar Nab, Staithes. For the purposes of this report, report and for consistency with previous reporting, it has been sub-divided into six areas, namely:

- Coatham Sands
- Redcar Sands
- Marske Sands
- Saltburn Sands
- Cattersty Sands (Skinningrove)
- Staithes

The Staithes frontage straddles the boundary of jurisdiction of Redcar & Cleveland Council and Scarborough Borough Council and therefore reporting has been duplicated in both reports.

1.2 Methodology

Along Redcar & Cleveland Borough Council's frontage, the following surveying is undertaken:

- Full Measures survey annually (since 2008) each autumn/early winter comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along Coatham Sands
    - Topographic survey along Redcar Sands
    - Topographic survey along Marske Sands
    - Topographic survey along Saltburn Sands
    - Topographic survey along Cattersty Sands
- Partial Measures survey annually each spring (since 2009) comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along Redcar Sands
    - Topographic survey along Saltburn Sands
    - Topographic survey along Cattersty Sands
- Cliff top survey annually at:
    - Staithes

The Full Measures survey was undertaken along this frontage in September 2011, when weather conditions were fine and dry and the sea state was calm.

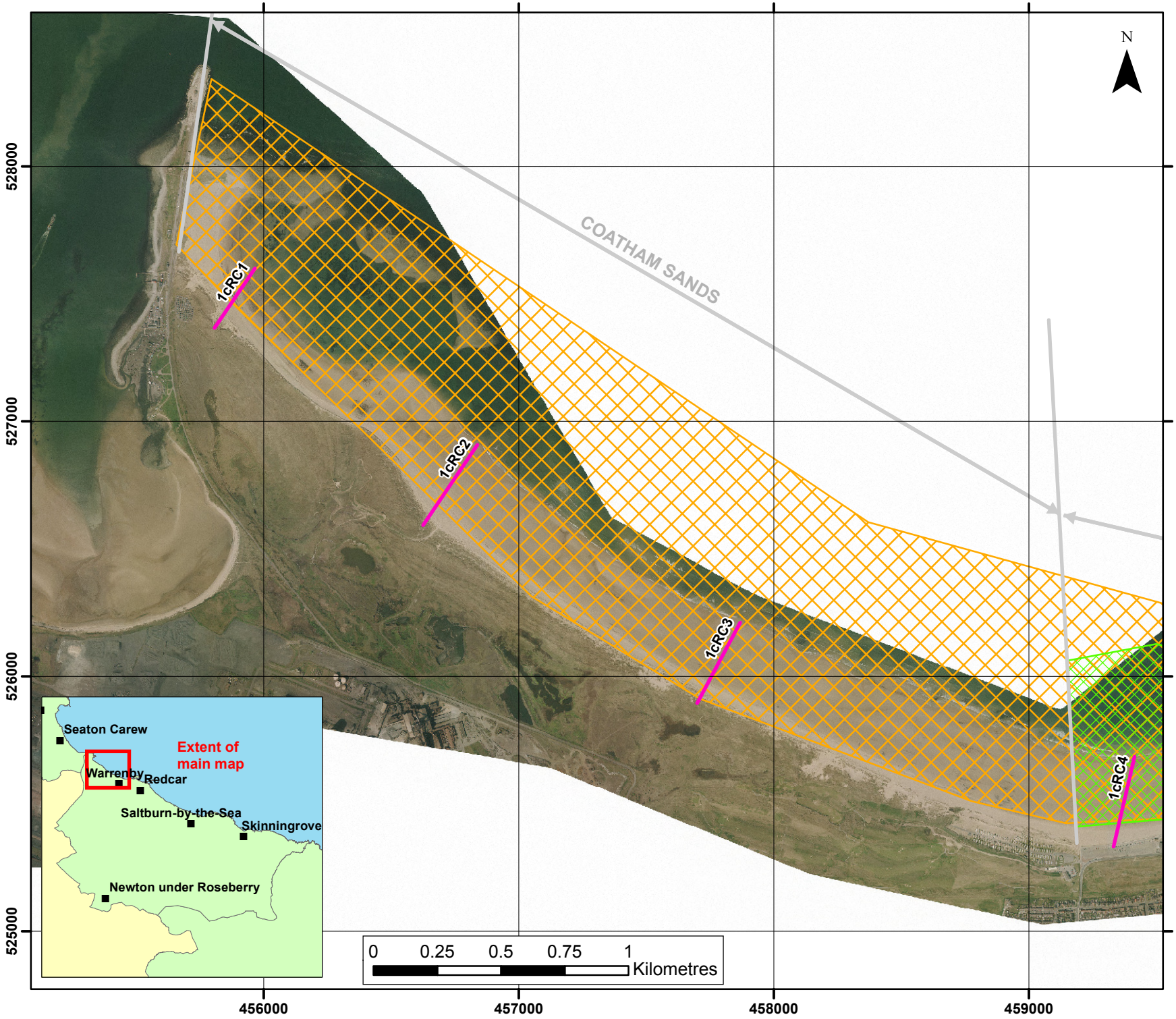
All data have been captured in a manner commensurate with the principles of the Environment Agency's *National Standard Contract and Specification for Surveying Services* and stored in a file format compatible with the software systems being used for the data analysis, namely SANDS and ArcGIS. This data collection approach and file format is comparable to that being used on other regional coastal monitoring programmes, such as in the South East and South West of England.

Upon receipt of the data from the survey team, they are quality assured and then uploaded onto the programme's website for storage and availability to others and also input to SANDS and GIS for subsequent analysis.

The Analytical Report is then produced following a standard structure for each authority. This involves:

- description of the changes observed since the previous survey and an interpretation of the drivers of these changes (Section 2);
- documentation of any problems encountered during surveying or uncertainties inherent in the analysis (Section 3);
- recommendations for 'fine-tuning' the programme to enhance its outputs (Section 4); and
- providing key conclusions and highlighting any areas of concern (Section 5).

Data from the present survey are presented in a processed form in the Appendices.



KEY

Topographic Profiles
- Annual
- 6 monthly

Topographic Surveys
- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs
- 50m centres
- 100m centres
- 300m centres

(Indicative Survey Extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2 - Map 1
Survey Locations
Coatham Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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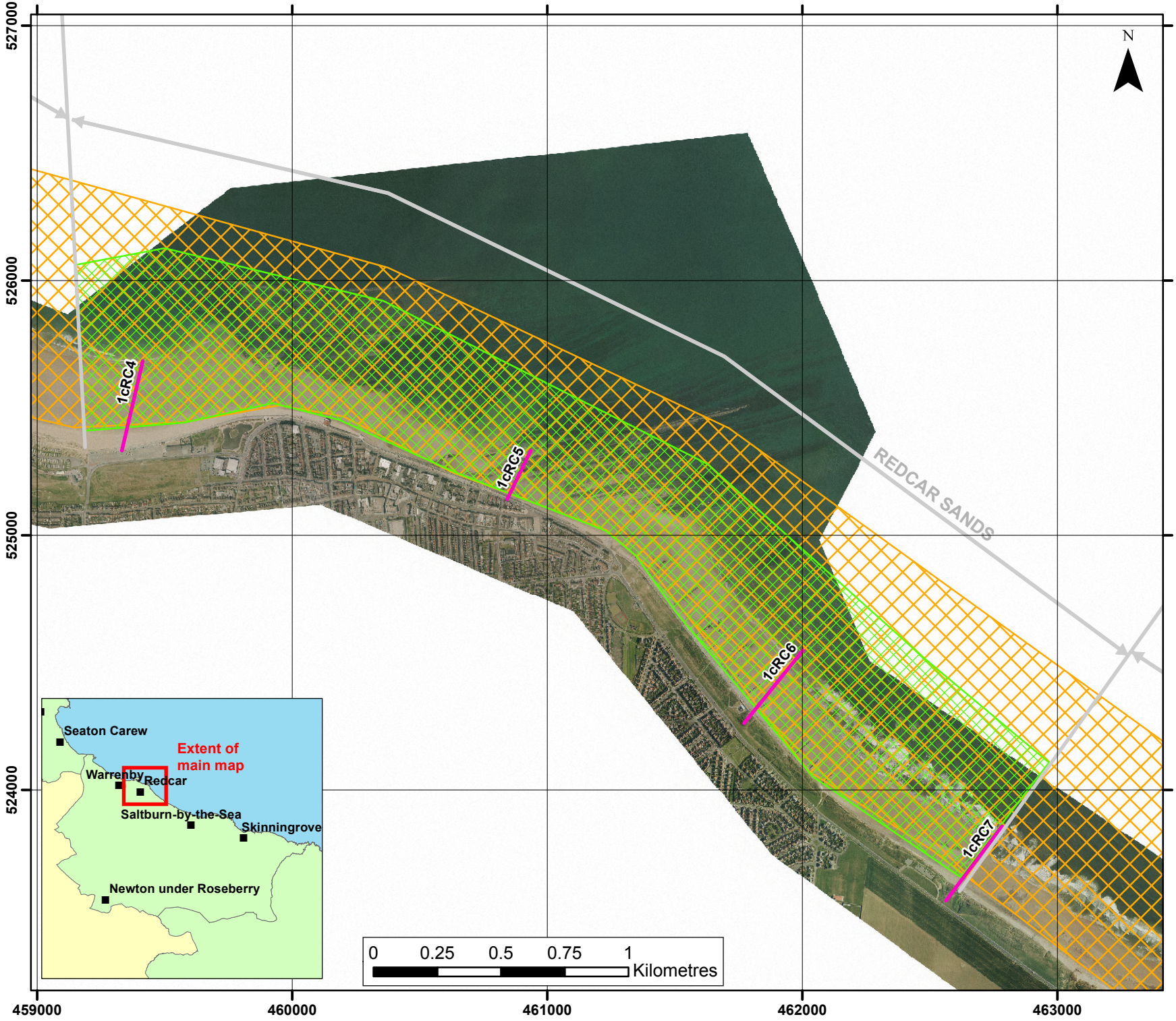

KEY

Topographic Profiles
- Annual
- 6 monthly

Topographic Surveys
- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs
- 50m centres
- 100m centres
- 300m centres

(Indicative Survey Extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2 - Map 2
Survey Locations
Redcar Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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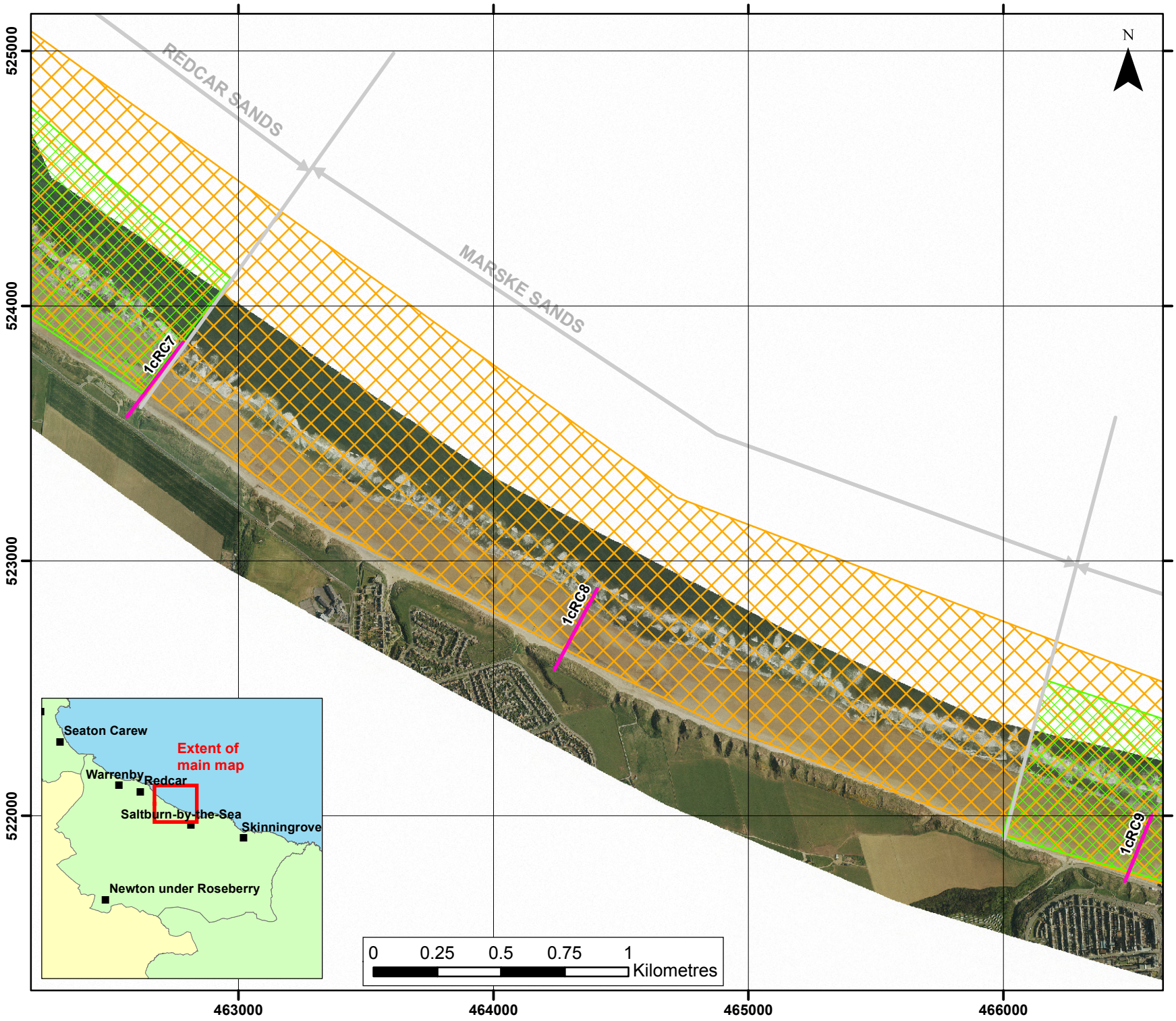

KEY

Topographic Profiles
- Annual
- 6 monthly

Topographic Surveys
- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs
- 50m centres
- 100m centres
- 300m centres

(Indicative Survey Extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2 - Map 3 Survey Locations Marske Sands Redcar&Cleveland Borough Council

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Full Measures Survey
Winter 2011

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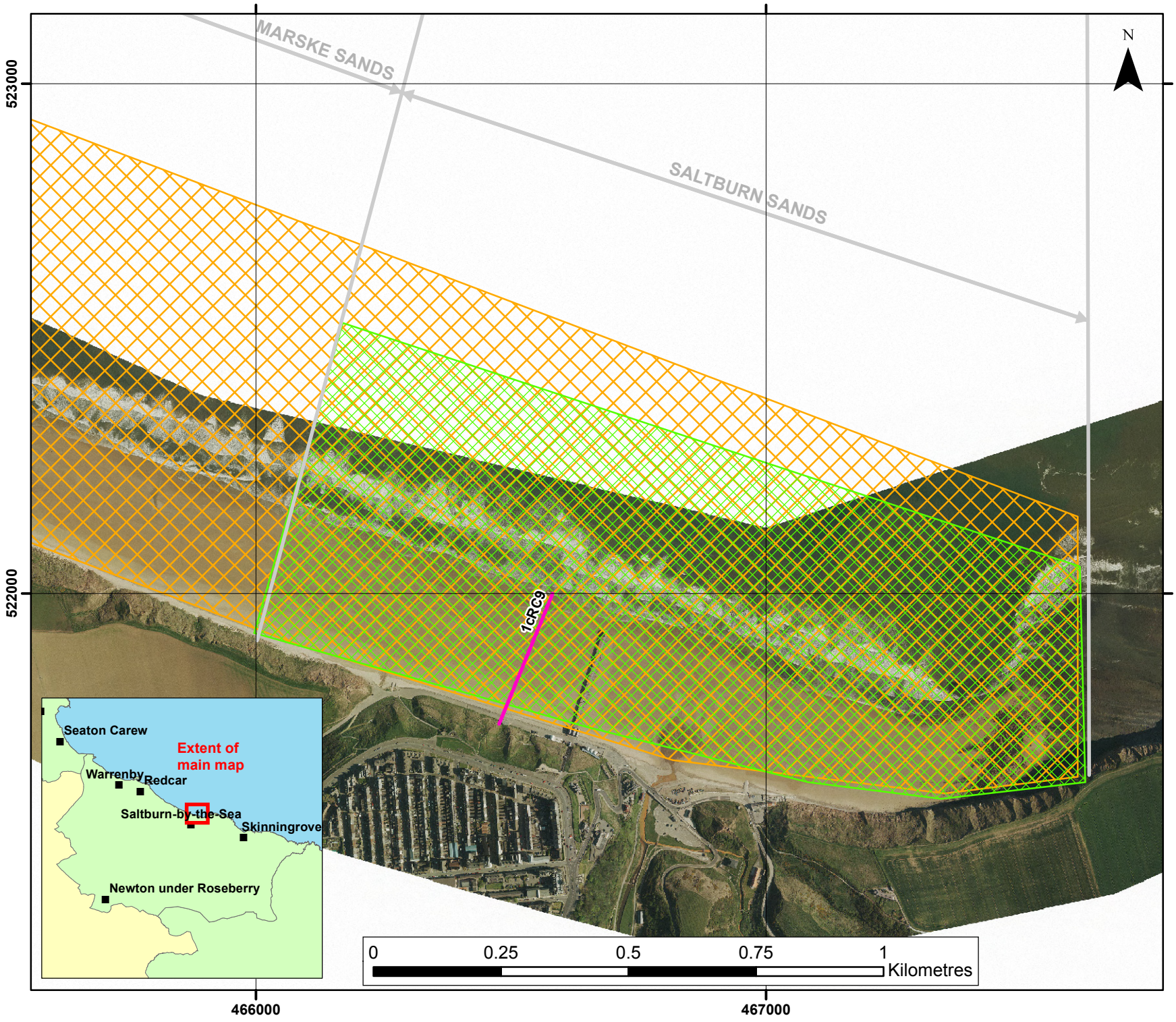

KEY

Topographic Profiles

- Annual
- 6 monthly

Topographic Surveys

- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs

- 50m centres
- 100m centres
- 300m centres

(Indicative Survey Extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2- Map 4 Survey Locations Saltburn Sands Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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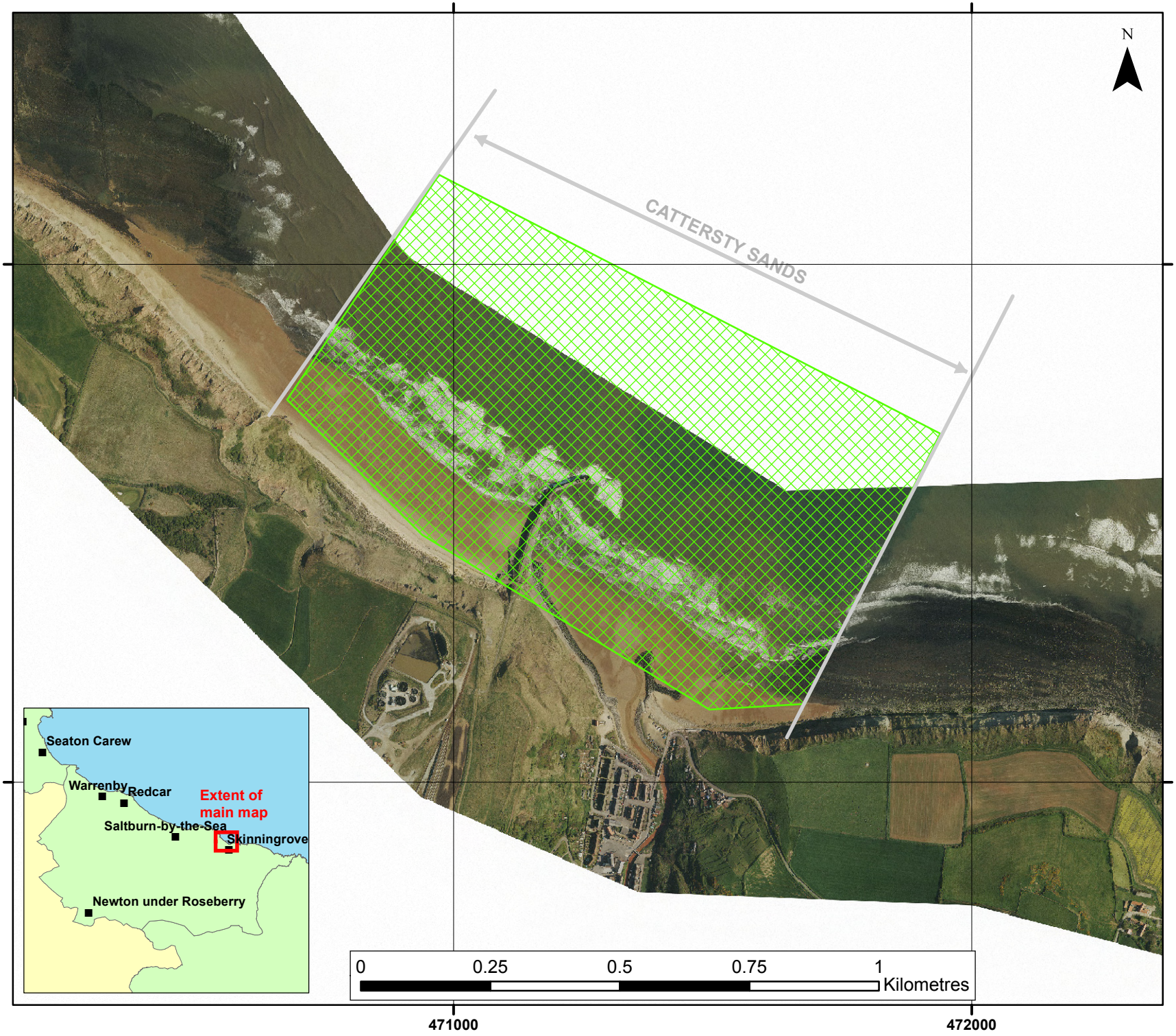

KEY

Topographic Profiles

- Annual
- 6 monthly

Topographic Surveys

- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs

- 50m centres
- 100m centres
- 300m centres

(Indicative Survey Extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2 - Map 5
Survey Locations
Cattersty Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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2. Analysis of Survey Data

2.1 Coatham Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
27th Oct 2011	**Beach Profiles:** Coatham Sands is covered by four beach profile lines during the Full Measures survey (RC1 to RC4; Appendix A). Profile **1cRC1** is located approximately 300m south of the South Gare breakwater, immediately in the lee of the German Charlies slag banks. The upper profile is dominated by dune ridges, which have remained stable since the 2009 surveys. Overall the profile shows accretion since the last survey. Although between HAT and MHWS a berm was present in the last survey which has been smoothed out since the last survey. This is the third consecutive year where a natural berm has been formed in the spring and flattered by the autumn survey. At Profile **1cRC2** the upper and mid beach have remained stable since 2008. The part of the beach between HAT and MHWS has changed between the spring and autumn surveys, with the 0.8m high by 20m wide sand berm that was present in spring 2011 being absent by autumn 2011. Overall the beach between MHWS and MLWS has accreted by around 50m^2 on this profile over the summer months. Along Profile **1cRC3** the upper part of the beach is dominated by the dunes, which have not been subject to any large scale changes since 2009. The beach has been subject to accretion so that the beach level is high compared to previous years. **Topographic Survey:** Coatham Sands is covered by an annual topographic survey extending from the South Gare Breakwater, although the survey is contiguous with the Redcar Sands topographic survey (which is surveyed 6-monthly). Data have been used to create a DGM (Appendix B – Map 1a) using a Geographic Information System (GIS) package. This shows that the beach contours recorded in Winter 2011 were relatively consistent across the frontage, with a gently shelving beach slope and shore	In all three profiles the upper beach has remained stable since 2008. The berms which had been built up in the winter in RC 1 and 2 were flattened out in the summer. Accretion has occurred in the foreshore of all three profiles. The topographic change plots show that in the northern quarter of the frontage there has been erosion close to the shore and the South Gare breakwater. Seaward to that there is an area of accretion, which is likely to mean that the sediment has been redistributed in the local area. This pattern of beach flattening was observed in the 2010 Full Measures Report. The rest of the bay was characterised by small changes in topography over 2011. The lowest part of the beach captured in the topographic survey was prone to erosion with a similar intensity of accretion recorded slightly higher up the beach. This low intensity redistribution of sediments within the bay is expected during the summer months. Overall, the net change over 2011 has been one of foreshore steepening across the entire width of the beach.

Survey Date	Description of Changes Since Last Survey	Interpretation
	parallel contours. The GIS has also been used to calculate the differences between the current topographic (Winter 2011) survey and the earlier topographic survey (Winter 2010), as shown in Appendix B – Map 1b, to identify areas of erosion and accretion. The changes in elevation between Winter 2010 and Winter 2011 have been relatively small (generally under ±0.5m) across the frontage. There is some evidence of shore parallel bands of accretion and erosion but the beach can be divided into two sections. The most extreme changes have occurred in the northern-most quarter of the frontage, close to the shore between South Gare breakwater and the dunes, where up to 0.75m has been lost. The remaining three quarters of the frontage have relatively small changes of less than ±0.5m between Winter 2010 and Winter 2011.	

2.2 Redcar Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
27th Oct 2011	**Beach Profiles:** Redcar Sands is covered by three beach profile lines during the Full Measures survey (RC5 to RC7; Appendix A), with RC7 being approximately on the boundary with the Marske Sands area. At profile **1cRC 5** the beach above MHWS has remained stable since 2008. The beach below MHWS has remained stable overall but with localised areas of erosion. The lower beach is much more jagged in the October 2011 profile than in the April 2011 profile. This may be because the veneer of sand which was present in the spring had been removed by coastal processes. However, it is more likely that it is a result of the resolution of the survey results, because the October 2011 profiles had more data points than the April profiles. At profile **1cRC 6** the beach from 0m to 35m chainage has been stable since 2009. The profile from 35m to 85m chainage looks as though it has been interpolated because the area was not accessible to the surveyors in October 2011 due to the ongoing works on the seawall. Below MHWS the beach has accreted by 0.2m over the summer of 2011. Profile **1cRC7 (**October 2011) contains significant error and has not been analysed. In the Full Measures Report of 2010 it was reported that the profile generally experienced lowering along its entire length following the accretion that previously occurred between September 2009 and April 2010. The survey contractor should ensure good quality data re collected at this location in future surveys.	There is large variation between these profiles, with profile RC 5 undergoing erosion of the sand which had been overlying the rock platform. Profile RC 6 has accreted and Profile RC 7 can not be analysed. Over the summer of 2011 there was a pattern of patchy redistribution of sediment on the beach whereas in the 2010 report there was a clear difference between the north and south parts of Redcar Sands. **Longer term trends**: Over the summer of 2010 the northern part had eroded while the southern section has patchy changes which are not too severe. The erosion of the northern extreme of Redcar sands where it joins Coatham Sands is still evident in 2011.
	Topographic Survey: Redcar Sands is covered by a six-monthly topographic survey. Data have been used to create a DGM (Appendix B – Map 2a) using a Geographic Information System (GIS) package. This shows that the general beach contours move inland and in particular the higher beach contours become intercepted by the sea wall, in the vicinity of the main section of Redcar town. This is the area where a major coastal defence scheme was being constructed during the topographic survey. Beyond this 600m length, the contours run parallel to the frontage at regular intervals showing a straight slope.	

Survey Date	Description of Changes Since Last Survey	Interpretation
	The GIS has also been used to calculate the differences between the Spring 2011 and Winter 2011 topographic surveys, as shown in Appendix B – Map 2b, to identify areas of erosion and accretion. Over the summer of 2011 there has been accretion of the middle of the beach and parts of the lower beach. Erosion occurs in patches all over the beach, particularly on the lower and upper beach. There is an almost continuous thin band of erosion close to the shore along the majority of the frontage. The GIS has also been used to calculate the differences between the current topographic survey and the most recent (Winter 2011) topographic survey, as shown in Appendix B – Map 2c, to identify areas of erosion and accretion. Between the last survey in Spring 2011 and the current Winter 2011 survey the pattern of change along the main town frontage was one of erosion of the lower foreshore by up to 1.5m and accretion along parts of the upper foreshore of 0.25 to 0.5m. This is similar to the pattern observed in the 2010 Full Measures Report.	

2.3 Marske Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
27th Oct 2011	**Beach Profiles:** Marske Sands is covered by two beach profile lines during the Full Measures survey (RC7 to RC8; Appendix A), with RC7 being approximately on the boundary with the Redcar Sands area. Profile **1cRC7** is located along The Stray and has been discussed in Section 2.2. Overall, profile **1cRC8** has stayed stable since 2008. There has been some accretion of around 0.25m on the lower parts of the beach, beyond 140m chainage. **Topographic Survey:** Marske Sands is covered by an annual topographic survey, although the survey is contiguous with the Redcar Sands and Saltburn Sands topographic surveys (both of which are surveyed six-monthly). Data have been used to create a DGM (Appendix B – Map 3a) using a Geographic Information System (GIS) package. This shows that the beach contours are relatively consistent across the frontage and exhibit a gently sloping beach with shore parallel contours at regular intervals. The GIS has also been used to calculate the differences between the Winter 2010 and Winter 2011 topographic survey, as shown in Appendix B – Map 3b, to identify areas of erosion and accretion. Since the previous topographic survey in Winter 2010, there has been a general redistribution of sediment with changes of ±0.5 across much of the frontage. Patches of around 1m of change were observed in the shore parallel bands of accretion and erosion in front of Scanbeck Howle. The difference plots for Saltburn and Marske Sands, specifically 4b (Saltburn) and 3b (Marske), have Saltburn on both maps. However the pattern of change illustrated on each plot is different, due to the difference in data collection regime at Saltburn and Marske Sands. Saltburn has additional six month surveys, so the maps are comparing different data. Figure 4b shows the difference in the beach over a 12 month period, whereas Figure 3b is the difference following six months of change (spring to winter).	The beach profile for Marske Sands is showing signs of accretion, which is to be expected over the summer months. The plot of the changes in topography between Winter 2010 and Winter 2011 shows that there has been patchy redistribution of the sediment within the bay. There is no overall clear trend of erosion or accretion, which is similar to the observations made in the 2010 Full Measures Report.

2.4 Saltburn Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
27th Oct 2011	**Beach Profiles:** Saltburn Sands is covered by one beach profile during the Full Measures survey (RC9; Appendix A). Profile **1cRC9** shows that overall the beach has accreted since April 2011 and the October 2011 profile is among the highest profiles, up to 0.5m higher than the level recorded in November 2010. Accretion is to be expected during the summer months, but this summer was noteworthy. **Topographic Survey:** Saltburn Sands is covered by a six-monthly topographic survey, although the survey is contiguous with the Marske Sands topographic survey which is surveyed annually. Data have been used to create a DGM (Appendix B – Map 4a) using a Geographic Information System (GIS) computer software package. This shows that the beach contours are shore parallel and gently shelving for the majority of the frontage. The contours spike landwards opposite a stream on the hinterland, which is to be expected because a channel has formed on the beach. The GIS has also been used to calculate the differences between Spring 2011 and Winter 2011 topographic survey, as shown in Appendix B – Map 4b, to identify areas of erosion and accretion. During the summer of 2011 there was almost equal distribution between erosion and accretion west of Skelton Beck, with losses and gains around ±0.5m. However, east of Skelton Beck erosion was dominant with the majority of the area losing 0.25m of material. Comparison with the most recent Partial Measures survey in Spring in Appendix B – Maps 2b and 2c) shows that most of this change occurred over the Winter of 2010/11 and since Spring 2011 the foreshore has exhibited little net change. The difference plots for Saltburn and Marske Sands, specifically 4b (Saltburn) and 3b (Marske), have Saltburn on both maps. However the pattern of change illustrated on each plot is different, due to the difference in data collection regime at Saltburn and Marske Sands. Saltburn has additional six month surveys, so the maps are comparing different data. Figure 4b shows the difference in the beach over a 12 month period, whereas Figure 3b is the difference following six months of change (spring to winter).	The beach has accreted over the summer and the October 2011 profile is high compared to previous surveys. The topographic change plots of Saltburn Sands show redistribution of sediment west of Skelton Beck and erosion east of the beck. This is the second year in a row when the beach east of Skelton Beck has shown erosion.

2.5 Cattersty Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
	Topographic Survey: Cattersty Sands is covered by a six-monthly topographic survey. Data have been used to create a DGM (Appendix B – Map 5a) using a Geographic Information System (GIS) package. The GIS has also been used to calculate the differences between Spring 2011 and Winter 2011 topographic survey DGM, with better than 5m raster grids (as shown in Appendix B – Map 5b), to identify areas of erosion and accretion. The difference plot shows patches of erosion on the upper and lower beach with accretion in the centre of the beach. The seaward end of the beach along the majority of the Cattersty Sands frontage has experienced erosion of around 0.5m in most places with isolated areas eroding by 0.75m. The accretion recorded in the centre of the beach was up to 0.75 in most places. Close to the shore the picture is more mixed with an overall pattern of erosion of 0.5m of material. In previous years there has been an obvious difference on each side of the jetty. In 2011 the differences on the beach vary around the mouth of Kilton Beck. On the west side of the beck there is a mixture of accretion and erosion, while on the east accretion is the prevailing process.	The difference model shows Cattersty Sands to be a dynamic area, influenced by both marine and fluvial processes. In the 2011 plot there is a difference in beach behaviour on either side of Kilton Beck. The observed accretion just east of the mouth of the beck is likely to be due to the interaction of coastal and fluvial processes. There was much more erosion observed around the Jetty over the summer of 2011 than in the difference plot produced for the 2010 Full Measures Report. The rest of the plot looks similar between the 2010 and 2011 plots with shore parallel bands of accretion and erosion moving down the beach.

2.6 Staithes

Survey Date	Description of Changes Since Last Survey	Interpretation
3rd Oct 2011	**Cliff-top Survey:** Twenty ground control points have been established at Staithes for the purposes of biannual cliff top monitoring. The separation between any two points is around 100 m. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing. Appendix C provides results from the September 2010 survey, showing the distance from the ground control point to the edge of the cliff top along the defined bearing and changes in position since the November 2008 baseline survey.	When survey accuracy is taken into consideration, three of the twenty locations (points 14, 17, 18) have shown no change since the November 2008 survey, indicating local stability of the cliff face at these locations. Nine locations (points 3, 8, 9, 10, 12, 15, 16, 19) have shown an increase in distance to the cliff edge, which may relate to vegetation growth or survey error. . Cliff recession was recorded at eight locations. Survey location 13 has shown the greatest erosion with a loss of 2.2m between November 2008 and October 2011, resulting in a mean recession rate of 0.75m/yr. Two locations (points 1, 4) have shown cliff line recession ranging 0.1-0.2m. Points 4 and 13 have consistently registered cliff erosion in each full and partial measures report to date. Less consistent, but repeated, recession measurements are also determined for points 1, 2 and 5. These survey locations are principally located in the west adjacent to Cow Bar Lane.

3. Problems Encountered and Uncertainty in Analysis

There were no major problems encountered during the surveys.

Individual Surveys

One profile, 1cRC7 has a large error in the October 2011 data and as a result can not be analysed. The survey contractor should ensure good quality data are collected for this profile in future surveys to limit the impact to the long-term record.

Cliff Top Surveys

The cliff top surveys at Staithes are assumed to have a limit of accuracy of ± 0.1m due to the techniques used. At a number of locations apparent cliff advance has been calculated, which is highly unlikely, excepting a toppling mechanism of failure. It is more likely that this is due to a different point being identified as the edge of the cliff, especially with different seasonal vegetation covers. This problem is most marked at Staithes, which may reflect a particular site condition that requires further investigation. More accurate data on cliff recession at Staithes will be derived from analysis of aerial photos collected, or planned for collection, in 2010, 2012 and 2014.

4. Recommendations for 'Fine-tuning' the Monitoring Programme

The aim of cliff monitoring data is to gain a reliable record of the frequency and magnitude of cliff top failures. Data are collected every 6 months, but previous surveys have had a low accuracy, meaning that survey error is typically greater than any measured short term change. It is possible that a more reliable pattern of change will be determined over the longer term. However, in the short term, more reliable assessments of cliff recession will be derived from analysis of time-series remote sensing data. A high quality baseline survey, comprising LiDAR and aerial photography, was collected in 2010, a repeat survey was completed in Sept/Oct 2012 and a second repeat survey is planned for 2014. These data will be analysed to give more accurate information on the behaviour of the cliffs in a separate report.

5. Conclusions and Areas of Concern

- At Coatham Sands the beach profiles show overall stability. However the topographic change plot shows erosion near the South Gare Breakwater, with accretion seaward of that. This pattern of beach flattening was observed in the 2010 Full Measures Report. The reminder of the bay was subject to small changes in topography, which is likely to be due to the local redistribution of sediment during the summer months.

- Redcar Sands has shown a large variation between the beach profiles, with the NNE facing Profile 5 eroding and the ENE facing profile accreting. There were coastal defence works being carried out during the topographic survey in October 2011. The topographic change plots show that over the summer of 2011 there was a pattern of patchy redistribution of sediment on the beach.

- Marske Sands has accreted over the summer of 2011 according to the beach profiles. The topographic change plot shows patches of accretion and erosion, with no overall trend.

- The Saltburn Sands beach profiles show that the beach has accreted over the summer and is in high compared to previous surveys. The topographic change plots of Saltburn Sands show redistribution of sediment west of Skelton Beck and erosion east of the beck. This is the second year in a row when the beach east of Skelton Beck has shown erosion.

- The Cattersty Sands difference model shows that it is a dynamic area, influenced by both marine and fluvial processes. In the 2011 plot there is a difference in beach behaviour on either side of Kilton Beck. The observed accretion just east of the mouth of the beck is

likely to be due to the interaction of coastal and fluvial processes. Around the jetty there was notable erosion during the summer of 2011, which was not observed in the 2010 report.

- At Staithes, the cliff monitoring shows very similar pattern of behaviour to 2010, with localised areas of cliff recession to the east of Staithes Harbour. There are also areas where the data suggest cliff top advance. This may represent active toppling failures, but is more likely a result of survey error).

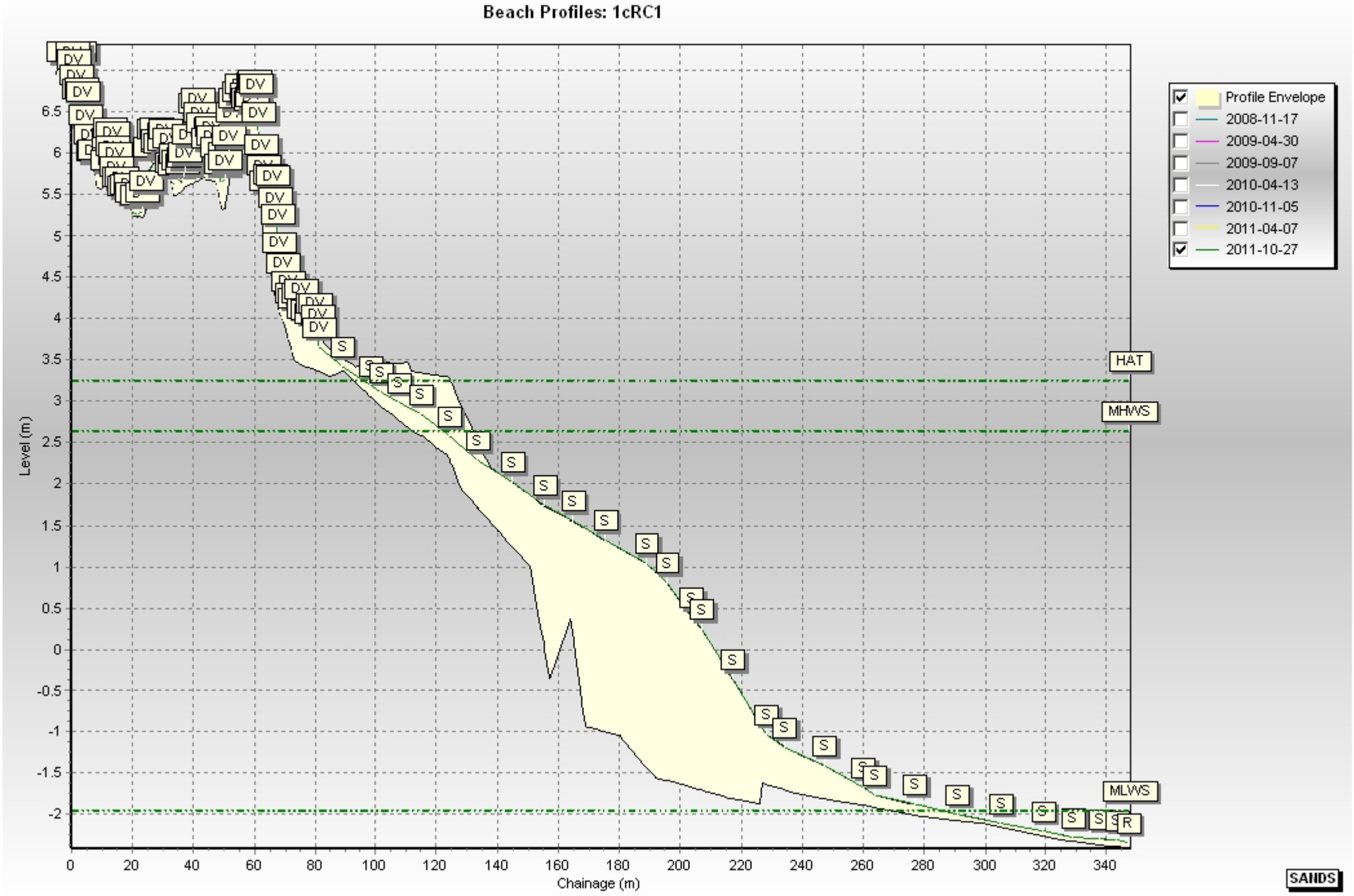
Appendices

Appendix A

Beach Profiles

The following sediment feature codes are used on some profile plots:

Code	Description
S	Sand
M	Mud
G	Gravel
GS	Gravel & Sand
MS	Mud & Sand
B	Boulders
R	Rock
SD	Sea Defence
SM	Saltmarsh
W	Water Body
GM	Gravel & Mud
GR	Grass
D	Dune (non-vegetated)
DV	Dune (vegetated)
F	Forested
X	Mixture
FB	Obstruction
CT	Cliff Top
CE	Cliff Edge
CF	Cliff Face
SH	Shell
ZZ	Unknown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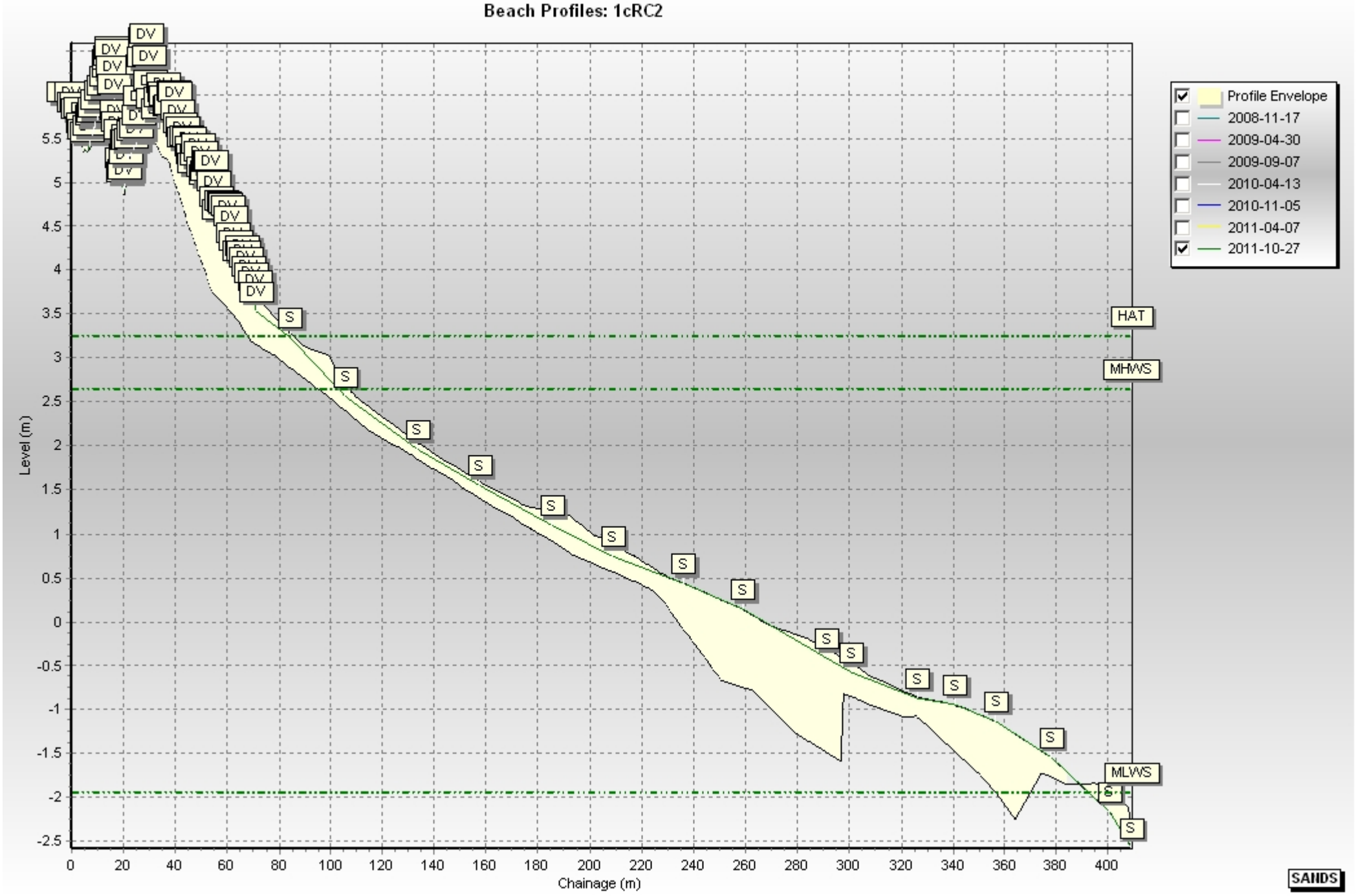
2009-04-30
2009-09-07
2010-04-13
2010-11-05
2011-04-07
2011-10-27
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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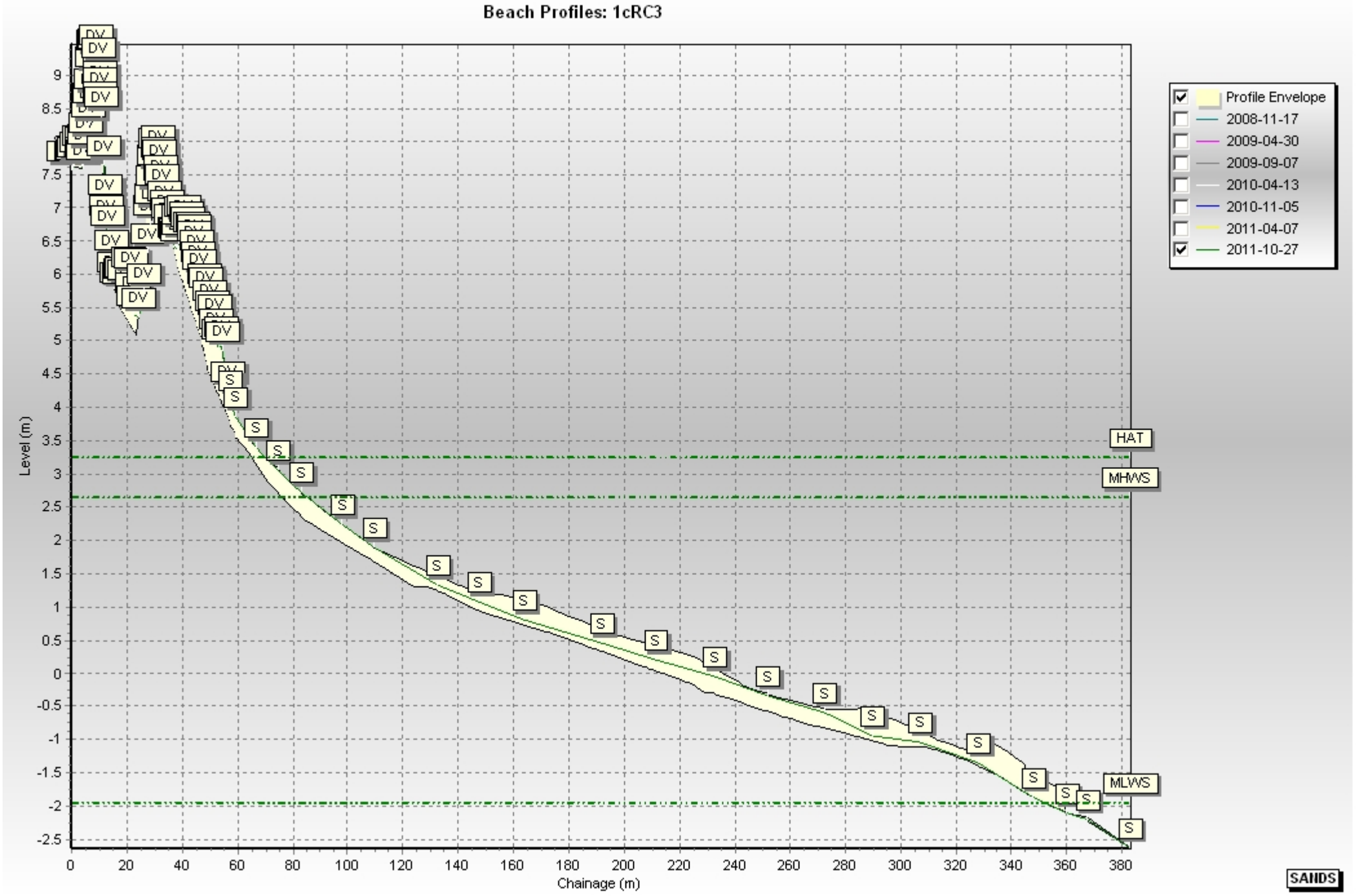
2009-04-30
2009-09-07
2010-04-13
2010-11-05
2011-04-07
2011-10-27
HAT
MHWS
MLWS
DV
S
Level (m)
Chainage (m)
SANDS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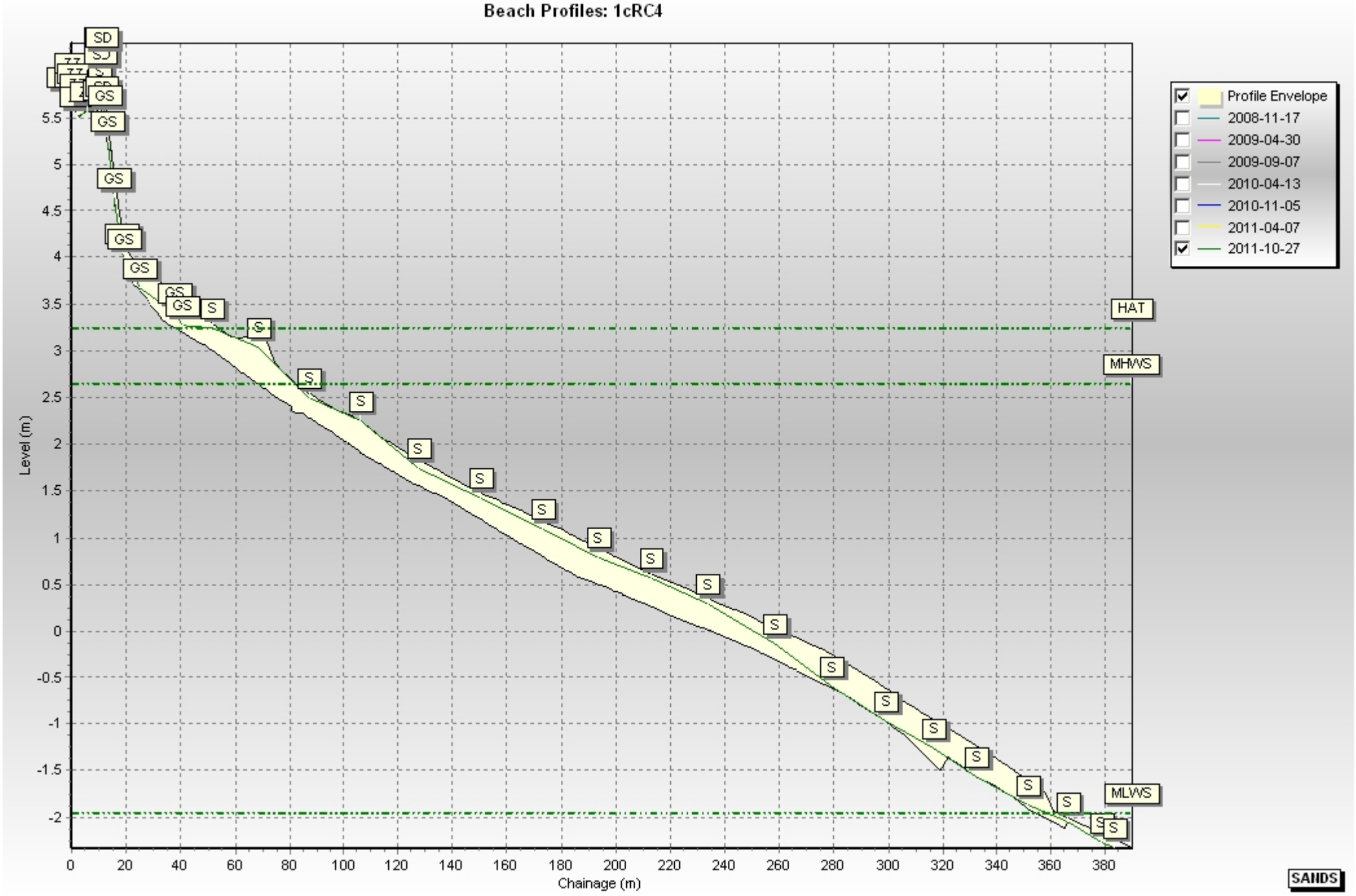
2009-09-07
2010-04-13
2010-11-05
2011-04-07
2011-10-27
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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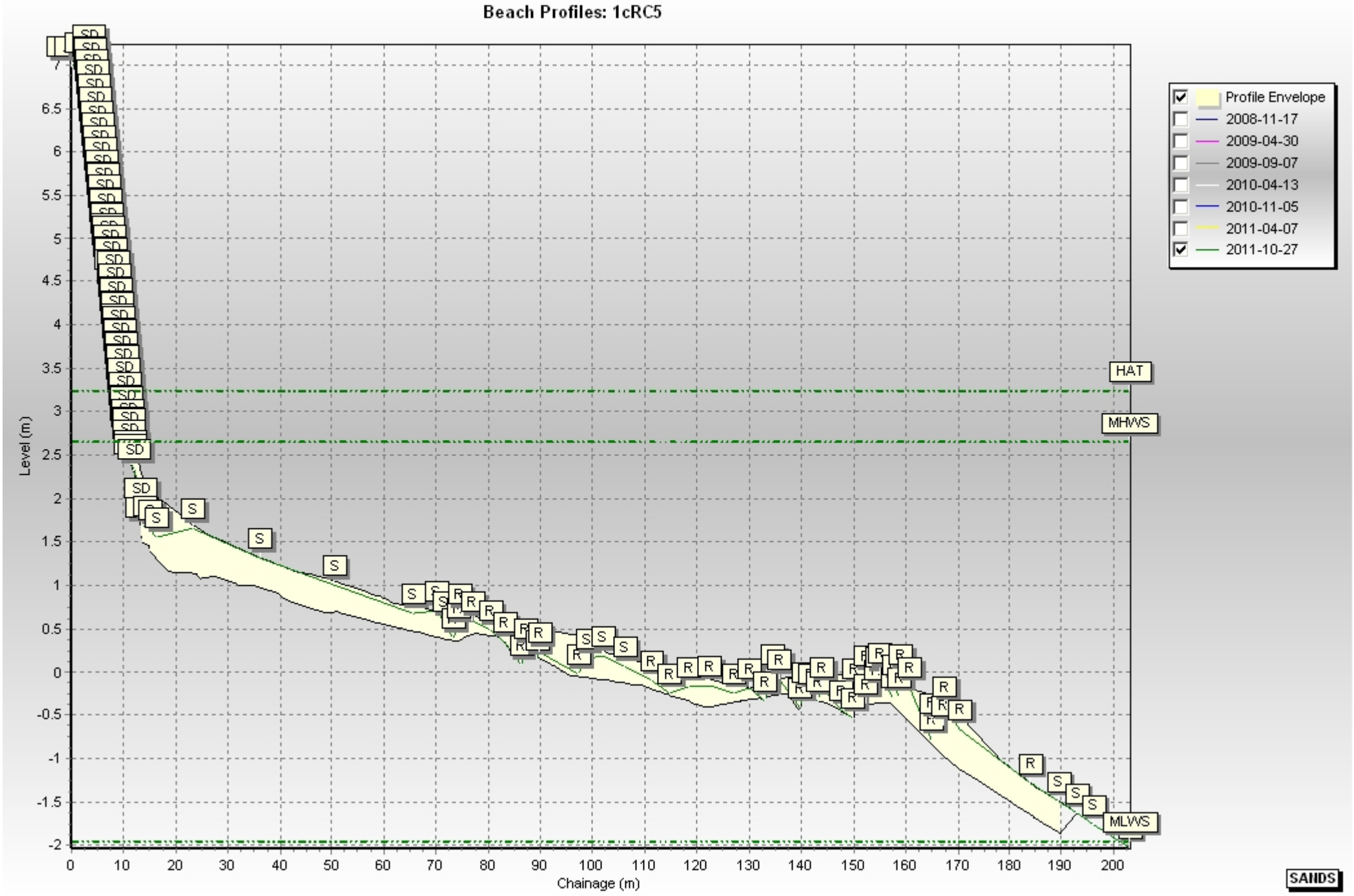
Profile Envelope
2008-11-17
2009-04-30
2009-09-07
2010-04-13
2010-11-05
2011-04-07
2011-10-27
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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Profile Envelope
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2009-04-30
2009-09-07
2010-04-13
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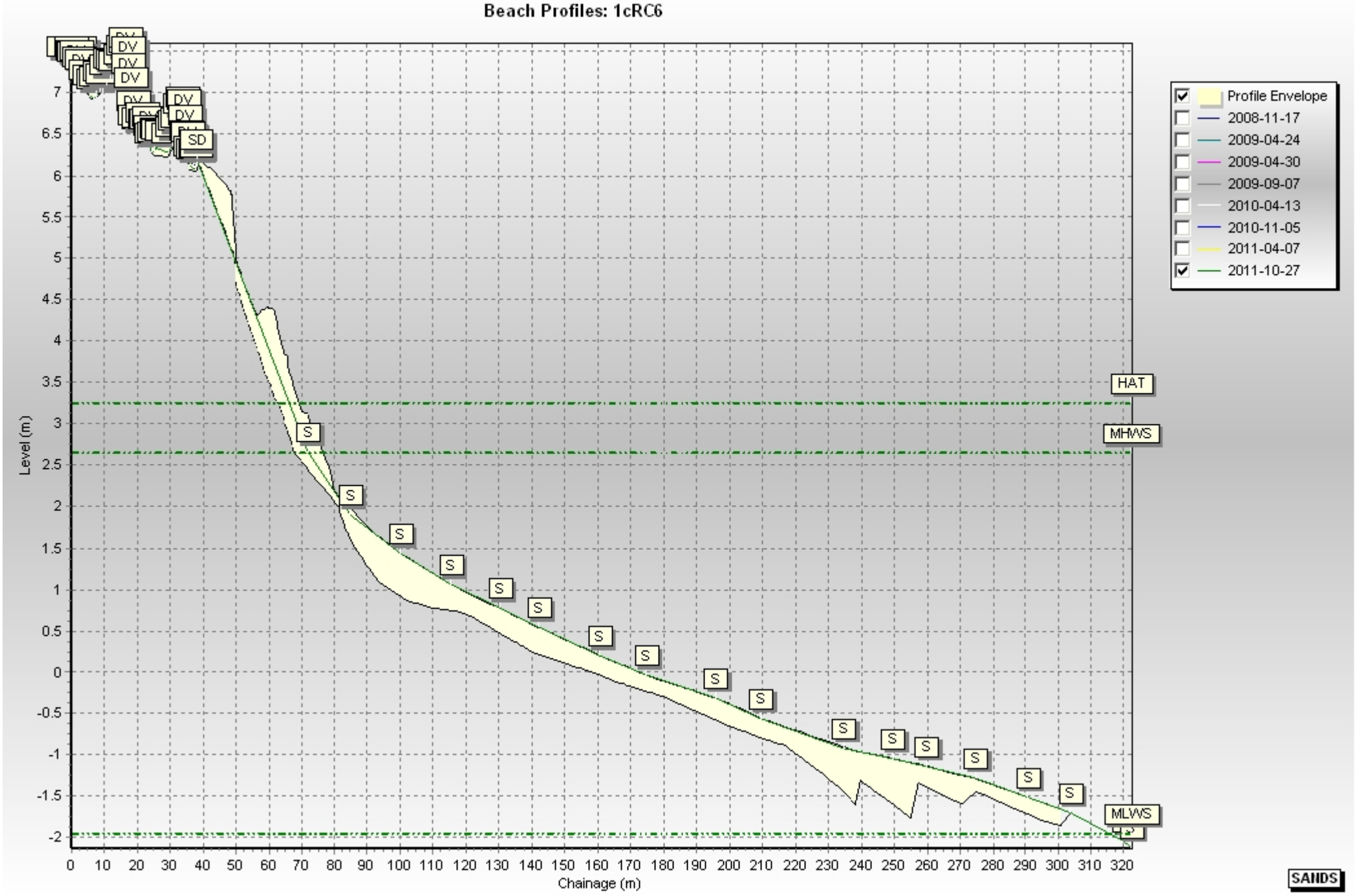
2011-04-07
2011-10-27
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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2009-04-24
2009-04-30
2009-09-07
2010-04-13
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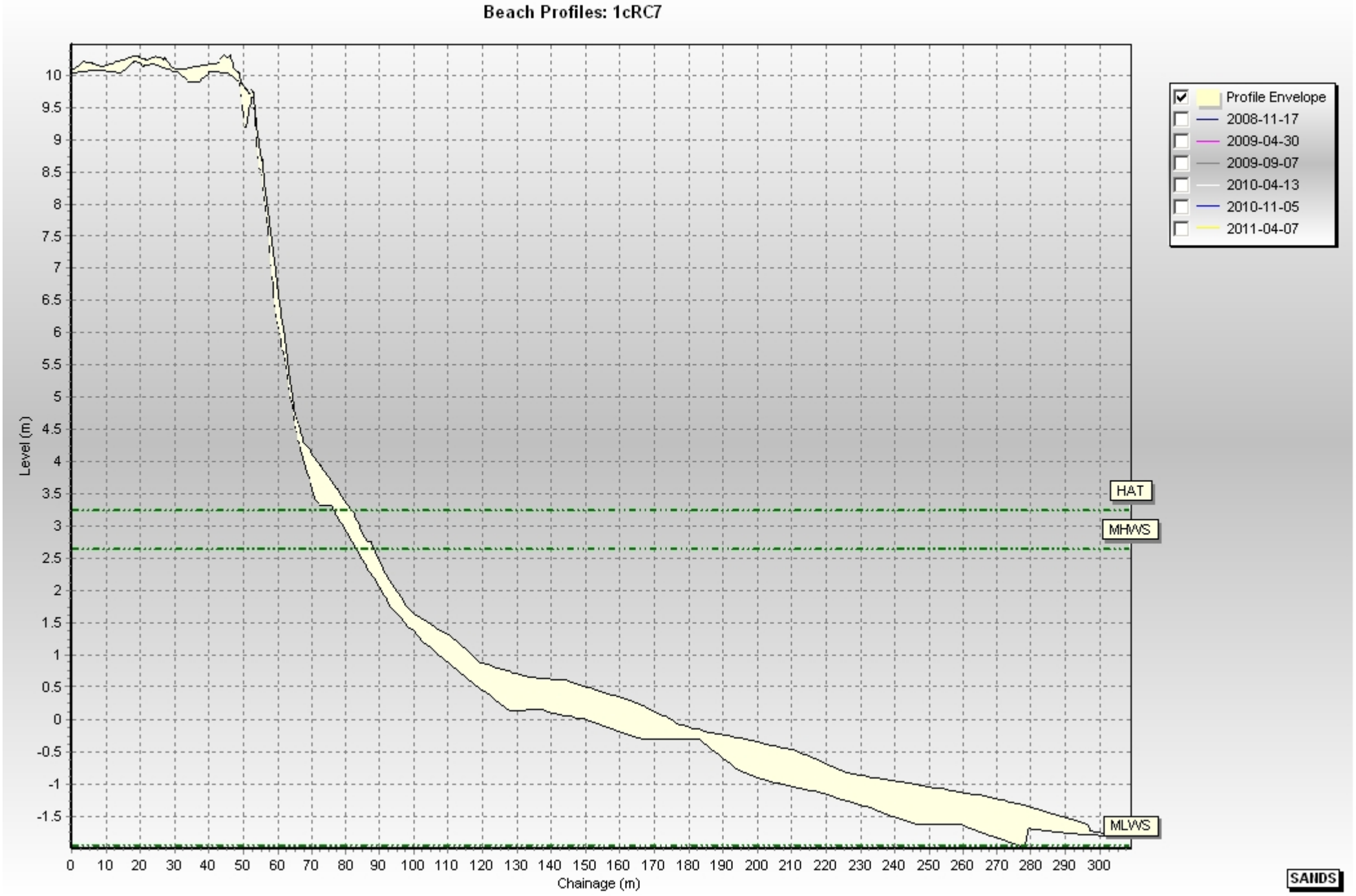
2011-04-07
2011-10-27
HAT
MHWS
MLWS
DV
SD
S
Level (m)
Chainage (m)
SANDS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Profile Envelope
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2009-04-30
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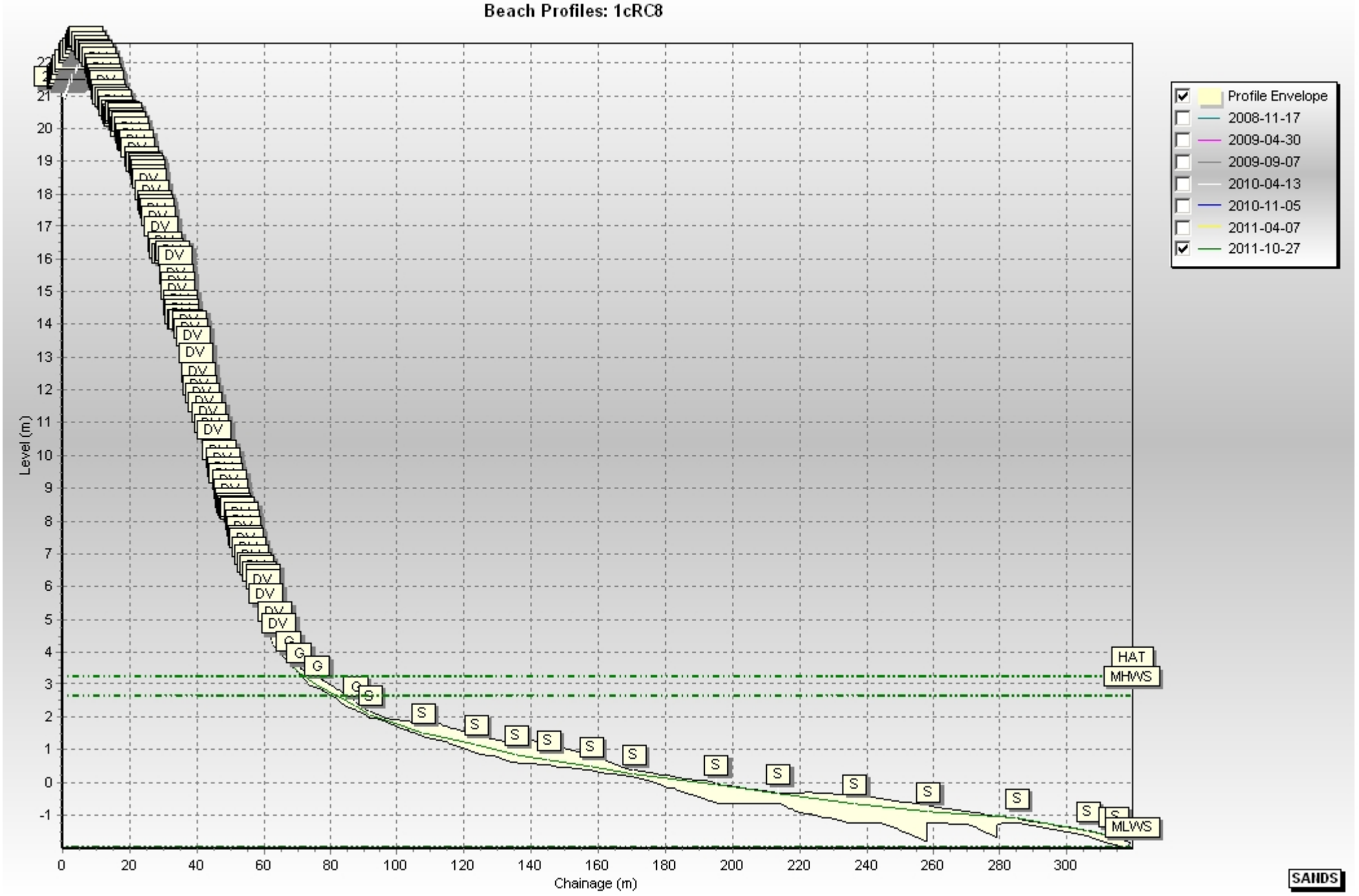
2010-04-13
2010-11-05
2011-04-07
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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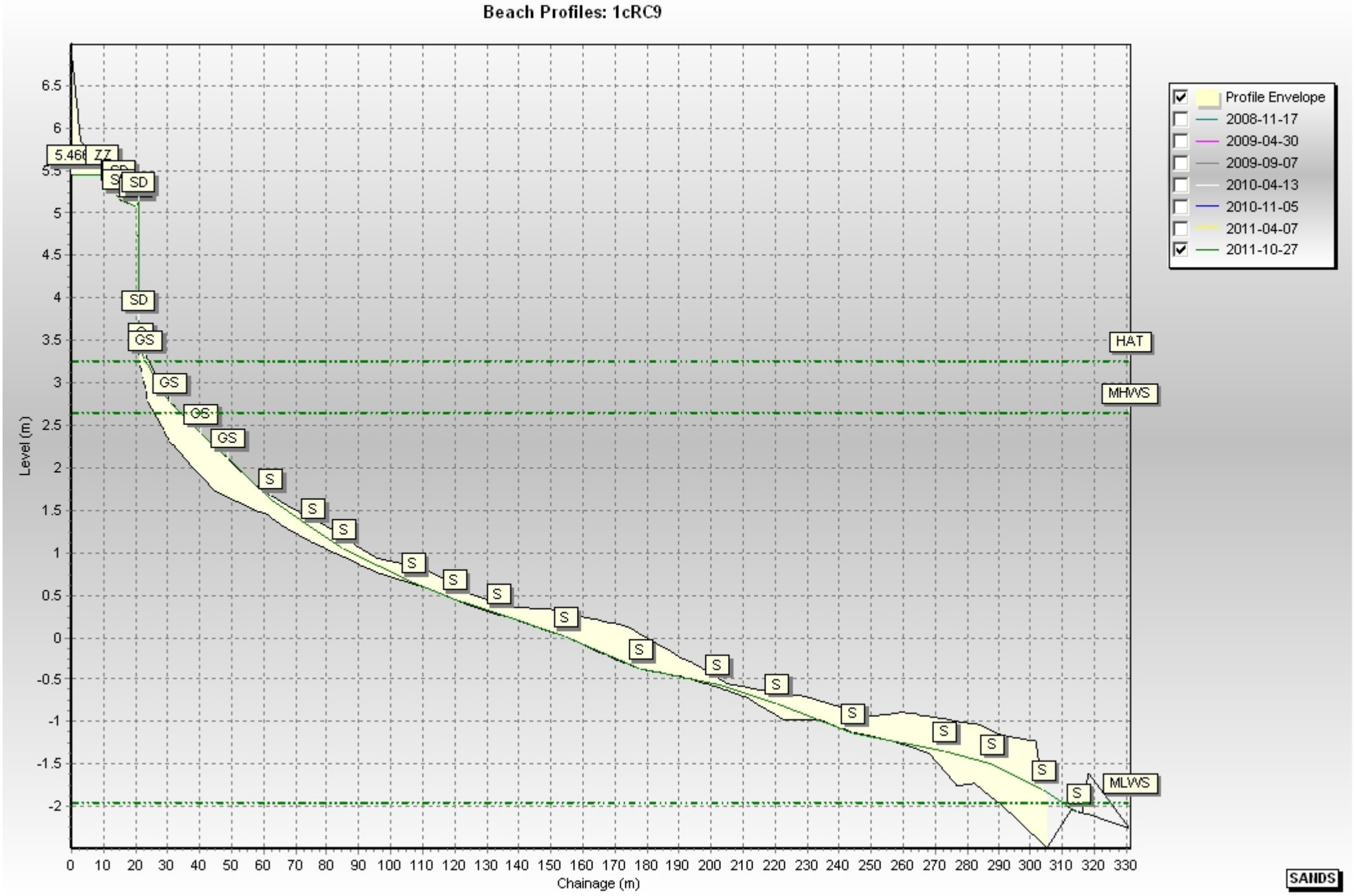
2009-09-07
2010-04-13
2010-11-05
2011-04-07
2011-10-27
Level (m)
Chainage (m)
HAT
MHWS
MLWS
DV
G
S
SANDS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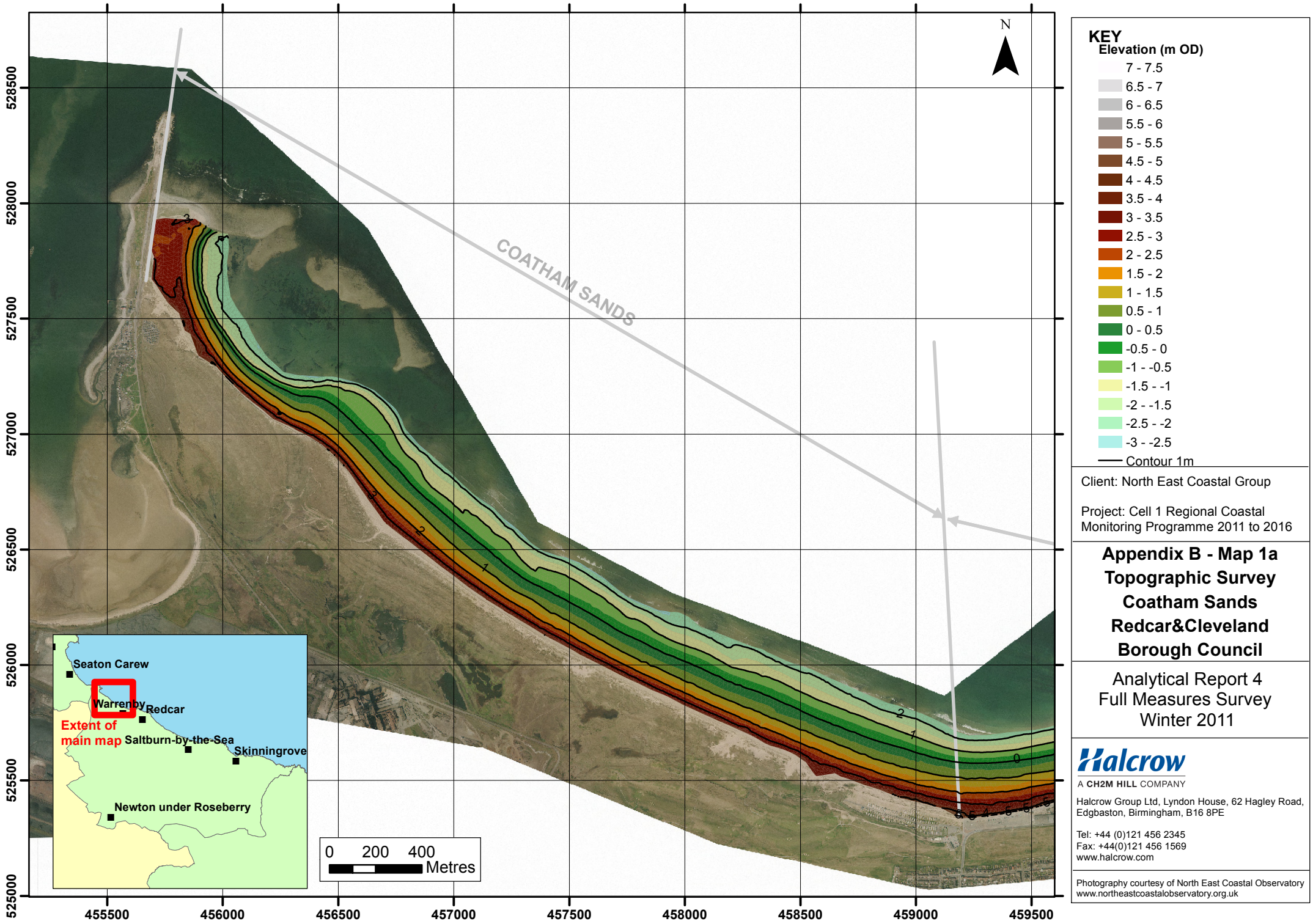
2009-04-30
2009-09-07
2010-04-13
2010-11-05
2011-04-07
2011-10-27
HAT
MHWS
MLWS
SD
GS
S
Level (m)
Chainage (m)
SANDS

Appendix B

Topographic Survey



KEY

Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 5.5 - 6
- 5 - 5.5
- 4.5 - 5
- 4 - 4.5
- 3.5 - 4
- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1 - -0.5
- -1.5 - -1
- -2 - -1.5
- -2.5 - -2
- -3 - -2.5
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1a
Topographic Survey
Coatham Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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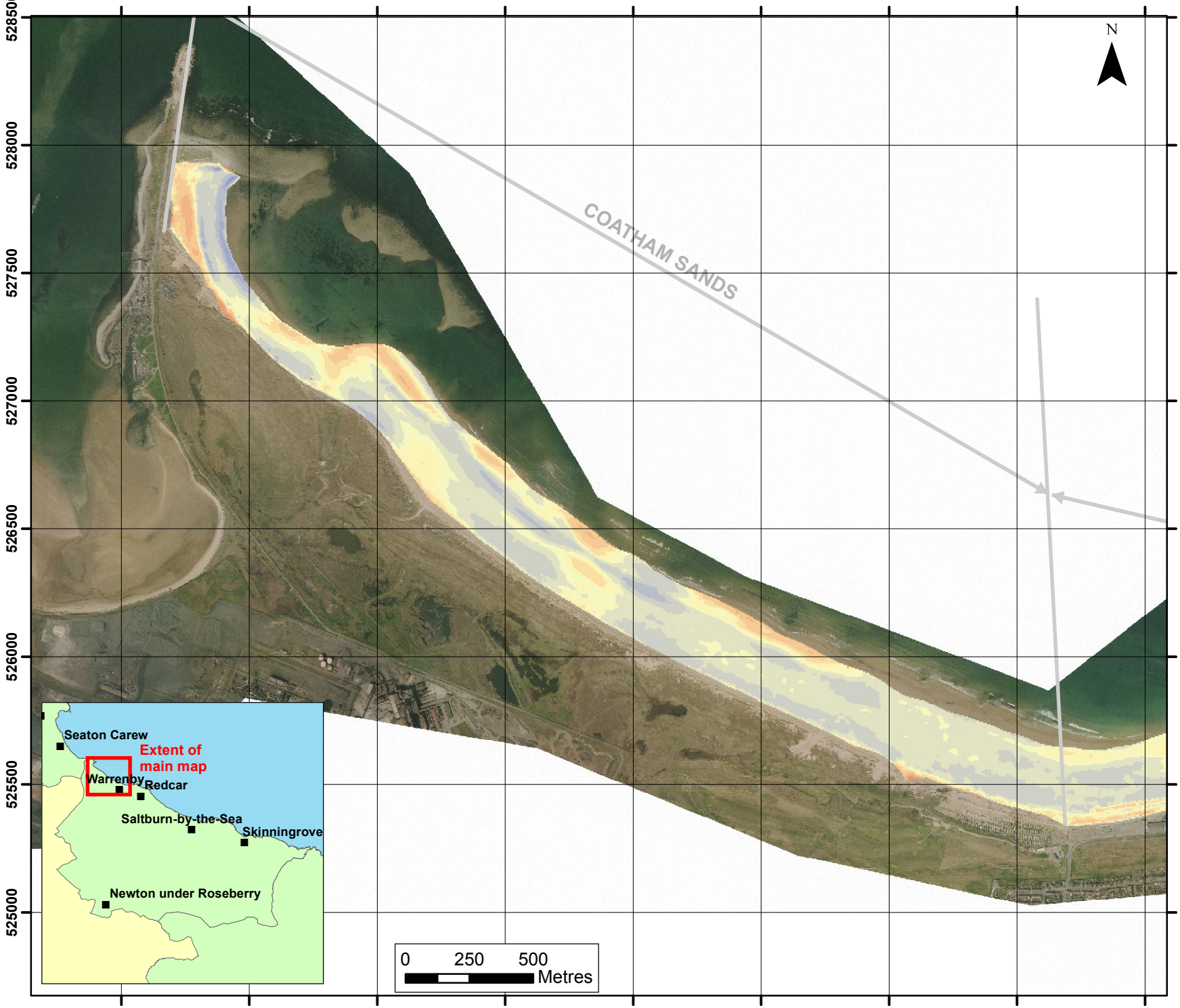

KEY Winter 2010 and Winter 2011
Change in elevation (m OD)

<-2	Loss
-2 - -1.75	
-1.75 - -1.5	
-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

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Appendix B - Map 1b
Topographic Difference
Coatham Sands
Redcar&Cleveland Borough Council

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Winter 2011

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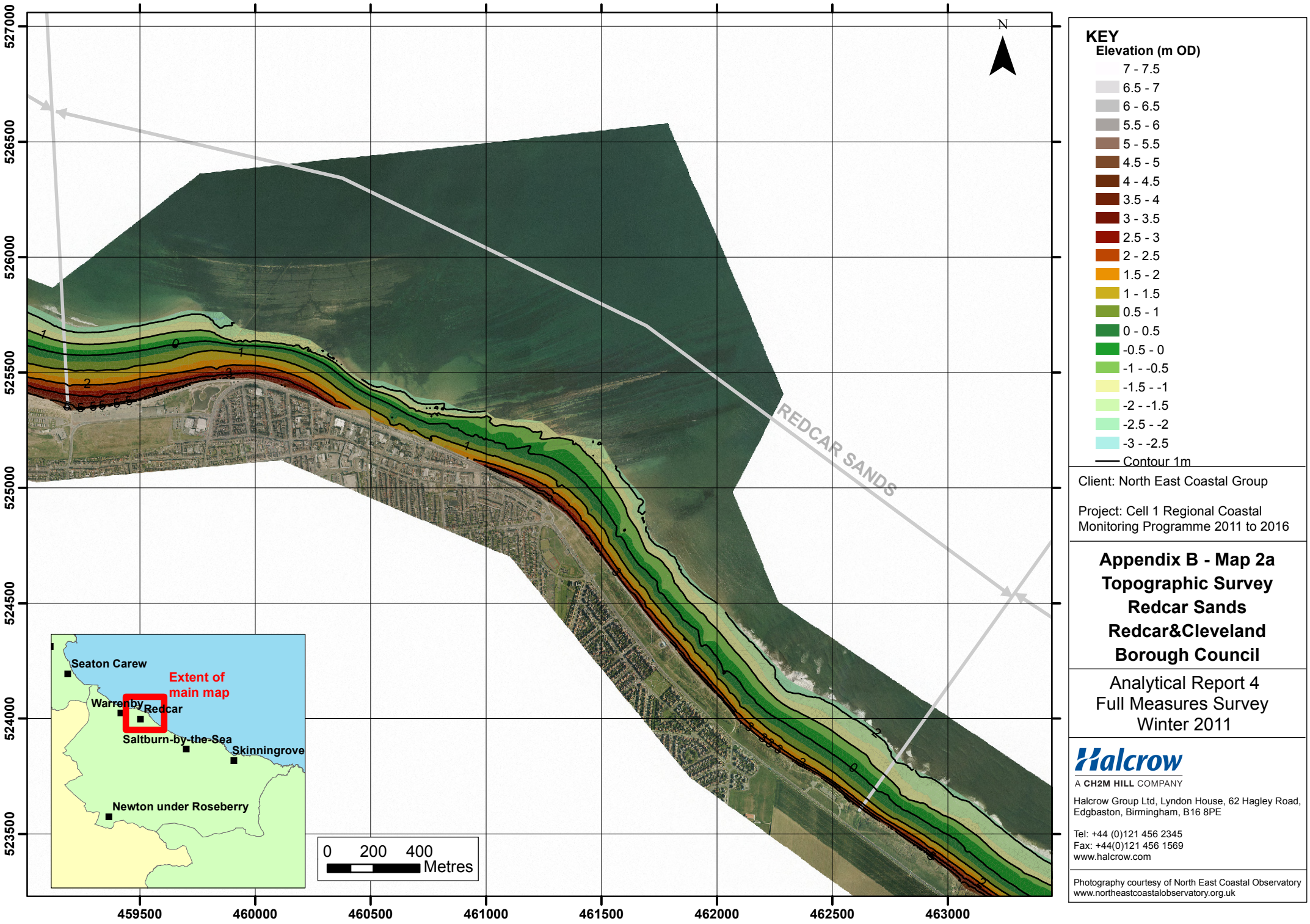

KEY

Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 5.5 - 6
- 5 - 5.5
- 4.5 - 5
- 4 - 4.5
- 3.5 - 4
- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1 - -0.5
- -1.5 - -1
- -2 - -1.5
- -2.5 - -2
- -3 - -2.5
- Contour 1m

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Appendix B - Map 2a
Topographic Survey
Redcar Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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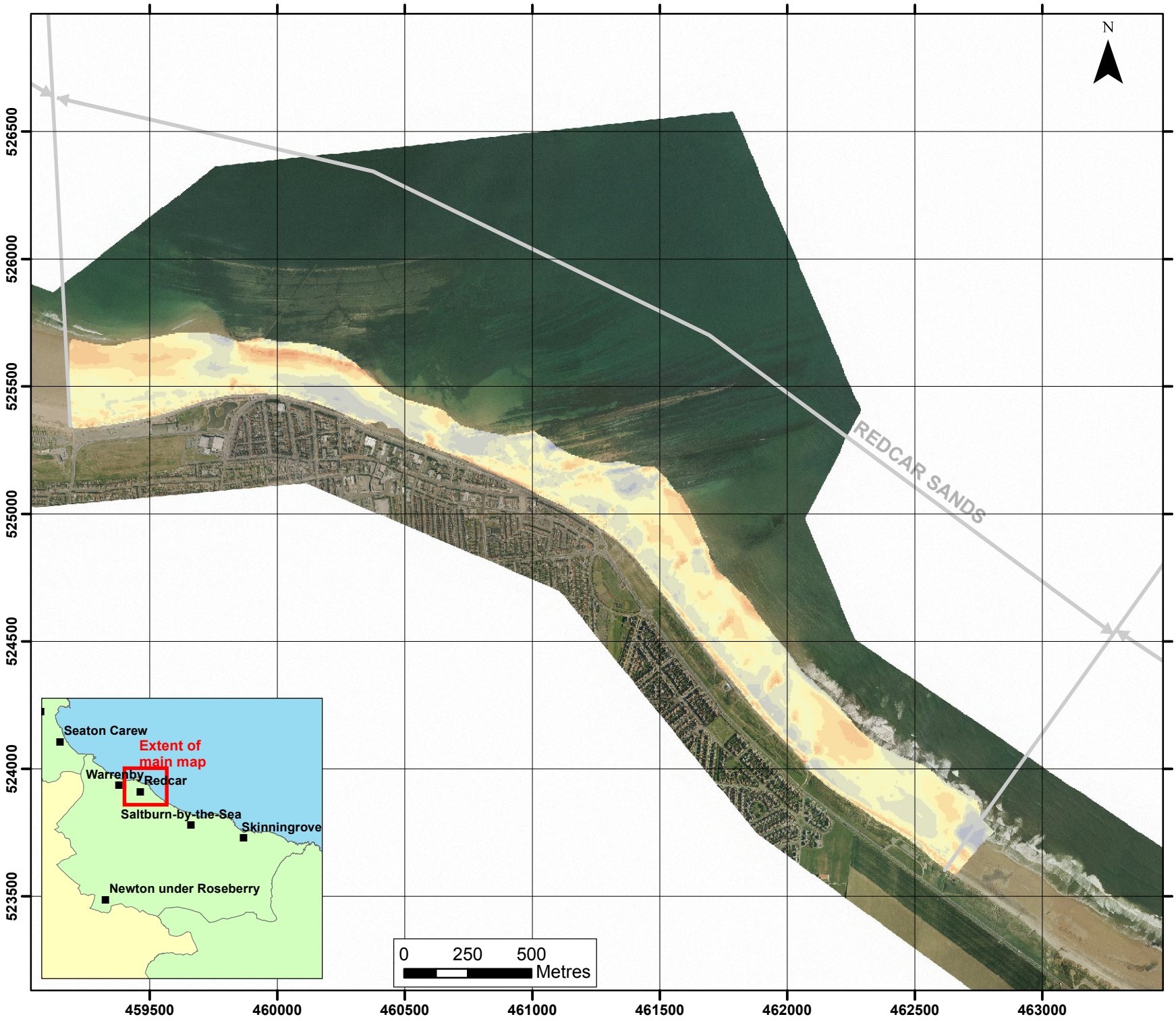

KEY Spring 2011 and Winter 2011
Change in elevation (m OD)

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-1.75 - -1.5	
-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

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Appendix B- Map 2b Topographic Difference Redcar Sands Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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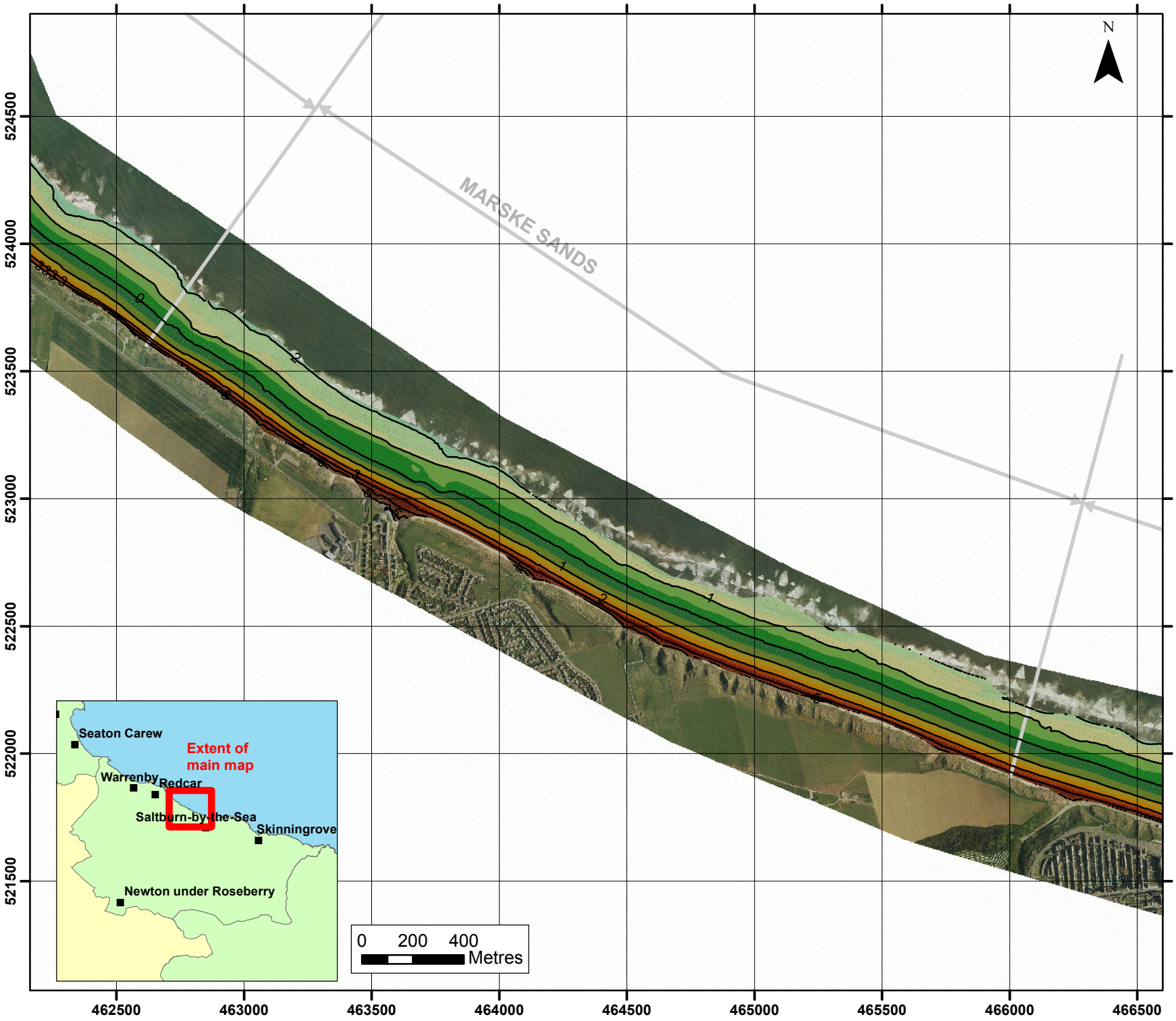

KEY

Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 5.5 - 6
- 5 - 5.5
- 4.5 - 5
- 4 - 4.5
- 3.5 - 4
- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1 - -0.5
- -1.5 - -1
- -2 - -1.5
- -2.5 - -2
- -3 - -2.5
- Contour 1m

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Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 3a
Topographic Survey
Marske Sands
Redcar&Cleveland Borough Council

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Full Measures Survey
Winter 2011

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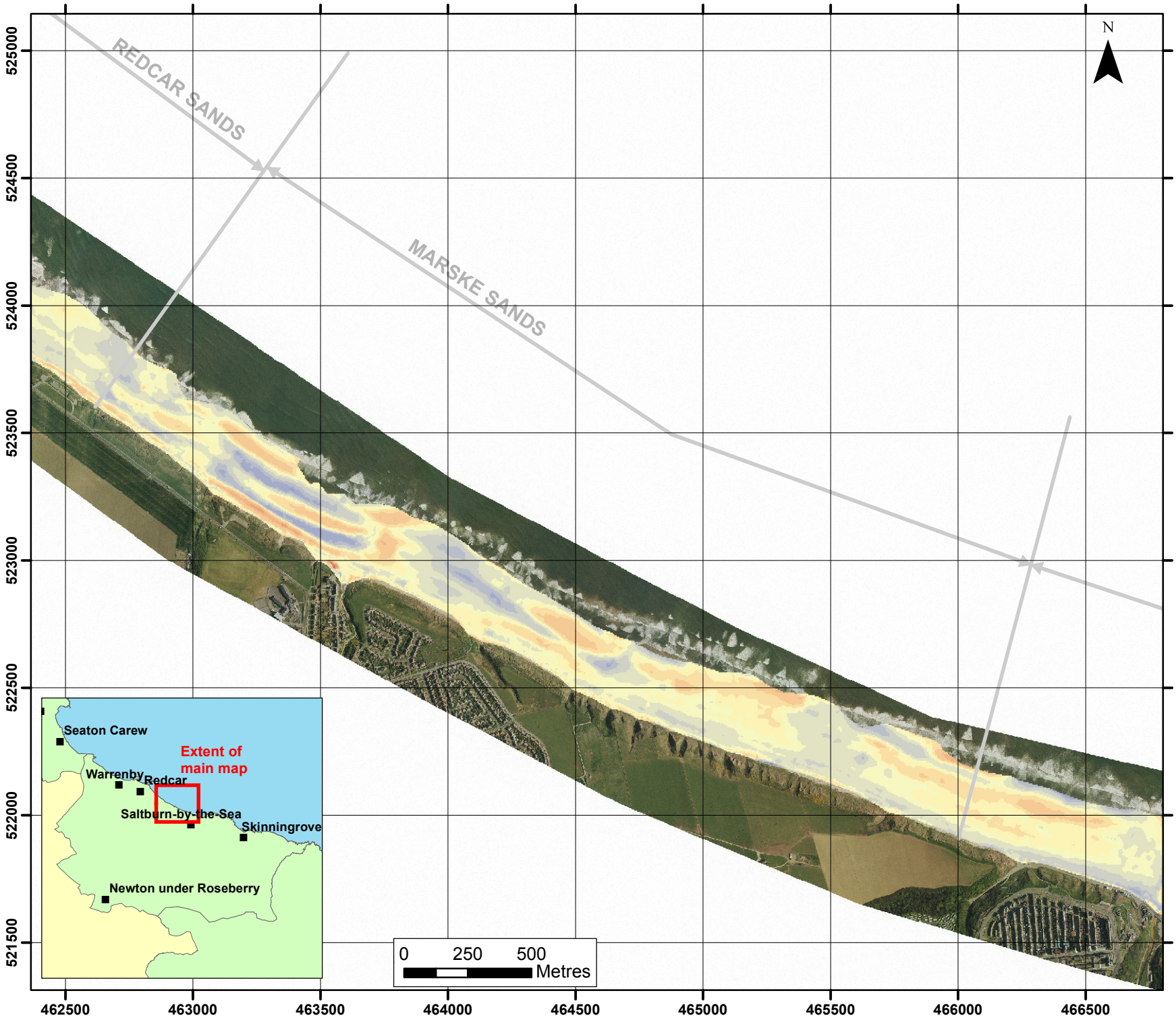

KEY Winter 2010 and Winter 2011 Change in elevation (m OD)

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-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

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Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 3b
Topographic Difference
Marske Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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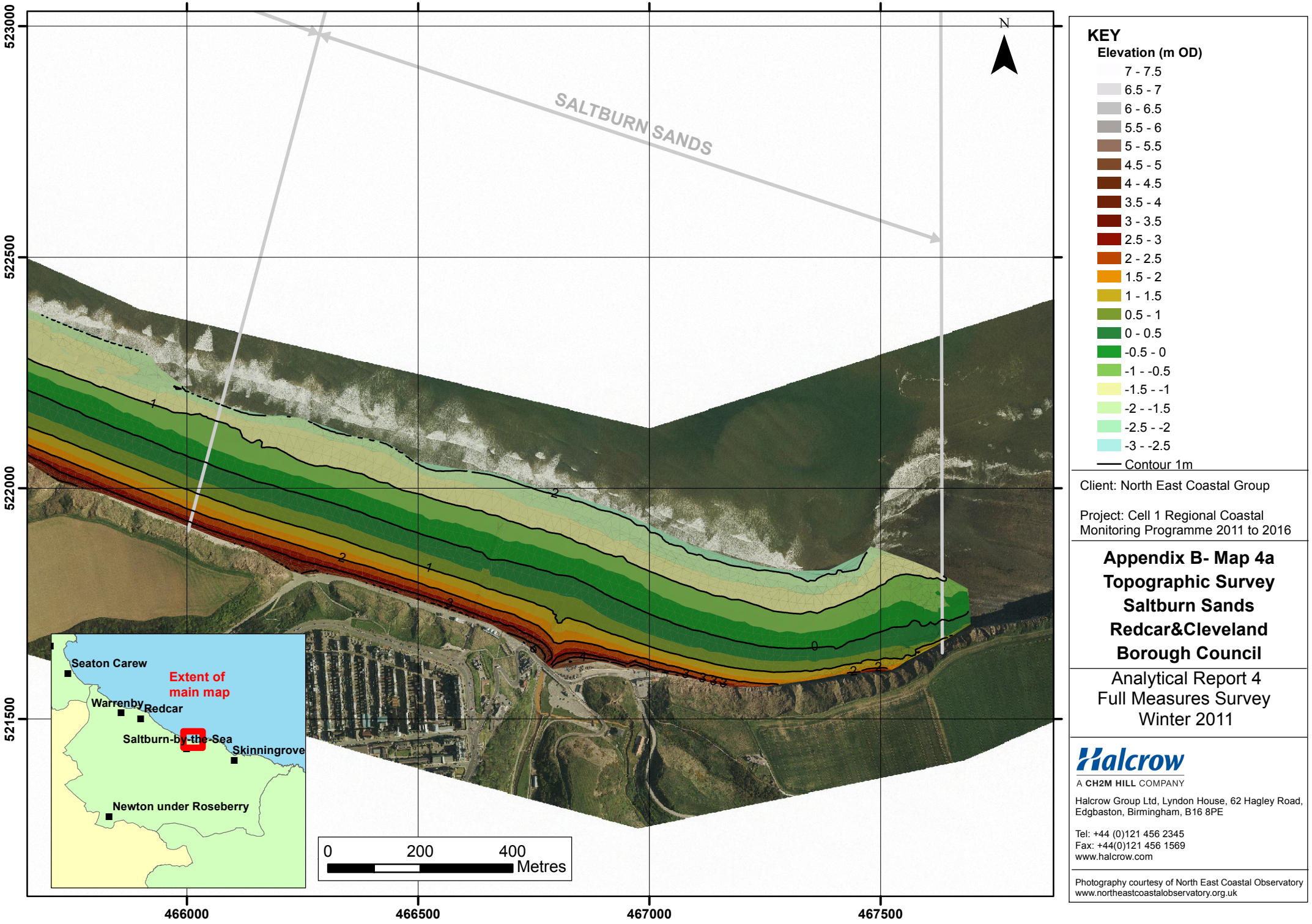

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Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 4a
Topographic Survey
Saltburn Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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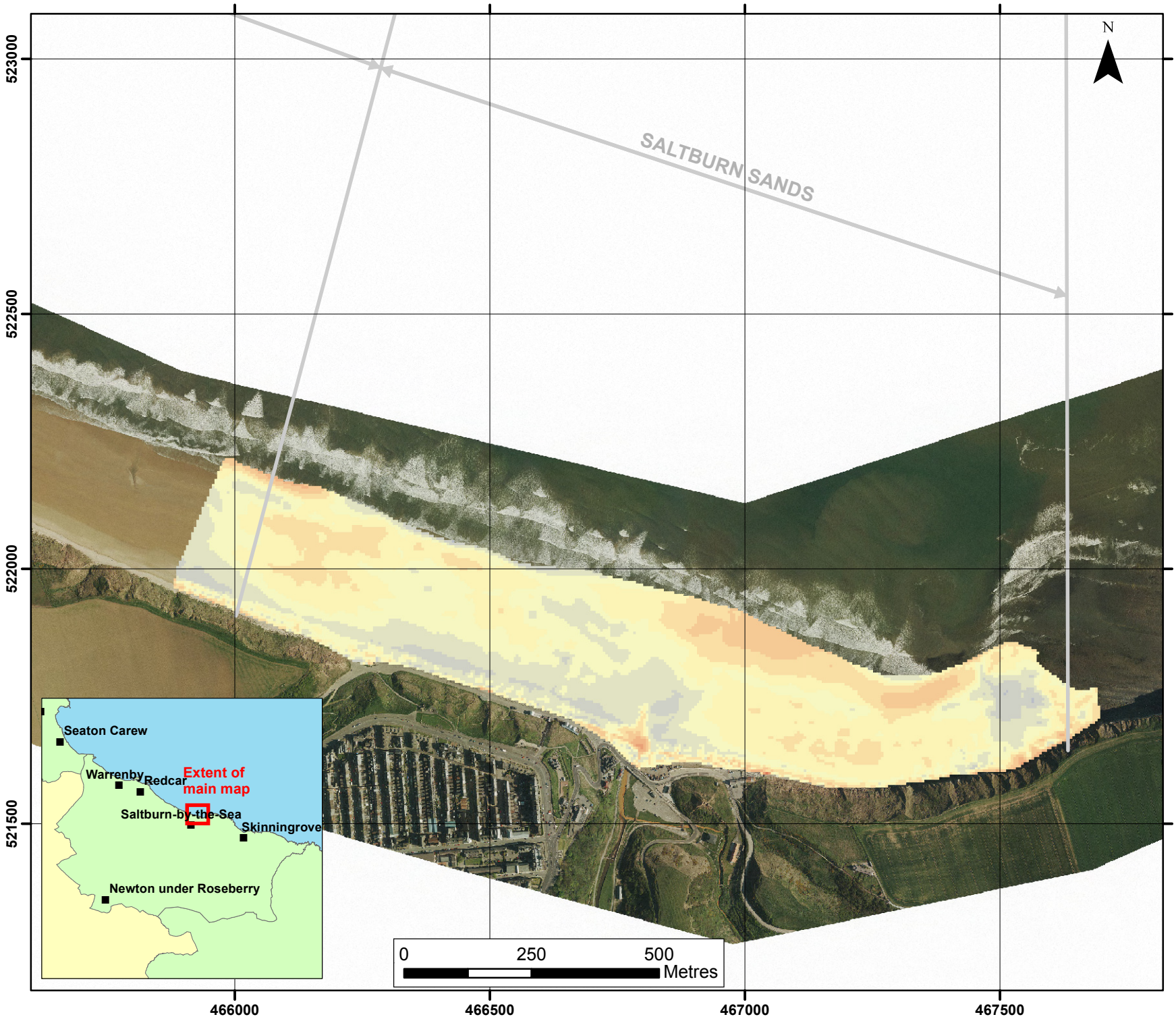

KEY Spring 2011 and Winter 2011
Change in elevation (m OD)

<-2	Loss
-2 - -1.75	
-1.75 - -1.5	
-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 4b Topographic Difference Saltburn Sands Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

Halcrow
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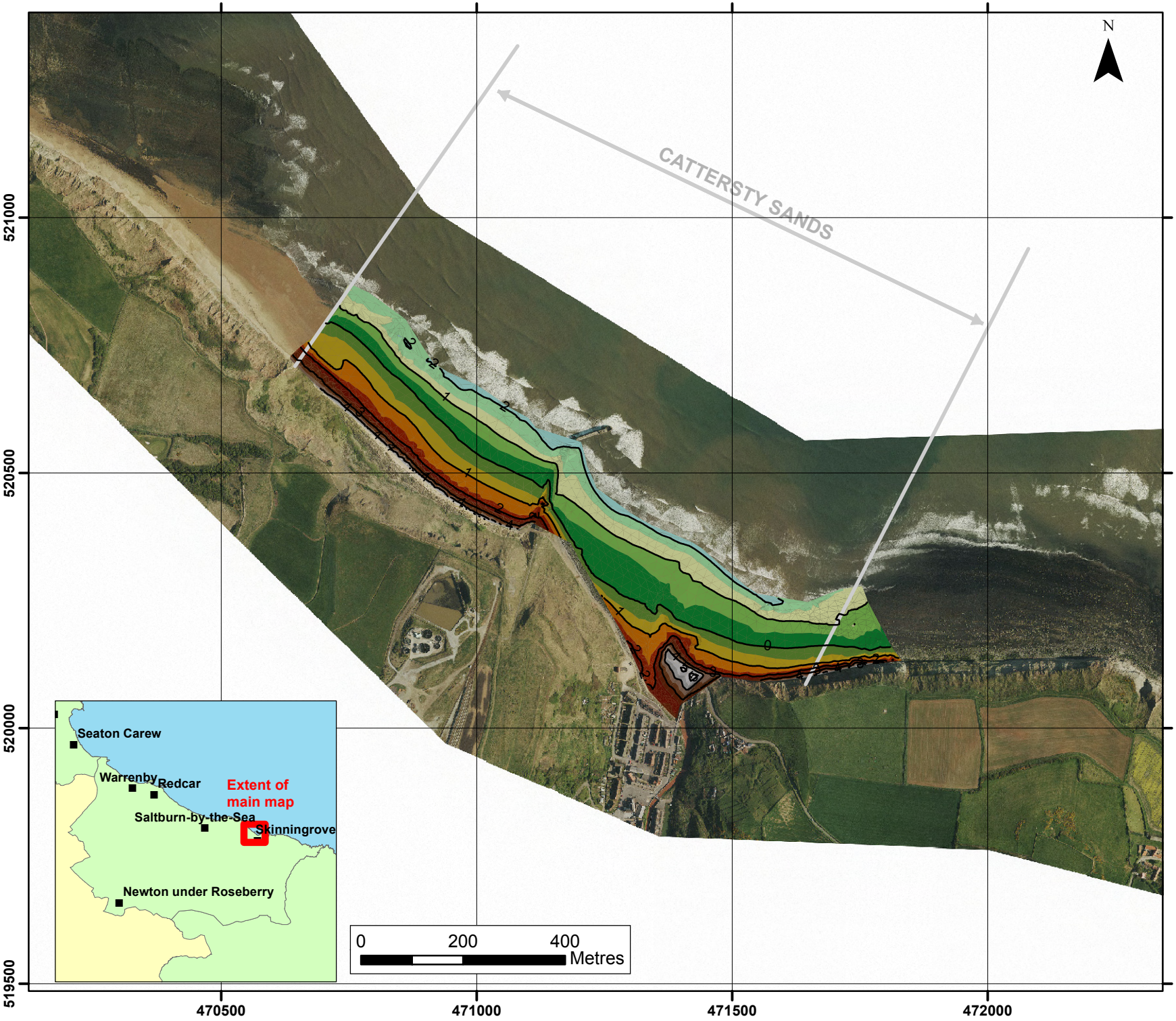

KEY

Elevation (m OD)

- 5 - 5.5
- 4.5 - 5
- 4 - 4.5
- 3.5 - 4
- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1 - -0.5
- -1.5 - -1
- -2 - -1.5
- -2.5 - -2
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 5a Topographic Survey Cattersty Sands Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

Halcrow
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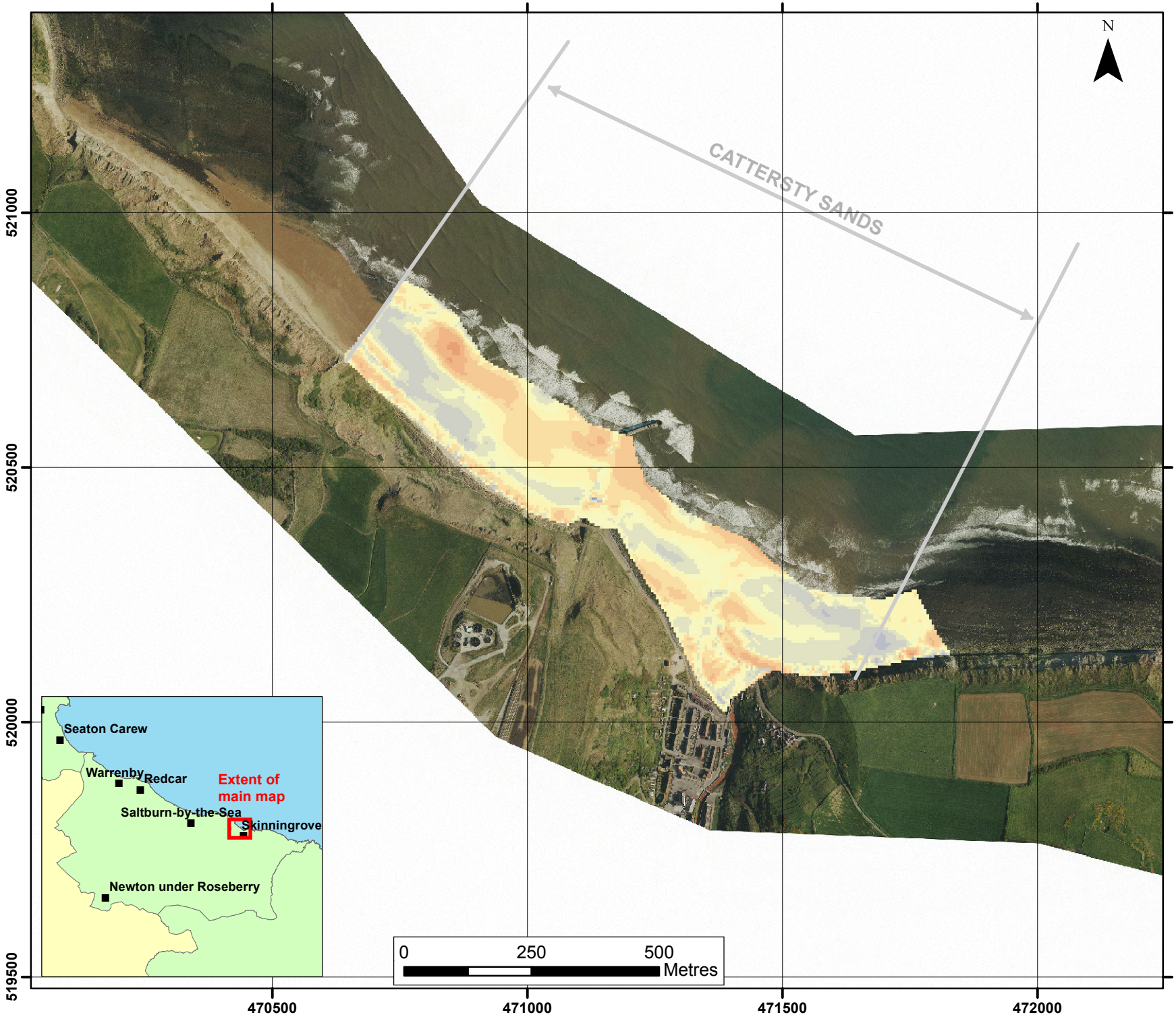

KEY Spring 2011 and Winter 2011
Change in elevation (m OD)

<-2	Loss
-2 - -1.75	
-1.75 - -1.5	
-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 5b
Topographic Difference
Cattersty Sands
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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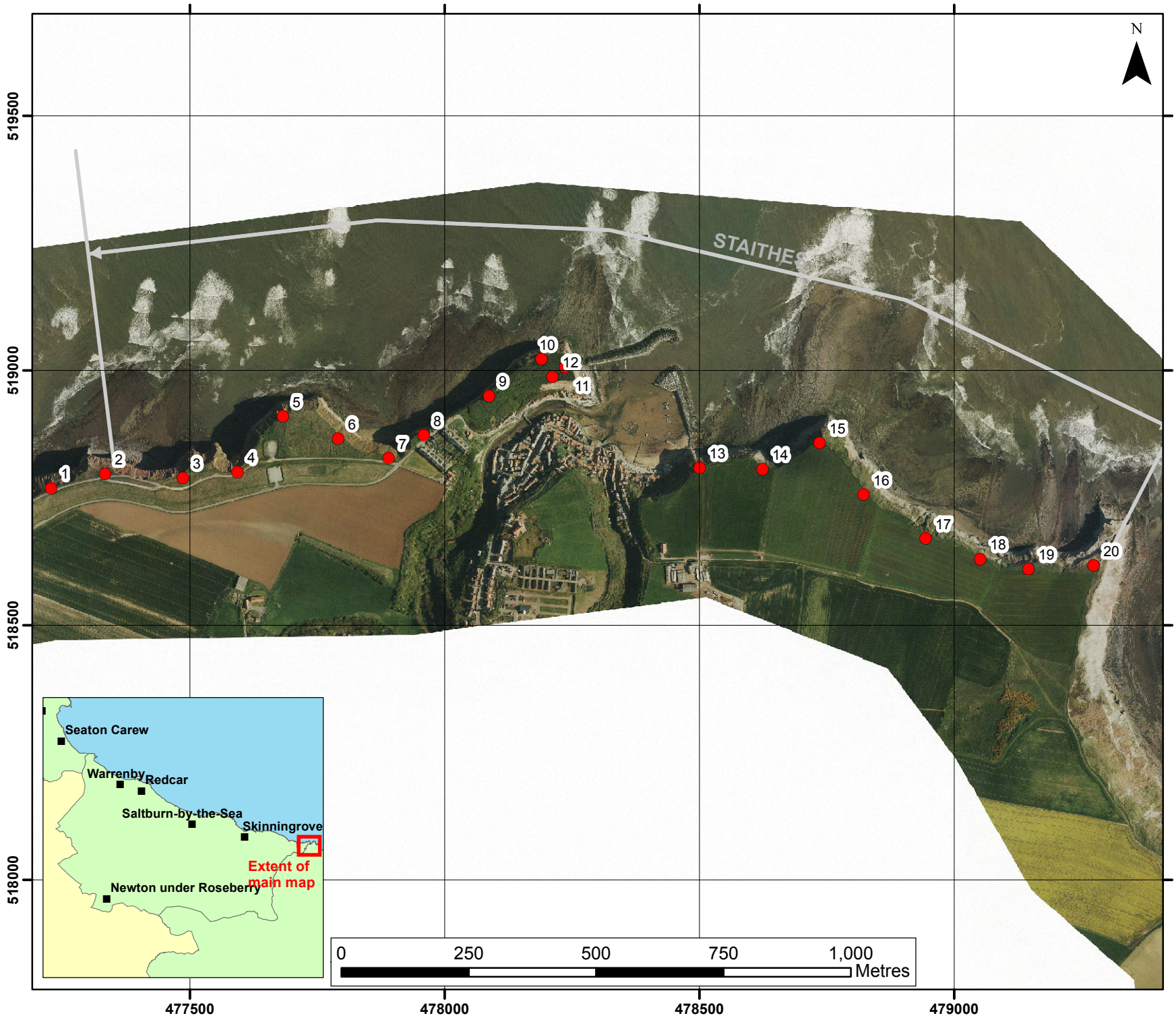
Appendix C

Cliff Top Survey



KEY

- Ground Control Points

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C - Map 1
Ground Control Points
Staiths
Redcar&Cleveland Borough Council

Analytical Report 4
Full Measures Survey
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Cliff Top Survey

Staithes

Twenty ground control points have been established within Staithes (Figure C1). The maximum separation between any two points is nominally 100m.

The cliff top surveys at Staithes are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

Table C1 provides baseline information about these ground control points and results from the 2008 (baseline) survey showing the position from the ground control point to the edge of the cliff top along the defined bearing. Future reports will show results from subsequent surveys and provide a means of assessing erosion since the baseline survey.

Table C1 – Cliff Top Surveys at Staithes

Ground Control Point Details				Distance to Cliff Top (m)			Total Erosion (m)		Erosion Rate (m/year)
Ref	Easting	Northing	Bearing (º)	Baseline Survey (Nov 2008)	Previous Survey (April 2011)	Present Survey (Oct 2011)	Baseline (Nov 2008) to Present (Oct 2011)	Previous (April 2011) to Present (Oct 2011)	Baseline (Nov 2008) to Present (Oct 2011)
1	477228	518769	320	1.9	1.7	1.6	-0.3	-0.1	-0.1
2	477334	518798	0	10.9	10.8	10.6	-0.3	-0.2	-0.1
3	477487	518789	350	7.1	8.5	8.2	1.1	-0.3	0.4
4	477594	518801	340	5.9	5.4	5.2	-0.7	-0.2	-0.2
5	477683	518911	350	8.4	9.7	9.4	1.0	-0.3	0.3
6	477792	518867	30	8.6	8.5	8.5	-0.1	0.0	0.0
7	477891	518828	60	7.7	7.7	7.5	-0.2	-0.2	-0.1
8	477959	518873	350	8.7	9.8	9.6	0.9	-0.2	0.3
9	478088	518950	350	7.6	8.4	8.0	0.4	-0.4	0.1
10	478191	519023	340	8.4	8.9	8.7	0.3	-0.2	0.1
11	478237	519007	60	6.9	6.8	6.7	-0.2	-0.1	-0.1

12	478213	518988	150	6.1	6.5	6.5	0.4	0.0	0.1
13	478501	518809	15	11.4	9.4	9.2	-2.2	-0.2	-0.8
14	478624	518807	20	7.5	7.5	7.5	0.0	0.0	0.0
15	478737	518858	60	6.1	6.2	6.4	0.3	0.2	0.1
16	478823	518757	60	8	8.4	8.4	0.4	0.0	0.1
17	478944	518671	30	9.3	9.9	9.4	0.1	-0.5	0.0
18	479052	518630	20	9.2	9.4	9.3	0.1	-0.1	0.0
19	479147	518610	0	14.2	14.5	14.3	0.1	-0.2	0.0
20	479274	518618	20	11.4	11.5	11.2	-0.2	-0.3	-0.1

Note: It is assumed that the accuracy of cliff top monitoring using this technique is ±0.1m. Therefore observed changes have been altered by this amount prior to calculation of an erosion rate. Erosion rates are not calculated where the cliff line shows advance. This is likely to be the product of differing survey interpretation, and far less likely to be a toppling cliff edge.