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Cell 1 Regional Coastal Monitoring Programme
Analytical Report 6: 'Full Measures' Survey 2013

Redcar and Cleveland Borough Council
Final Report

February 2014

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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.

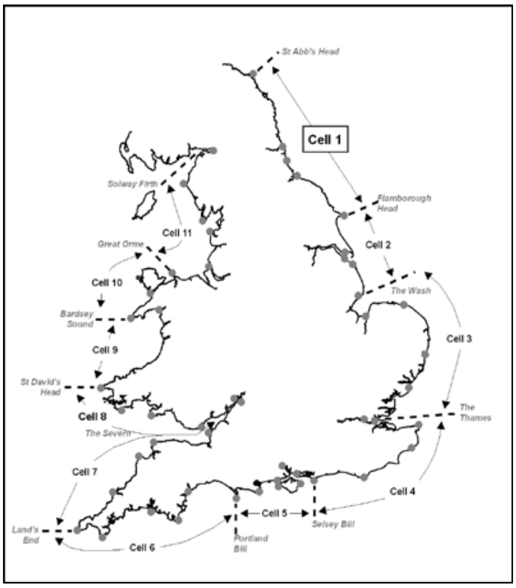


Figure 1 Sediment Cells in England and Wales

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:

Northumberland County Council
North Tyneside Council
South Tyneside Council
Northumberland Coast Area of Outstanding Natural Beauty
Sunderland City Council
Durham County Council
Redcar & Cleveland Borough Council
Hartlepool Borough Council
Borough of Scarborough – A great place to live, work & play
East Riding of Yorkshire Council
Environment Agency
Natural England
The National Trust

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 (rebranded as CH2M HILL since 2013).

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	Mar-May 12	Feb 13	
5	2012/13	Sep 12	Mar 13	Feb- Mar 13	May 13	
6	2013/14	Oct-Nov 13	Feb 14(*)			

* The present report is **Analytical Report 6** and provides an analysis of the 2013 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 October and November 2013. The weather was dry with sunny spells at Redcar and Staithes. At Skinningrove the weather was overcast but dry. For further details please refer to the Survey Report from Academy Geomatics.

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.

1.3 Uncertainties in data and analysis

While uncertainty due to survey accuracy or systematic error is likely to be present in all datasets, the work is carefully managed to ensure data are as accurate as possible and results are not misleading. Error may arise from the limits of precision of survey techniques used, from low accuracy measurements being taken or from systematic failings of equipment.

For beach profiles and topographic surveys, all incoming data are checked allowing systematic errors to be identified, and removed from plots and subsequent analysis. The accuracy of these surveys is not known, but it is likely that all measurements are correct to ±0.1m. Therefore, changes are less than ±0.1m are ignored and greyed out in the topographic change plots. For cliff top erosion surveys, there are commonly problems in precisely recognising the cliff edge due to vegetation growth and the convex shape of the feature. Errors manifest themselves as results that suggest the cliff edge has advanced, which is very unlikely unless a toppling failure has been initiated, but the block has not yet fully detached. The accuracy of cliff top surveys are also unknown, but it is assumed that each measurement is accurate to ±0.1m.

These limits of accuracy mean that comparison of annual or biannual data can be of limited value if the measured change is less than or equal to the assumed error. However, all results become more significant over longer time periods when the errors in measurement in years 1 and *x* are averaged over the monitoring period:

$$\text{Error rate of change per year} = \frac{\text{Error in first measurement} + \text{Error in last measurement}}{\text{Years between measurements}}$$

The effect of averaging error over different monitoring periods is summarised in Table 3, which assumes that each annual survey is accurate to 0.1m.

Table 3 Error bands for long-term calculations of change.

Years between surveys	Error in inter-survey comparison (±m/yr)
1	0.200
2	0.100
3	0.067
4	0.050
5	0.040
5	0.033
7	0.029
8	0.025
9	0.022
10	0.020

While considering the uncertainty in comparing and analysing change between monitoring data sets it is also relevant to raise caution about drawing conclusions about short or longer term trends. Clearly the longer the data set the more confidence that can be given to likely ranges of beach changes and trends in change. Potential for seasonal, annual and longer term cycles need to be considered. Studies of long term monitoring data sets for other coastal and estuarial data have established that there are long period cyclical trends related to the 18.6 years lunar nodal cycle which need to be accounted for. Simply put this means that although the Cell 1 monitoring programme now has data in some locations up to 11 years, another 8 to 10 years of consistent data is needed before confidence can be given in trends from the analysis. In the context of this report "Longer Term Trends" are mentioned in each section and it should be noted that this is based on simple visual interpretation of the available data since the current programme began, and is generally based on only 5 years of data.

2 Wave Data and Interpretation

2.1 Introduction

Wave monitoring data relevant to the Cell 1 Regional Coastal Monitoring Programme is available from one offshore regional wave buoy located at Tyne and Tees and three regional wave buoys, which are further inshore at Newbiggin, Whitby and Scarborough. The Tyne Tees buoy is managed by Cefas as part of the WaveNet system, while the three inshore buoys are managed by Scarborough Borough Council as part of the Cell 1 monitoring programme.

An assessment of baseline wave data is presented in the 2011 Wave Data Analysis Report, which reviewed all readily available data in the region. In 2014 a wave data update report will update the baseline with analysis of the wave data collected under the programme for 2013, including the 5th and 6th December storm. In order to help put the beach and cliff changes discussed in this report into context analysed storm data for the wave buoys is presented in this section.

The longest consistent relevant wave data record in the Cell 1 region is from the WaveNet Tyne Tees buoy deployed under the national coastal monitoring programme by Cefas. Data has been downloaded from WaveNet and loaded into SANDS for analysis alongside the beach and cliff monitoring data. Results from analysis of the data to extract details of significant storms are presented in Table 4 below.

To aid interpretation of the results in Table 4 alternate years have been shaded and the storm with the largest peak wave height each year has been highlighted in bold. The annual storm with the highest wave energy at peak has also been highlighted in bold red text as this depends on wave period as well as wave height and so is not always the same as the largest wave height, e.g. in 2009 and 2010.

Table 4 SANDS Storm Analysis at Tyne/Tees WaveNet Buoy

General Storm Information					At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Direction Vector (Degrees)**	**Hs (m)**	**Tp (s)**	**Direction (Degrees)**	**Energy @ Peak (KJ/m/s)**
19/03/2007 10:30	21/03/2007 05:30	43	20/03/2007 14:30	79.0	6.2	12.4	22	11759.3
25/06/2007 20:00	26/06/2007 13:30	17.5	26/06/2007 10:00	81.6	4.4	8.6	22	2832.6
26/09/2007 03:00	27/09/2007 05:00	26	26/09/2007 19:00	80.4	4.6	11.6	6	5488.7
08/11/2007 20:00	**12/11/2007 15:00**	**91**	**09/11/2007 08:30**	**78.7**	**6.2**	**13.4**	**6**	**13698.9**
19/11/2007 03:30	25/11/2007 21:30	162	23/11/2007 05:00	78.8	4.9	10.7	17	5353.7
08/12/2007 03:00	10/12/2007 14:30	59.5	08/12/2007 03:30	85.1	4.1	10.8	17	3816.4
03/01/2008 10:30	04/01/2008 01:30	15	03/01/2008 23:30	14.8	4.2	9.1	62	2964.9
01/02/2008 15:00	02/02/2008 09:30	18.5	02/02/2008	80.9	6.0	13.8	17	13641.7
10/03/2008 08:30	10/03/2008 12:30	4	10/03/2008 11:00	307.6	4.6	8.0	141	2631.9
17/03/2008 15:00	**25/03/2008 03:00**	**180**	**22/03/2008 05:00**	**83.8**	**7.9**	**12.4**	**6**	**19123.9**
05/04/2008 22:00	07/04/2008 05:00	31	06/04/2008 19:00	83.8	4.6	11.6	6	5520.5
20/07/2008 16:00	21/07/2008 09:30	17.5	20/07/2008 23:30	75.9	4.2	9.9	11	3492.5
03/10/2008 03:00	03/10/2008 20:30	17.5	03/10/2008 16:30	82.4	4.7	11.4	22	5728.4
21/11/2008	25/11/2008	104.5	22/11/2008	75.8	6.0	13.1	11	12267.5

General Storm Information					At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Direction Vector (Degrees)	Hs (m)	Tp (s)	Direction (Degrees)	Energy @ Peak (KJ/m/s)
04:00	12:30		11:30					
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	331.9	4.9	8.3	129	3286.2
31/01/2009 16:30	03/02/2009 09:00	64.5	02/02/2009 22:00	7.1	5.8	9.5	84	6078.5
23/03/2009 20:30	28/03/2009 20:30	120	28/03/2009 18:30	89.7	4.9	9.3	0	4053.0
10/07/2009 01:30	10/07/2009 02:30	1	10/07/2009 01:30	78.8	4.2	9.9	11	3504.3
29/11/2009 20:00	**30/11/2009 15:00**	**19**	**30/11/2009 00:30**	**73.4**	**6.0**	**9.4**	**11**	**6331.4**
17/12/2009 10:30	18/12/2009 05:00	18.5	17/12/2009 19:30	26.4	5.4	10.6	68	**6549.5**
30/12/2009 09:00	30/12/2009 23:00	14	30/12/2009 12:30	7.7	5.1	7.5	90	2866.0
06/01/2010 05:30	06/01/2010 11:00	5.5	06/01/2010 06:30	63.7	4.2	10.7	11	4044.1
29/01/2010 10:30	30/01/2010 00:30	14	29/01/2010 22:30	83.9	5.4	8.6	6	4258.2
26/02/2010 22:30	27/02/2010 02:30	4	27/02/2010 01:00	72.6	4.6	8.5	17	2925.7
19/06/2010 07:00	20/06/2010 08:30	25.5	19/06/2010 20:00	69.4	5.4	10.7	22	**6611.8**
29/08/2010 14:00	30/08/2010 06:30	16.5	29/08/2010 22:30	91.8	4.9	8.9	0	3715.5
06/09/2010 22:30	07/09/2010 16:00	17.5	07/09/2010 15:30	353.3	4.6	8.8	90	3192.5
17/09/2010 07:00	17/09/2010 18:30	11.5	17/09/2010 08:30	80.8	4.7	11.0	11	5323.3
24/09/2010 03:00	26/09/2010	45	24/09/2010 10:00	73.1	5.3	10.1	11	5564.7
20/10/2010 02:00	24/10/2010 16:30	110.5	20/10/2010 10:00	78.3	4.2	11.3	17	4514.5
08/11/2010 14:00	**09/11/2010 20:30**	**30.5**	**09/11/2010 10:00**	**3.1**	**5.6**	**8.8**	**73**	**4870.6**
17/11/2010 11:00	17/11/2010 18:30	7.5	17/11/2010 12:00	322.2	4.7	7.8	129	2646.0
29/11/2010 19:30	02/12/2010 08:30	61	29/11/2010 21:00	11.8	5.1	9.4	56	4474.2
16/12/2010 15:00	17/12/2010 06:30	15.5	17/12/2010 03:30	80.2	4.6	10.5	17	4504.6
23/07/2011 14:00	**24/07/2011 11:00**	**21**	**24/07/2011 03:00**	**67.5**	**4.7**	**10.8**	**17**	**5082.6**
24/10/2011 18:30	25/10/2011 09:30	15	25/10/2011 09:30	348.5	4.1	9.5	79	2986.1
09/12/2011 08:30	09/12/2011 10:00	1.5	09/12/2011 08:30	84.4	4.1	11.9	6	4669.0
05/01/2012 15:30	06/01/2012 05:00	13.5	06/01/2012 00:30	81.4	4.5	9.9	14	3896.6
03/04/2012 13:30	04/04/2012 10:30	21	04/04/2012 03:00	26.5	5.7	8.4	90	4510.0
24/09/2012 07:30	25/09/2012 11:00	27.5	24/09/2012 17:30	17.2	5.3	9.3	77	4786.2
26/10/2012 12:00	27/10/2012 15:00	27	26/10/2012 23:00	78.9	4.9	12.9	11	**7839.9**
05/12/2012 15:00	**15/12/2012 01:30**	**226.5**	**14/12/2012 18:30**	**39.6**	**6.1**	**8.4**	**107**	**5080.9**
20/12/2012 06:00	21/12/2012 14:30	32.5	20/12/2012 23:30	347.3	6.0	8.8	103	5436.3
18/01/2013 17:30	22/01/2013 07:30	86	21/01/2013 09:30	7.6	6.8	9.3	83	7978.4
06/02/2013 08:00	07/02/2013 08:30	24.5	06/02/2013 12:30	82.6	5.6	9.9	11	6039.7
07/03/2013 21:00	11/03/2013 04:00	79	08/03/2013 04:00	24.3	5.1	8.4	82	3667.4

General Storm Information					At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Direction Vector (Degrees)	Hs (m)	Tp (s)	Direction (Degrees)	Energy @ Peak (KJ/m/s)
18/03/2013 07:00	**25/03/2013 02:00**	**163**	**23/03/2013 10:30**	**4.5**	**7.3**	**9.3**	**89**	**9164.3**
23/05/2013 18:00	24/05/2013 12:00	18	23/05/2013 22:30	77.5	6.7	10.5	17	9678.4
10/09/2013 13:00	10/09/2013 19:30	6.5	10/09/2013 14:00	79.3	4.4	9.2	11	3237.0
29/11/2013 22:30	30/11/2013 05:30	7	30/11/2013 00:30	82.8	5.6	10.7	11	7071.5
05/12/2013 14:00	07/12/2013 04:30	38.5	06/12/2013 20:00	80.4	4.7	14.3	6	8937.4
27/12/2013 09:30	27/12/2013 12:30	3	27/12/2013 10:00	249.3	4.1	6.1	202	1237.4

The storms mostly arrive from the north to northeast direction, 0 to 40 degrees, which has the longest fetch, but there are also a significant number of storms from other directions, particularly 80 to 140 degrees.

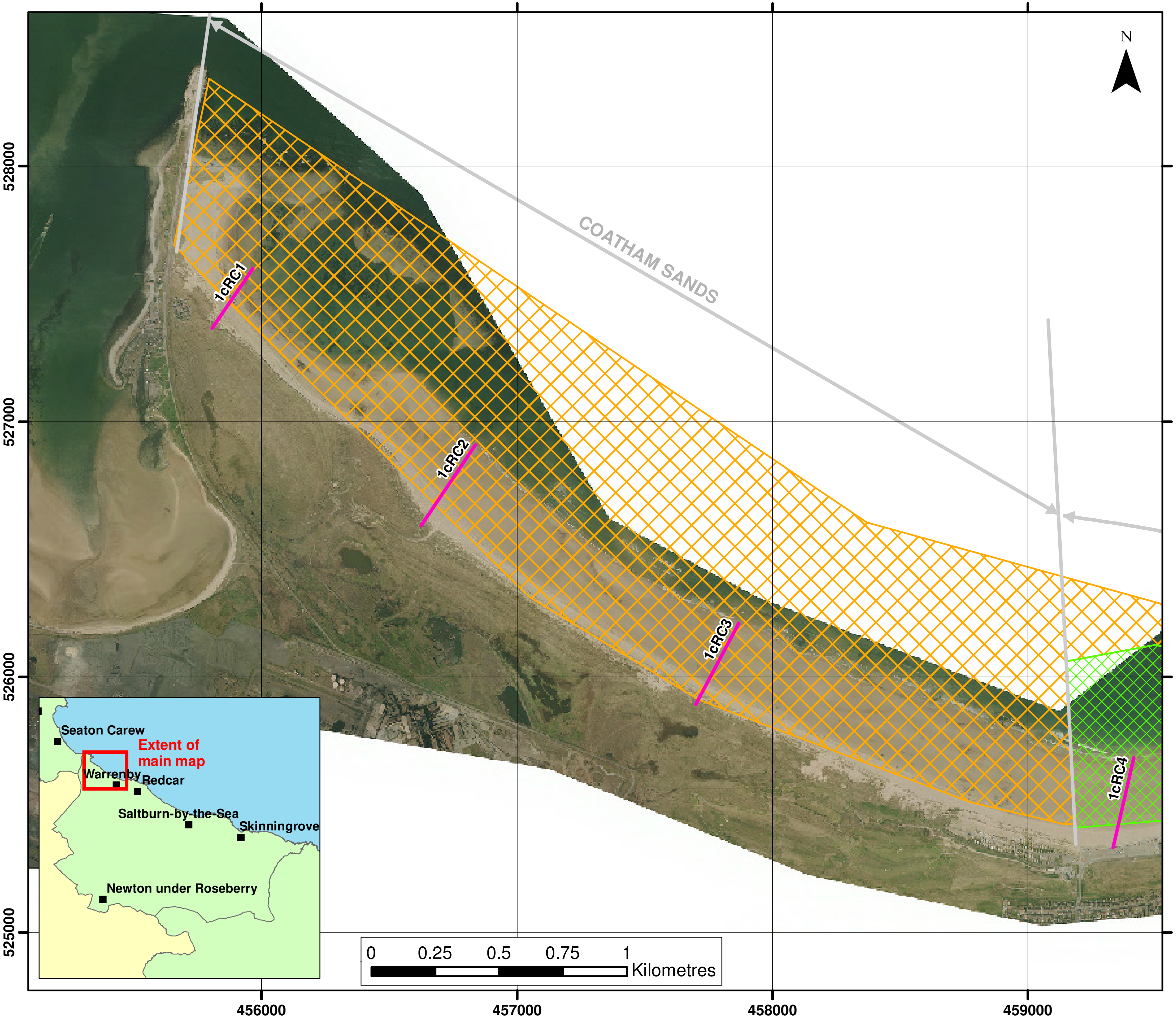
The record for 2008 to 2013 shows that 2010 had the most storms, with 13 events recorded. Furthermore, in 2010 the largest storm had an incident direction of 73 degrees, which is relatively unusual and is likely to have led to a short-duration reversal of the longshore drift direction that was noted in several of the 2010 Full Measures reports.

The year with the fewest storms was 2011. This was reflected by accretion recorded in a number of the annual Full Measures reports for the year.

The winter of 2012/13 appears to have experienced atypically large storms, with the second largest peak wave height (7.3m) recorded on 23rd March 2013. The longest duration storm in the record was from 5th to 15th December 2012 (226.5 hours).

The storm on the 5th to 7th December, was particularly notable. Although this event did not have as large waves as the 23rd March 2013 storm, it had a high peak energy and exceptionally long wave period at 14.3 seconds. The 6th December storm was also accompanied by a significant storm surge with recorded water levels around 1.75m higher that predicted tide levels. The combined high water levels and large waves causing significant damage to many coastal defences and beaches on the northeast coast. However, the Autumn 2013 full-measures survey data set which is assessed in this report was collected in October and November and so as no post storm surveys were available the impacts will not be seen until the Spring 2014 Partial Measures surveys.

The majority of the beaches were surveyed on the 10th October and 4th November. As a result the beach data shows the impact of a number of small storm events, which occurred early in the autumn period and may have led to atypical beach profiles.



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 6
Full Measures Survey
Autumn 2013

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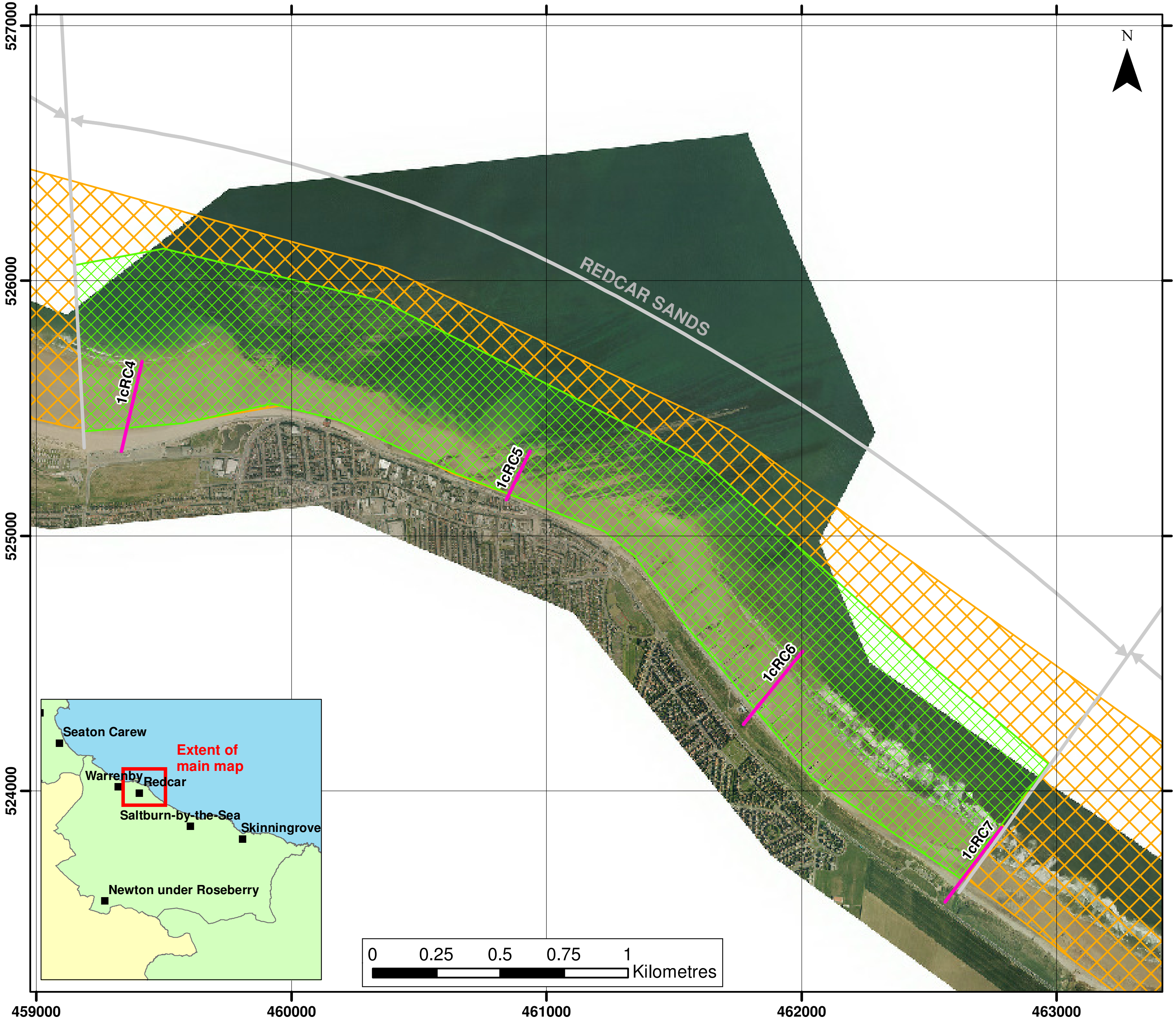

KEY

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 6
Full Measures Survey
Autumn 2013

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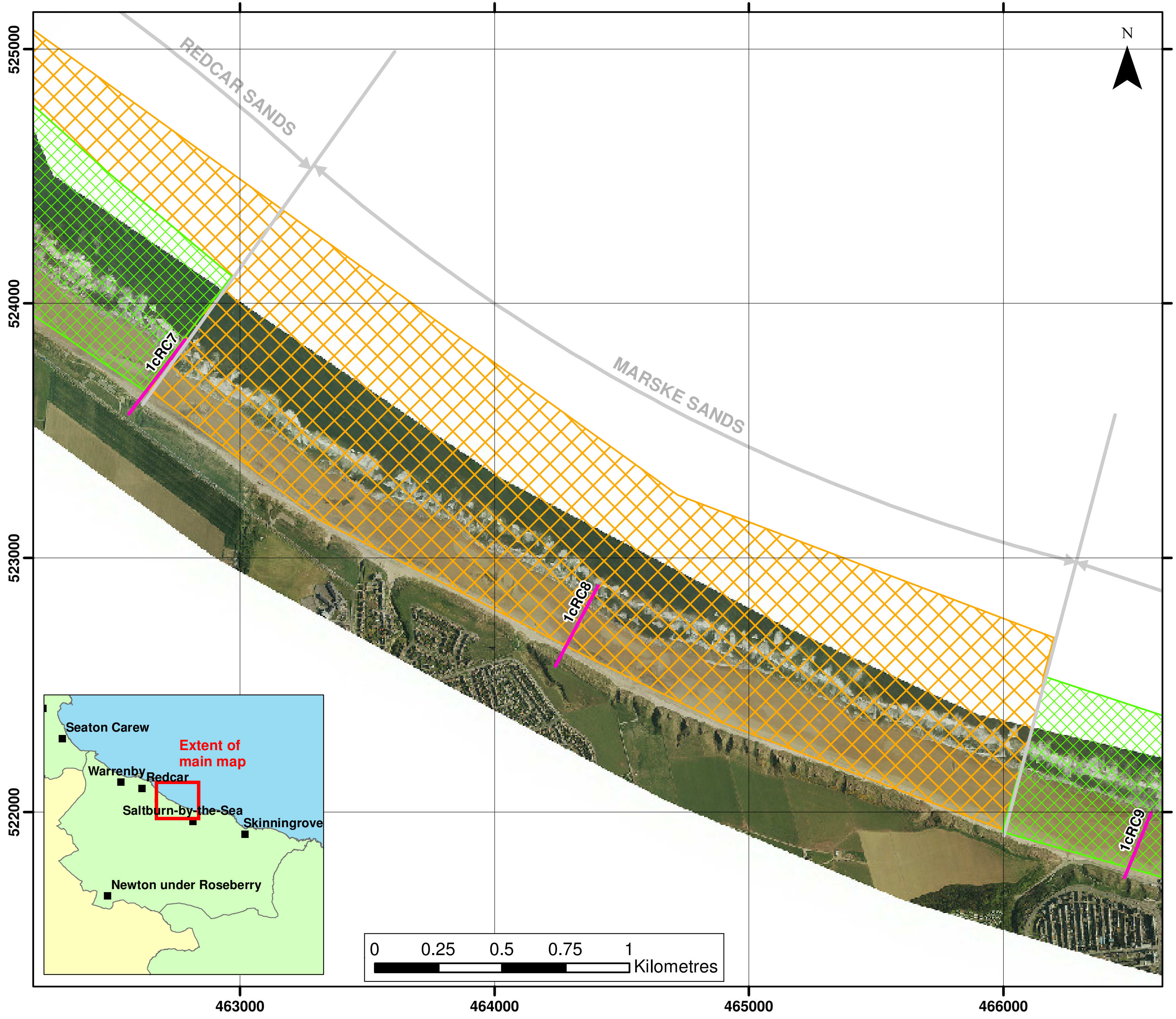

KEY

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

Analytical Report 6
Full Measures Survey
Autumn 2013

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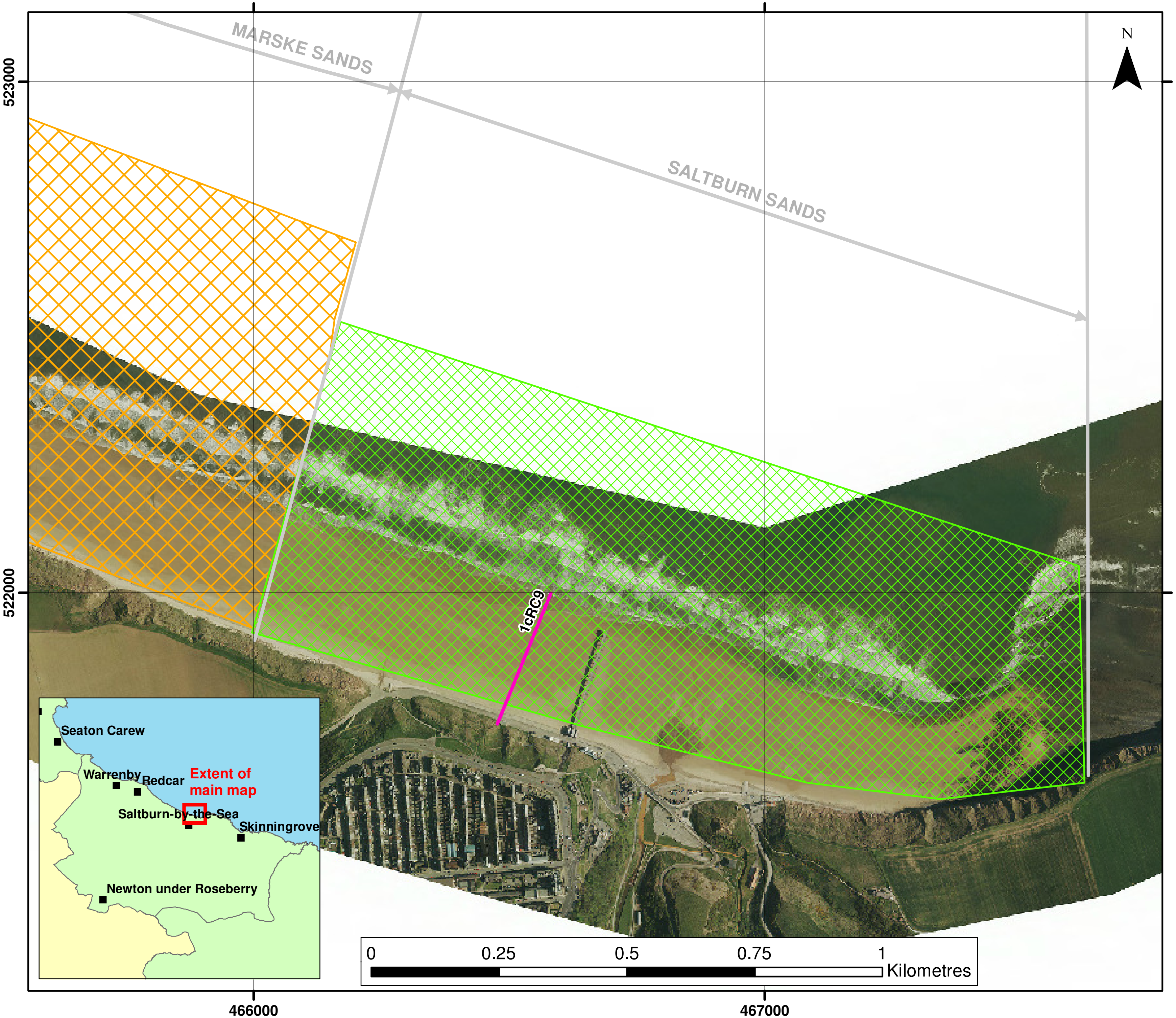

KEY

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 6
Full Measures Survey
Autumn 2013

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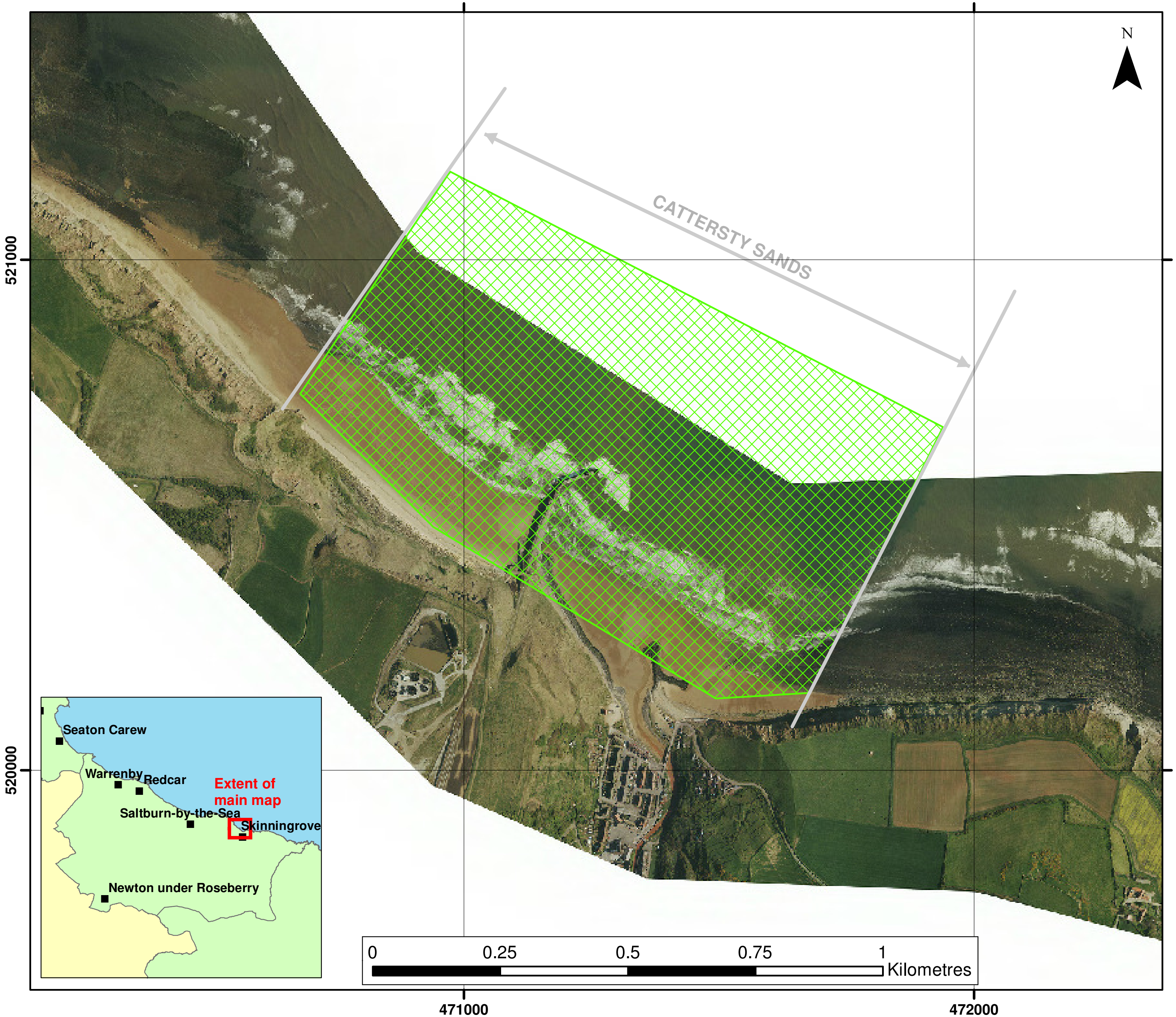

KEY

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 6
Full Measures Survey
Autumn 2013

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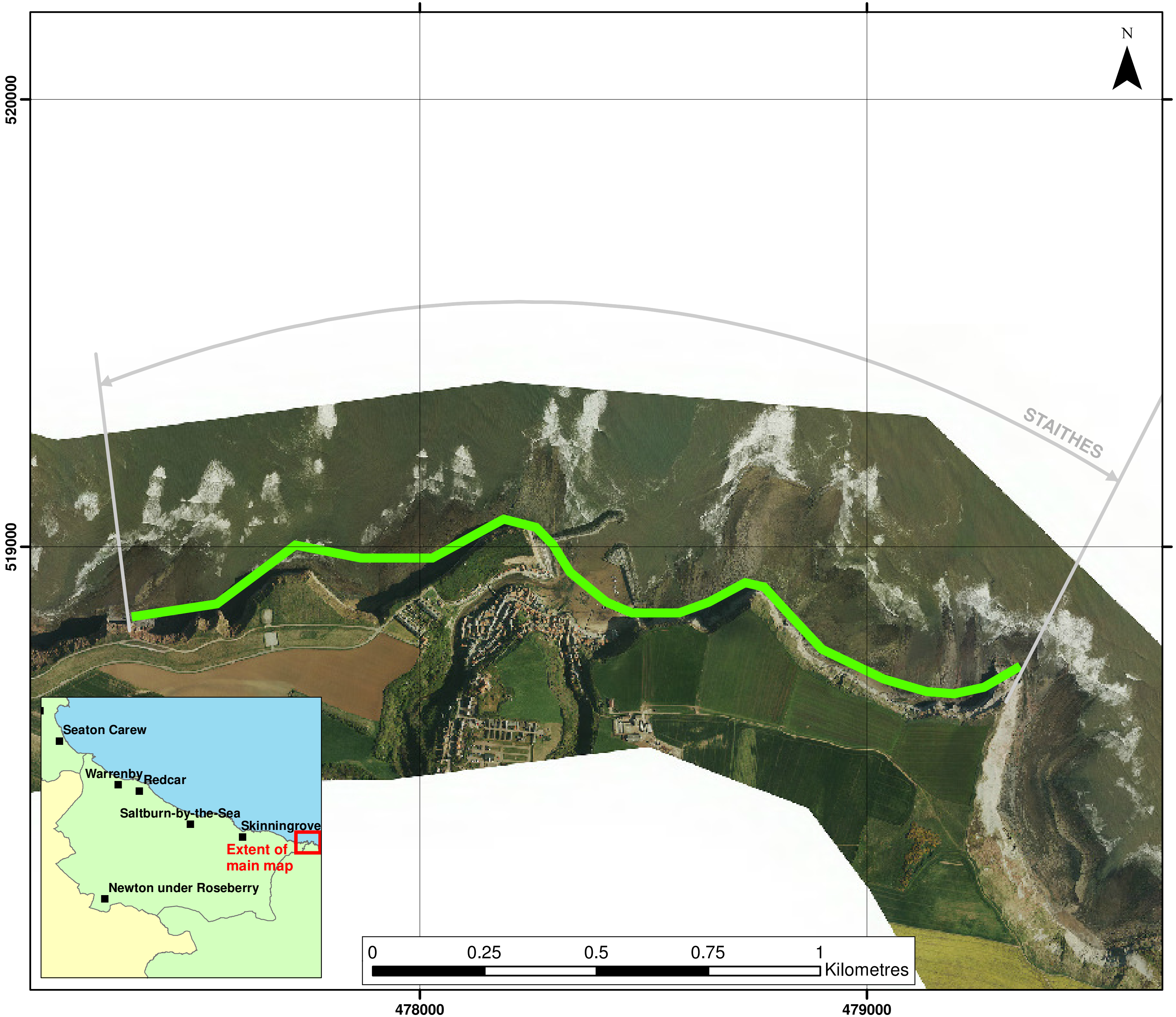

KEY

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 6
Survey Locations
Staithes
Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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www.northeastcoastalobservatory.org.uk

3. Analysis of Survey Data

3.1 Coatham Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
10th Oct 2013	**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, 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. At the toe of the dunes a foredune is forming, which was in place in the March and October 2013 and has remained stable. At the HAT level the beach has eroded by 0.5m since March 2013. The reminder of the beach has kept a similar form and gradient since March 2013, but it has accreted by 0.1m over the summer. At Profile **1cRC2** the beach and dunes are high compared to the profiles recorded since 2008. The seaward face of the dunes above HAT appears to have accreted by around 0.1m since March 2013. Overall the beach has accreted and formed two berms, whereas in March 2013 there was only one berm. From the HAT level at around 80m to 180m the beach has accreted by 0.2m. From 180m to 240m chainage the beach has accreted by 0.5m since between March and October 2013. The beach has eroded by 0.8m between 240m and 280m chainage. From 280m to the end of the survey at 340m chainage the beach has accreted by around 1m, forming a berm on the lower shore. Profile **1cRC3** had a reasonably stable dune area, the foredune had accreted by 0.4m since March 2013. Overall the beach had remained stable, with one berm forming where there had been two berms previously. From 60m chainage (above HAT) to 170m chainage the beach has accreted by around 0.1m over the summer of 2013. Between 170m and 210m chainage the beach accreted by 0.6m between March and October 2013. From 210m to 250m the beach had accreted by 0.4m. Between 250m chainage and the end of the survey the October beach level drops below the March 2013 level. Profile **1cRC4** is the beginning of the defended section. There has been little change recorded along the	Accretion of the foredune has been observed in profiles RC1, 2 and 3, which shows the continuing health of the dune system at Coatham. At profiles RC1 and 4 the shape of the beach has remained stable overall with a slight change of less than ±0.2m since March 2013 Profiles RC 2 and 3 had stable mid and upper beaches with the main changes being due to the movement of berms on the lower beach. Overall the October 2013 profiles are within the previous range of profiles, which the exception of lower beach areas that have tended to accrete berms. The topographic change plot shows the northern quarter of the frontage the recorded changes were dominated by a band of up to 2m of accretion on the lower beach and up to 1m of erosion on the upper beach. The centre of the bay had bands of accretion and erosion. There was a particularly noticeable band of erosion seaward of the promontory in the northern third of the frontage. This pattern reflects migration of berms. The southern quarter of the bay had been subject to more widespread erosion with a maximum of 1m loss being recorded at the seaward extent of the survey.

Survey Date	Description of Changes Since Last Survey	Interpretation
	whole of the profile. Although it has flattened to some extent with 0.1m of erosion since March 2013 between 45m and 85m chainage. Between 100m and 350m chainage the beach has accreted by up to 0.2m over the summer of 2013.	**Longer term trends**: The 2012 Full Measures topographic change plots showed modest accretion. The 2013 plots show erosion throughout the frontage, particularly in the southern third of the frontage. The promontory in the northern third of the frontage has continued to erode through 2013, continuing the pattern seen since 2011. Between 2011 and 2013 the southern two-thirds of the bay have been subject to limited change associated with migration of beach berms. **Autumn 2008 to Autumn 2013 trends** The long term plots show there have been three areas that display consistent patterns over the last five years. In the north of the bay near the breakwater there the foreshore has accreted to form a stable crescent-shaped bay. The accretion observed in this location is the single largest, consistent change on this frontage. The central third of the bay has accreted by 0.5m overall although there is a shore-parallel band of erosion in the central beach, probably reflecting the effects of berm migration. The southern third of the bay is dominated by erosion of around 0.5m. The area of most severe erosion was 1m of loss at the seaward extent of the survey. This pattern suggests a net movement of sediment in the bay towards the north.
	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 GIS. This shows that the beach contours recorded in Winter 2013 were relatively consistent across the frontage, with a gently shelving beach slope. The beach is narrower and steeper in the north, close to the breakwater. The GIS has also been used to calculate the differences between the current topographic (Autumn 2013) survey and the earlier topographic survey (Autumn 2012), as shown in Appendix B – Map 1b, to identify areas of erosion and accretion. The topographic difference plots show erosion overall, with many places loosing up to 1m of material over 2013. There are patches of accretion on the seaward extent of the survey in the northern half of the bay. The largest observed changes are a series of shore parallel patches of accretion and erosion in the north of the study area close to the breakwater. Between Winter 2011 and Winter 2012 the elevation changes were modest, within ±0.2m across most of the frontage. This trend was reversed between 2012 and 2013 where erosion was dominant. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The long term difference plot (Appendix B – Map 1c) shows three distinct areas of behaviour on this frontage. The northern area close to the South Gare Breakwater has had erosion of up to 1m on the upper beach close to the shore and up to 2m of accretion down the beach. The remaining areas of the frontage are more stable, with more modest changes. The middle part of the bay has accreted by up to 0.5m, with the exception of a shore parallel band of erosion in the centre of the beach. The southern third has eroded by 0.5m in most areas, but up to 1m loss was recorded at the seaward extent.	

3.2 Redcar Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
10th Oct 2013	**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. The upper part of the profile at RC5 and RC6 have changed significantly following construction of new coastal defences.  The new defence at Profile RC6. At profile **1cRC5** the new, higher defence is shown in the March and October 2013 profiles, as a result there is little change in the profile above MHWS. Overall the October 2013 profile is steeper than the March 2013 profile. From 15m chainage to 40m chainage the beach has accreted by 0.4m. The beach has remained stable between 40m and 100m chainage. From 100m chainage to 200m chainage the beach has eroded by up to 0.4m, exposing the foreshore rock platform. From 200m to the end of the	Profile RC5 was steep and when compared to the previous surveys the beach level is high on the upper beach and low on the lower beach to the point where the rocks were fully exposed. The lower beach was also comparatively low at RC6. At RC7 the berms are much larger than any similar features in the previous surveys dating back to 2008. The topographic change plots support the pattern of localised changes to beach berms shown in the beach profiles. There was accretion overall although the north-east facing part of the frontage had a patchy distribution of accretion and erosion. **Longer term trends**: The construction of a new defence means that this 2012 Full Measures Report will act as a new baseline for the behaviour of the beach in front of the defence. The overall observed pattern is an uneven distribution of erosion and accretion, which is likely to be due to the redistribution of sediment across the beach. **Autumn 2008 to Autumn 2013 trends** The plot of long term net change between Autumn 2008 and Autumn 2013 shows erosion pattern of erosion of up to 1m in the central part of frontage which highlights the needs for the coastal defences. The eastern part of the frontage shows more

Survey Date	Description of Changes Since Last Survey	Interpretation
	survey at 230m chainage the beach has eroded by 0.2m At profile **1cRC6** the new defence has been included in the profile in March and October 2013, as a result there is little change in the profile above HAT. Between 70m chainage and 180m chainage there is very little difference in beach level between March and October 2013. From 180m to 270m chainage the beach has accreted by 0.3m. Beyond 270m the beach has eroded by 0.2m. Profile **1cRC7** experienced no changes on the section above MHWS between March and October 2013. Below MHWS the beach accreted two large berms with the dip in the middle reaching close to the March 2013 beach level. From 80m to 140m chainage the beach had accreted by 0.6m. From 140m to 170m there was little change. The second bund formed between 170m and the end of the survey at 300m chainage, which had accreted by 0.8m over the summer of 2013.	widespread accretion of up to 1m. This may relate to the defence improvements introducing a less reflective seawall and improvements and repairs to the groynes in this area. It is not possible to determine the net drift direction from the available data.
	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 GIS. The plot shows shore-parallel contours for most of the frontage with the exception of the beach in front of Redcar, where a bay is shown between the Redcar Rocks and West Scar outcrops. The most landward part of this embayment is close to Redcar Esplanade, which is therefore fronted by a steep beach. This is where the coastal defence scheme has been constructed between the October 2012 and March 2013 surveys. The GIS has also been used to calculate the differences between the current topographic survey (Autumn 2013) and the most recent (Spring 2013) topographic survey, as shown in Appendix B – Map 2b, to identify areas of erosion and accretion. Over the summer of 2013 there was no clear pattern of change. The western section of the frontage that faces north was stable with most changes within a range of ±0.25m. The central section of the beach, which faces NE, had more notable changes with accretion of around 0.5m at the toe of the defences. There was erosion of up to 0.75m at the seaward extent of the survey and particularly over the rock outcrops. The eastern part of the frontage, which faces ENE, has accreted overall. There is limited erosion in the form of a shore parallel bar in the centre of the beach. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The plot of changes between Autumn 2008 and Autumn 2013 (Appendix B Map 2c) shows a variable	

Survey Date	Description of Changes Since Last Survey	Interpretation
	distribution of net erosion and accretion, but with a similar pattern to that seen over the most recent monitoring period. In the western section has experienced modest accretion of around 0.5m. The central third of the frontage between Redcar Rocks and West Scar has equal areas of erosion and accretion of ±1m. The eastern section has experienced widespread accretion. Erosion of up to 1m has occurred on where the rocks meet the shoreline, but this probably reflects loss of transient sand cover present shortly before the baseline survey. The southern third of the frontage is dominated by accretion of up to 1m, with only limited erosion at the back of the beach.	

3.3 Marske Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
10th Oct 2013	**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 3.2. Overall, profile **1cRC8** has stayed stable above the HAT level since 2008. The general trend through the summer of 2013 is that the beach profile has become steeper and more even, with no berms present. From 65m to 140m chainage the beach has accreted by 0.5m. Between 140m and 200m change the beach has remained reasonably stable, only changing by 0.2m. From 200m chainage to the end of the survey at 290m chainage the beach has eroded by around 1m. **Topographic Survey:** Marske Sands is covered by an annual topographic survey. This survey is contiguous with the Redcar Sands and Saltburn Sands topographic surveys which are both surveyed six-monthly. Data have been used to create a DGM (Appendix B – Map 3a) using GIS. The GIS has also been used to calculate the differences between the Autumn 2012 and Autumn 2013 topographic survey, as shown in Appendix B – Map 3b, to identify areas of erosion and accretion. Since the previous topographic survey in Autumn 2012 the upper-most section of beach has accreted by up to 1m, and there are patches are accretion in the west, towards Redcar Sands. In contrast, the majority of the central and lower beach has eroded by up to 1m, with over 1m of erosion observed in patches in the middle of the frontage. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The changes observed over the five years shown in Appendix B – Map 3c show a similar pattern to that seen over the past 12 months. The majority of the upper beach and much of the western part of the frontage have accreted by up to 1m, while the eastern part of the frontage has eroded by up to 1m.	The beach profiles for Marske Sands are slightly beyond the normal range of results. Profile RC7 had two large berms which were higher than previous profiles. Profile RC8 was the steepest profile recorded. The upper beach was one of the highest profiles recorded and the lowest beach was the lowest recorded by a margin of 0.5m. The difference plot for Autumn 2012 to Autumn 2013 shows accretion on the upper beach and erosion on the lower beach, which reflects the behaviour observed in the profiles. **Longer term trends**: In 2012 the difference plots showed modest change in shore-parallel bars, reflecting migration of berms. **Autumn 2008 to Autumn 2013 trends** The long term difference plots show a similar pattern and magnitude of change as that indicated over the last 12 months, with consistent accretion in the upper beach and on the western foreshore, and erosion in the lower beach. The fact that net change since 2008 is similar to that observed over the past year suggests significant seasonal variation about a more subtle underlying trend. The underlying trend is likely to involve sediment inputs from cliff recession locally, or up-drift, and net movement of material from east to west (i.e. towards the north).

3.4 Saltburn Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
10th Oct 2013	**Beach Profiles:** Saltburn Sands is covered by one beach profile during the Full Measures survey (RC9; Appendix A). Profile **1cRC9** was reasonably stable between 0m and 30m chainage over the summer of 2013. The rest of the profile had eroded by around 0.2 along most of its length. The maximum recorded change was 0.6m close to the end of the profile. **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 GIS software package. This shows that the beach contours are shore parallel and gently shelving for the majority of the frontage. The contours are indented opposite Skelton Beck, which indicates the erosion of a channel across the beach. The GIS has also been used to calculate the differences over the six month period between Spring 2013 and Autumn 2013 topographic survey, as shown in Appendix B – Map 4b, to identify areas of net erosion and accretion. During the six months covered by the plot there was a small amount of accretion on the upper beach and in the east towards the margin of the bay, and more widespread erosion on the lower beach. West of the mouth of Skelton Beck the frontage is more dominated by erosion of around 1m with limited accretion of up to 0.5m at the base of the cliffs. East of Skelton Beck the upper half of the beach accreted by up to 0.5m, while the lower half has eroded by around 0.25m. The channel of Skelton Beck across the beach was an area of modest erosion. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The plot of the change over the last five years (Appendix B – Map 4c) shows a similar pattern to that observed over the last 12 months, but with greater net change. West of the mouth of Skelton Beck almost the entire frontage has eroded by up to 1m, with only very small areas of accretion at the base of the cliffs. East of the mouth of the beck the beach has accreted by up to 0.75m, with localised patches	The beach has eroded between March and October 2013. The October 2013 beach level was the lowest recorded profile since 2008 apart from on the mid and upper beach. The difference plot for 2013 show net accretion on the upper beach and erosion on the lower beach. The stream has been eroding through the summer of 2013, this is likely to be due to the scour at the mouth of the stream outweighing any accretionary process acting on the beach. **Longer term trends**: A comparison of the 2013 difference plots with those observed in 2012 shows that while the last 12 months showed erosion of the upper beach and accretion on the lower beach, the previous 12 months showed the reverse of this pattern. The long-term pattern (see below) is similar to that seen in 2013, suggesting the changes in 2012 were caused by atypical conditions. **Autumn 2008 to Autumn 2013 trends** The frontage has eroded west of Skelton Beak and accreted to the east, at the margins of the bay. The behaviour to the west of the beck is similar to the rest of the Marske/Redcar beach system that has experienced net loss of sediment. This pattern may indicate net movement of sediment to the north, in the area west of the beck, and accumulation of material at the margin of the bay due to the effects of wave

Survey Date	Description of Changes Since Last Survey	Interpretation
	of erosion at the base of the cliffs.	refraction. The long-term data also indicate most cliff erosion in the eastern area, which may have contributed to accumulation of sediment on the adjacent beach.

3.5 Cattersty Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
4th November 2013	**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 GIS package. The beach is steeper to the west of the breakwater than the east, but in both areas the gradient is uniform with no mounds or depressions. East of the breakwater the beach is punctuated by Kilton Beck and the harbour so the gradient is shallower. The stream has cut a channel, which is most deeply incised at its landward extent. The GIS has also been used to calculate the differences between Spring 2013 and Autumn 2013 topographic survey DGM (as shown in Appendix B – Map 5b), to identify areas of net erosion and accretion. The difference plot shows that west of the breakwater the majority of the beach has accreted by around 0.5m with erosion recorded at MLW, in a series of linear strips and adjacent to the breakwater. East of the breakwater the distribution of change is more complex, with erosion of around 0.5m dominating the centre of the beach and accretion immediately east of the breakwater and at the back of the beach. The clear pattern of different changes on either side of the breakwater has been seen in 2012 and 2013 surveys. The beach has varied significantly around the mouth of Kilton Beck in previous surveys, but this is not apparent in 2013. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The Autumn 2008 to Autumn 2013 plot (Appendix B – Map 5c) of elevation difference shows a similar pattern of change to that seen over the past year, but greater magnitude of change. West of the breakwater, erosion is prevalent and the back of the beach has lowered by over 1m. East of the breakwater accretion is more common, with gains of up to 1m at some parts of the shoreline. This area also has some significant areas of erosion, with 0.75m lowering at parts of the shoreline, at the beck, and over the rocks in the east of the survey area.	The difference model shows Cattersty Sands to be a dynamic area, influenced by both coastal and fluvial processes and the breakwater. In the plot of change over the summer of 2013 there is a marked difference in beach behaviour on either side of the breakwater. The east side, which includes with Kilton Beck, had equal areas of accretion and erosion. West of the breakwater the beach was dominated by accretion. **Longer term trends**: The change plots from the Full Measures Survey 2012 and 2013 show that the erosion on the rocky parts of the beach at the seaward extent of the survey continued. It is possible that this represents long-term down-wearing of the rocky shore platform, but is more likely to indicate removal of mobile sand cover. **Autumn 2008 to Autumn 2013 trends** The difference plot from the previous five years clearly highlights the differences on either side of the breakwater, with the west side showing erosion overall, particularly at the base of the cliff where over 1m has been lost, and the east side showing areas of accretion and erosion with no clear spatial pattern.

3.6 Staithes

Survey Date	Description of Changes Since Last Survey	Interpretation
October 2013	**Cliff-top Survey:** Twenty ground control points have been established at Cowbar and Staithes for biannual cliff top monitoring. Locations 1 to 11 are in the Redcar and Cleveland area. 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. Between April 2013 and October 2013 sixteen of the twenty posts showed change within a range of ±0.1m, which is not considered significant given the error of the technique. Two posts showed growth of the cliff, which is believed to be error caused by misidentification of the cliff edge. Posts 5 and 12 showed the largest erosion with 0.3m cliff recession recorded. Calculation of longer-term erosion rates based on the recorded change between 2008 and 2013 indicates that sixteen posts on the frontage recorded a change rate within a range of ±0.1m/yr, which is considered to be within the error of the measurement. Three of the remaining posts have positive rates, which is believed to be due to survey error. One post shows consistent erosion through the surveys, Post 13 (near the eastern breakwater) has a rate of 0.5m/yr. This pattern was very similar to that observed in the 2012 Full Measures Report. Appendix C provides results from the September 2013 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.	The majority of the Cowbar and Staithes frontage has remained stable over the summer of 2013. There was concern raised over the summer of 2012 due to numerous cliff falls on the eastern part of the bay, close to Point 13. However, that survey location recorded no change between April and October 2013. **Longer term trends**: Table C1 shows that survey location 13 has shown the greatest total erosion with a loss of 2.2m (±0.1m) between the November 2008 baseline and September 2012, resulting in a long term average recession rate of 0.5m/yr. This area is above the eastern breakwater, and is known to have experienced rock falls during 2013. Point 4, west of Cowbar Nab has shown activity in the past, but remained stable during 2013 resulting in a long-term rate of 0.1m/yr. The higher rates for these points are likely to be due to a small number of recent rockfalls that occur on an episodic basis. Given the relatively short monitoring period, this gives a comparatively high average recession rate.

4. Problems Encountered and Uncertainty in Analysis

There were no significant issues such as lack of access, or dense vegetation cover encountered during the surveys.

Individual Surveys

There were no noted errors in the October 2013 dataset. The construction of the coastal defence through part of the frontage means that the behaviour and volumes of the beaches pre and post construction can be compared.

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. Most locations monitored show no change, but location above the eastern breakwater, on Cowbar Nab and on the cliffs to the west show erosion rates of up to 0.5m/yr. This average rate reflects localised and episodic rock fall activity and may be misleading.

5. 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 six months, but previous surveys have had a low accuracy, meaning that survey error is typically greater than any measured short term change. It is likely that a more reliable pattern of change will be determined over the longer term. In addition, recent cliff recession data are available from the analysis of aerial survey data collected in 2010 and 2012-13 that was undertaken in 2013.

6. Conclusions and Areas of Concern

- At Coatham Sands the October 2013 profiles are within the previous range of profiles, which the exception of the areas which built out large beach berms on the lower beach. The topographic change plot shows in the northern quarter of the frontage the recorded changes were dominated by a band of up to 2m of accretion on the lower beach and up to 1m of erosion on the upper beach. The centre of the bay had bands of accretion and erosion. The southern quarter of the bay had been subject to erosion with a maximum of 1m loss being recorded at the seaward extent of the survey. There is no cause for concern

- For Redcar Sands the topographic change plots support the pattern of localised changes to beach berms shown in the beach profiles. There was accretion overall although the north-east facing part of the frontage had a patchy distribution of accretion and erosion. There is no cause for concern.

- At Marske Sands the 2013 beach profiles are slightly beyond the normal range of results. Profile RC7 had two large berms which were higher than previous profiles. Profile RC8 was the steepest profile recorded. The upper beach was one of the highest profiles recorded and the lowest beach was the lowest recorded by a margin of 0.5m. The difference plot for Autumn 2012 to Autumn 2013 shows accretion on the upper beach and erosion on the lower beach, which reflects the behaviour observed in the profiles.

- The beach at Saltburn Sands has eroded between March and October 2013. The October 2013 beach level was the lowest recorded profile since 2008 the mid and upper beach. The Full Measures difference plots for the summer of 2013 show accretion on the upper beach and erosion on the lower beach.

- The Cattersty Sands difference model shows that over the summer of 2013 there is a difference in beach behaviour on either side of the breakwater. The side with Kilton Beck had equal areas of accretion and erosion. West of the breakwater the beach was dominated by accretion.

- The measurements of the Cowbar and Staithes cliff top shows only localised areas of cliff recession, reflecting episodic rock fall activity. One point (to the east of the eastern breakwater) has eroded by 2.2m since November 2008, which is the maximum erosion observed for this frontage. A parallel study by Durham University is using terrestrial laser scanning to capture accurate data on changes on the Cowbar cliff face. These data have previously shown the cliff experiences a spatial and temporal average erosion rate of around 2mm/yr.

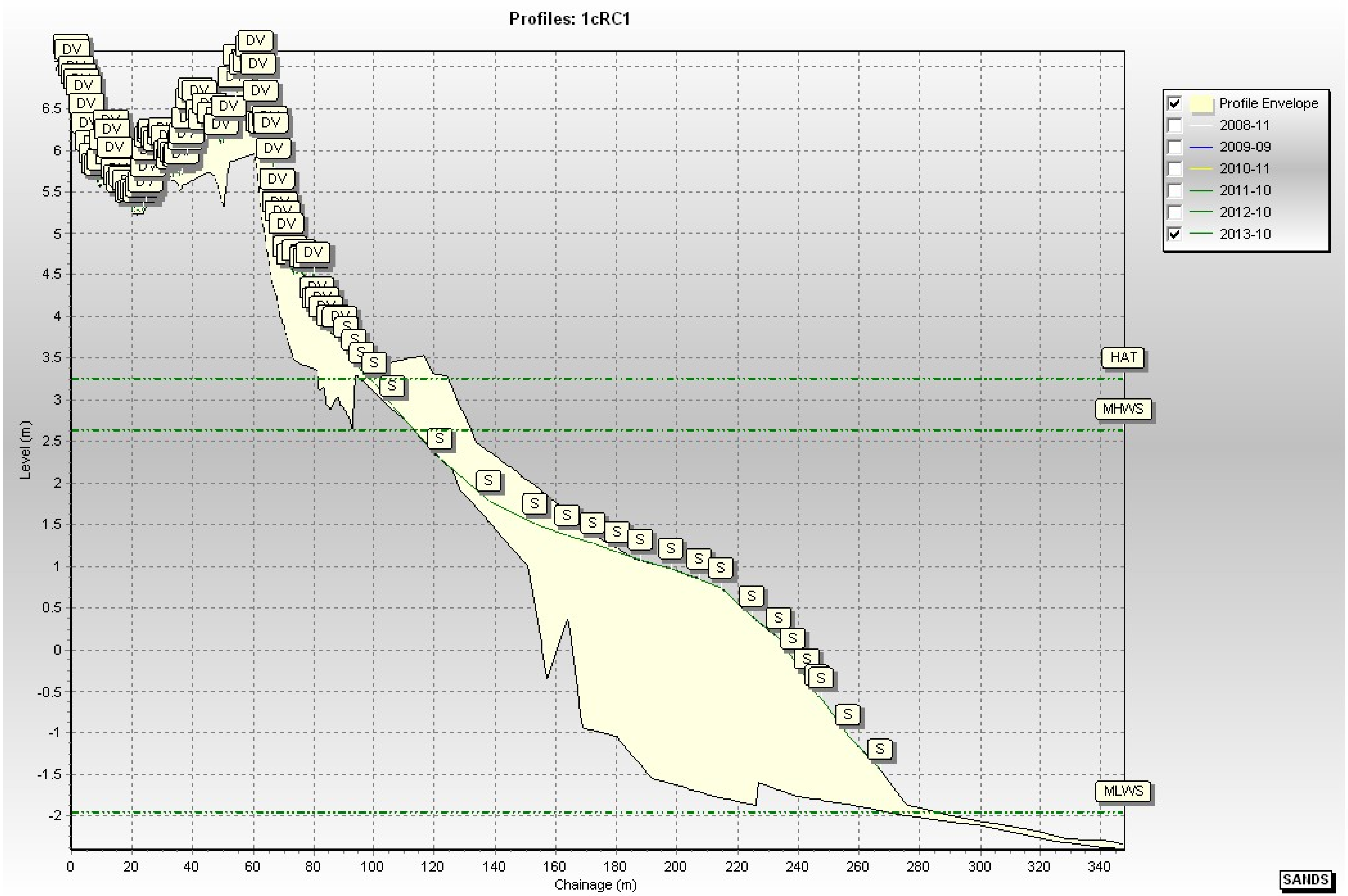
Appendices

Appendix A

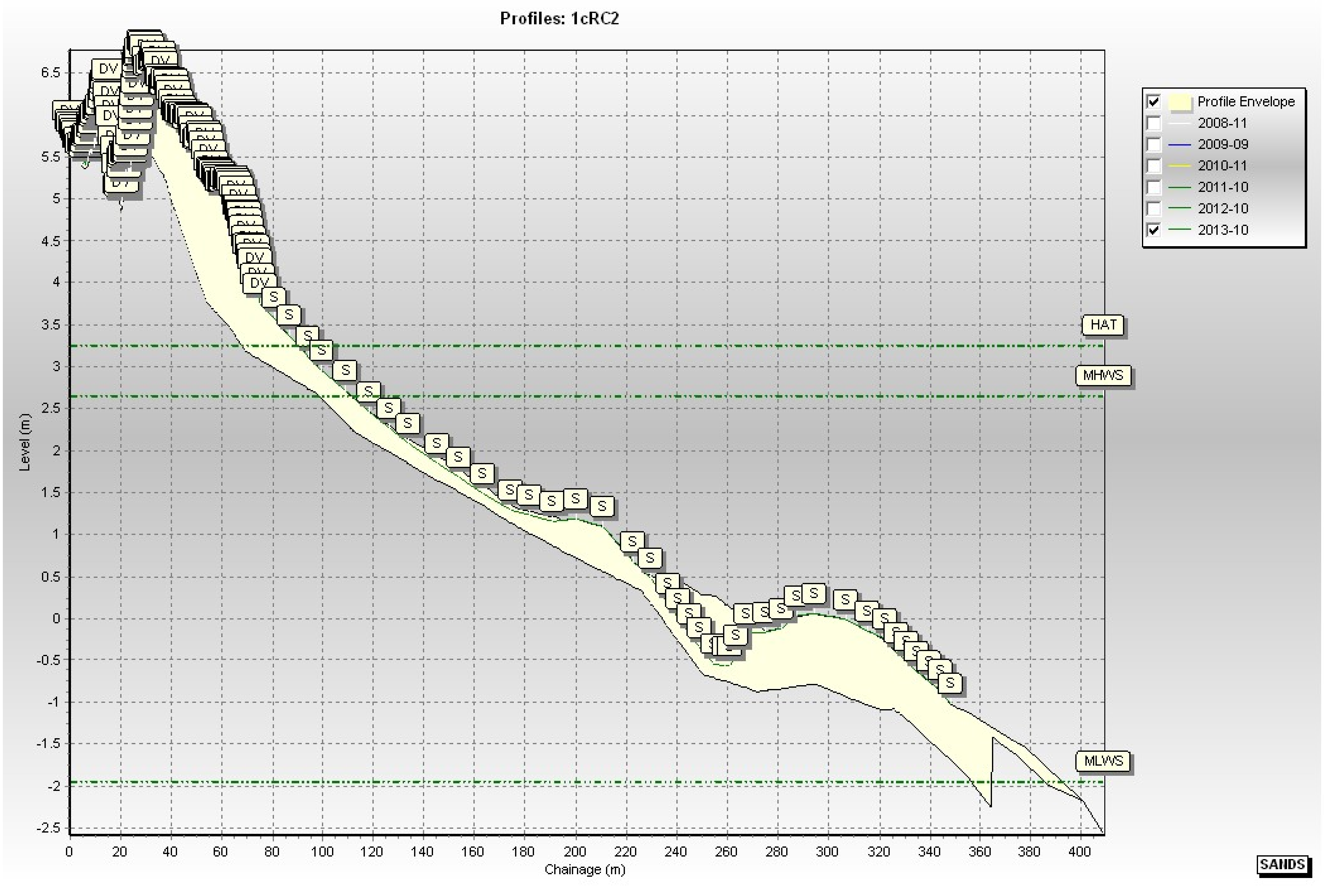
Beach Profiles

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

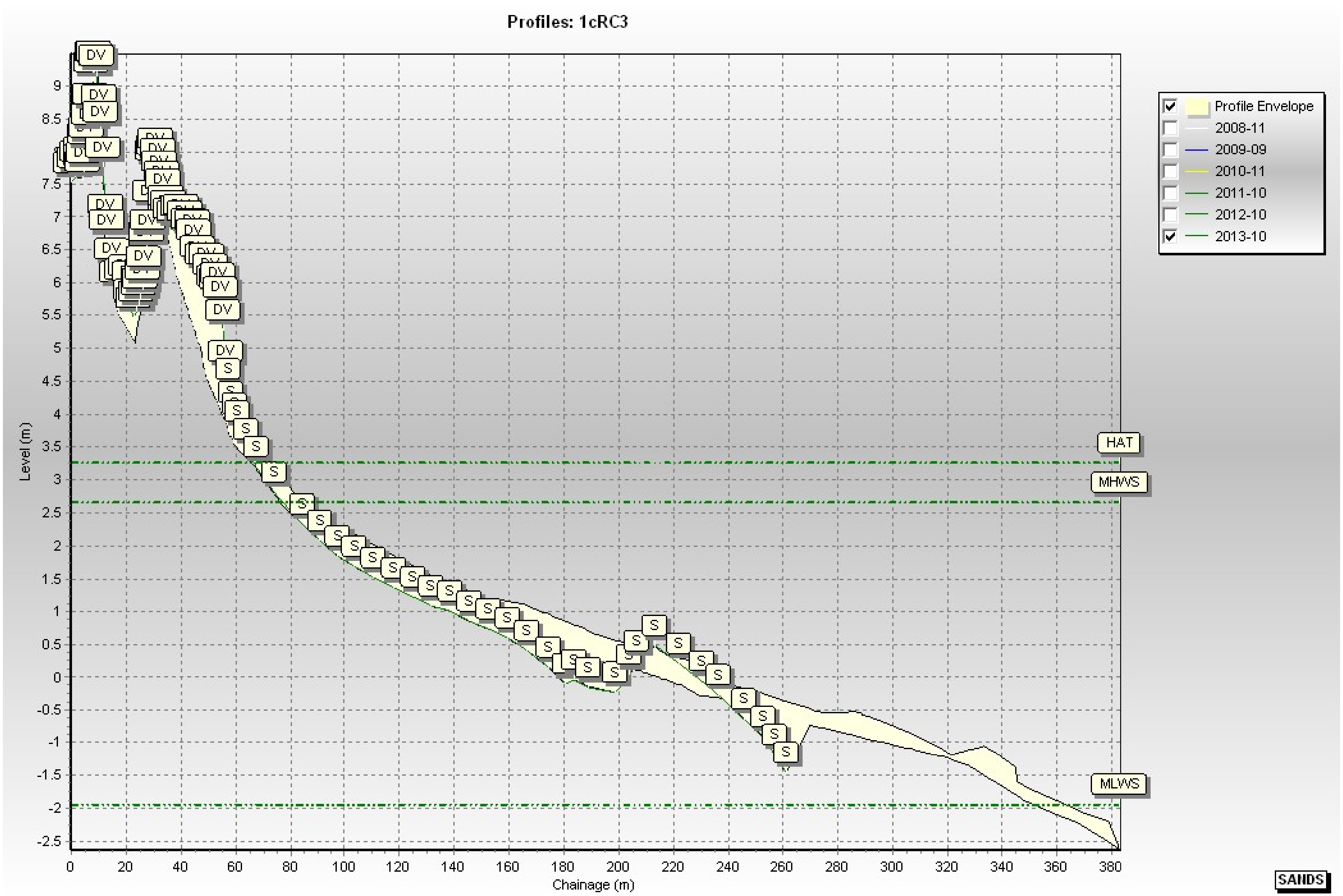
Code	Description
S	Sand
M	Mud
G	Gravel
GS	Gravel & Sand
MS	Mud & Sand
B	Boulders
R	Rock
SD	Sea Defence
SM	Saltmarsh
W	Water Body
GM	Gravel & Mud
GR	Grass
D	Dune (non-vegetated)
DV	Dune (vegetated)
F	Forested
X	Mixture
FB	Obstruction
CT	Cliff Top
CE	Cliff Edge
CF	Cliff Face
SH	Shell
ZZ	Unknown



Profiles: 1cRC1
Level (m)
Chainage (m)
Profile Envelope
2008-11
2009-09
2010-11
2011-10
2012-10
2013-10
HAT
MHWS
MLWS
SANDS



Profiles: 1cRC2
Profile Envelope
2008-11
2009-09
2010-11
2011-10
2012-10
2013-10
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS



Profiles: 1cRC3
Level (m)
Chainage (m)
Profile Envelope
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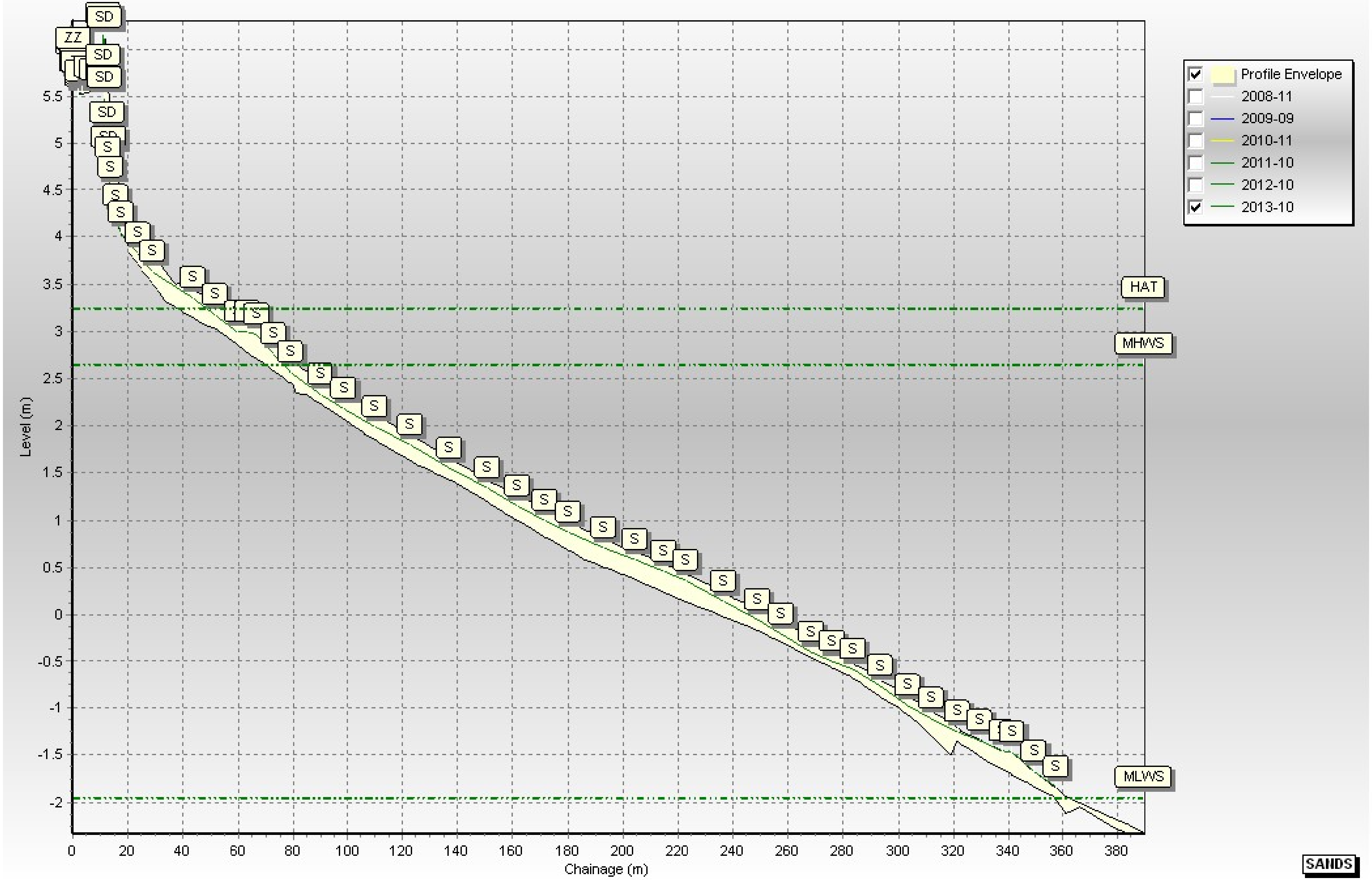
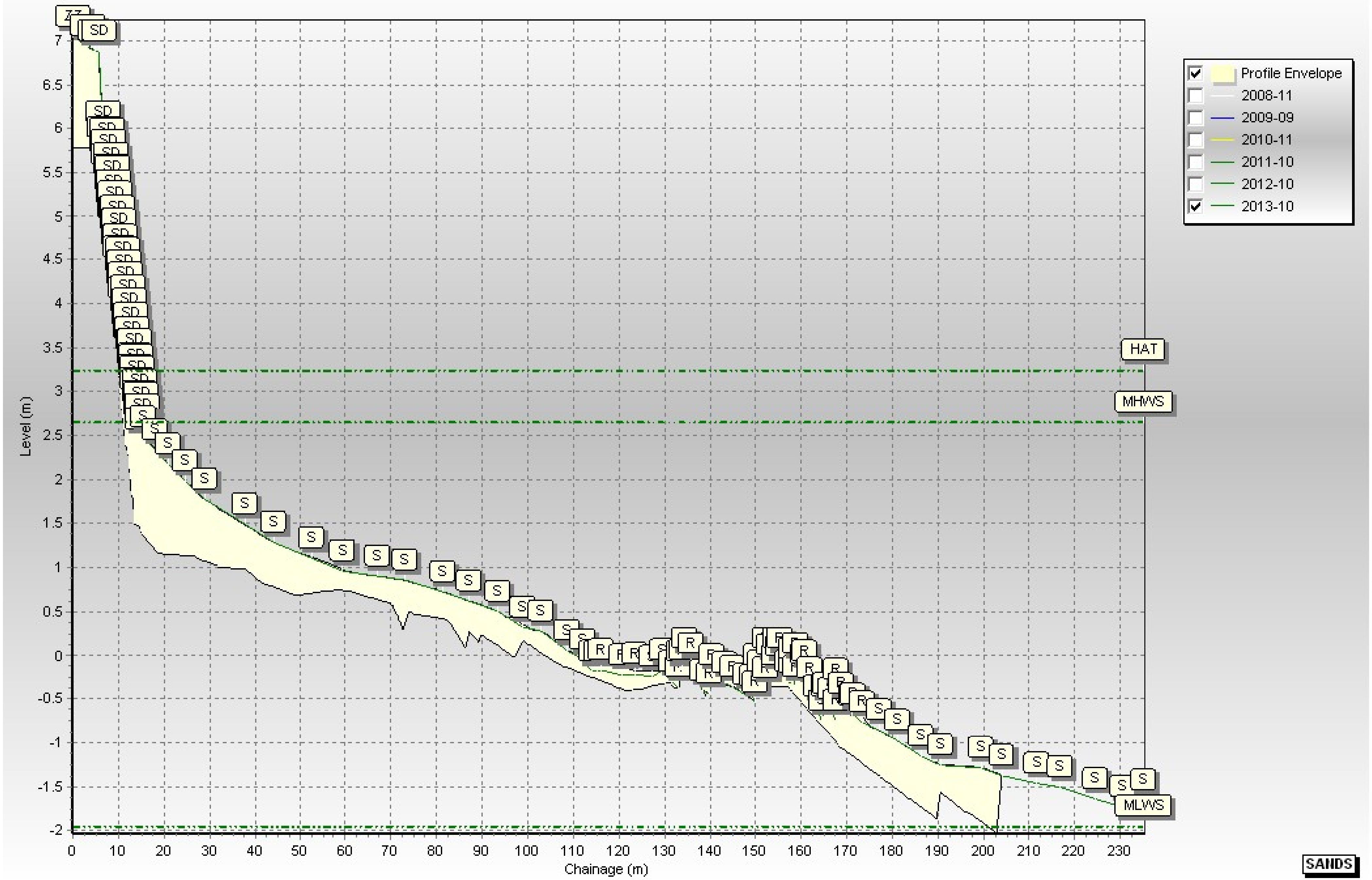
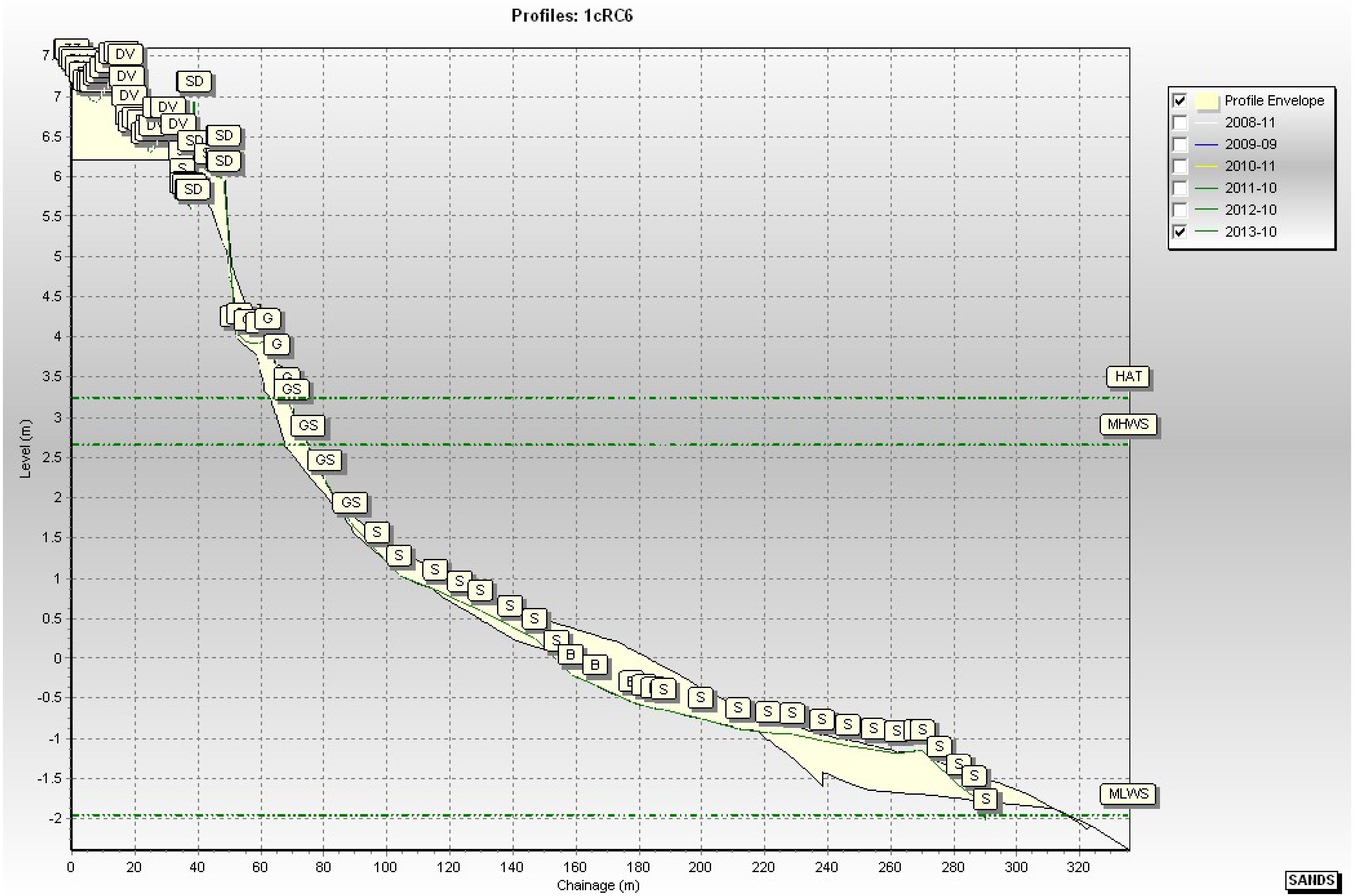
2009-09
2010-11
2011-10
2012-10
2013-10
HAT
MHWS
MLWS
DV
S
SANDS

Profiles: 1cRC4

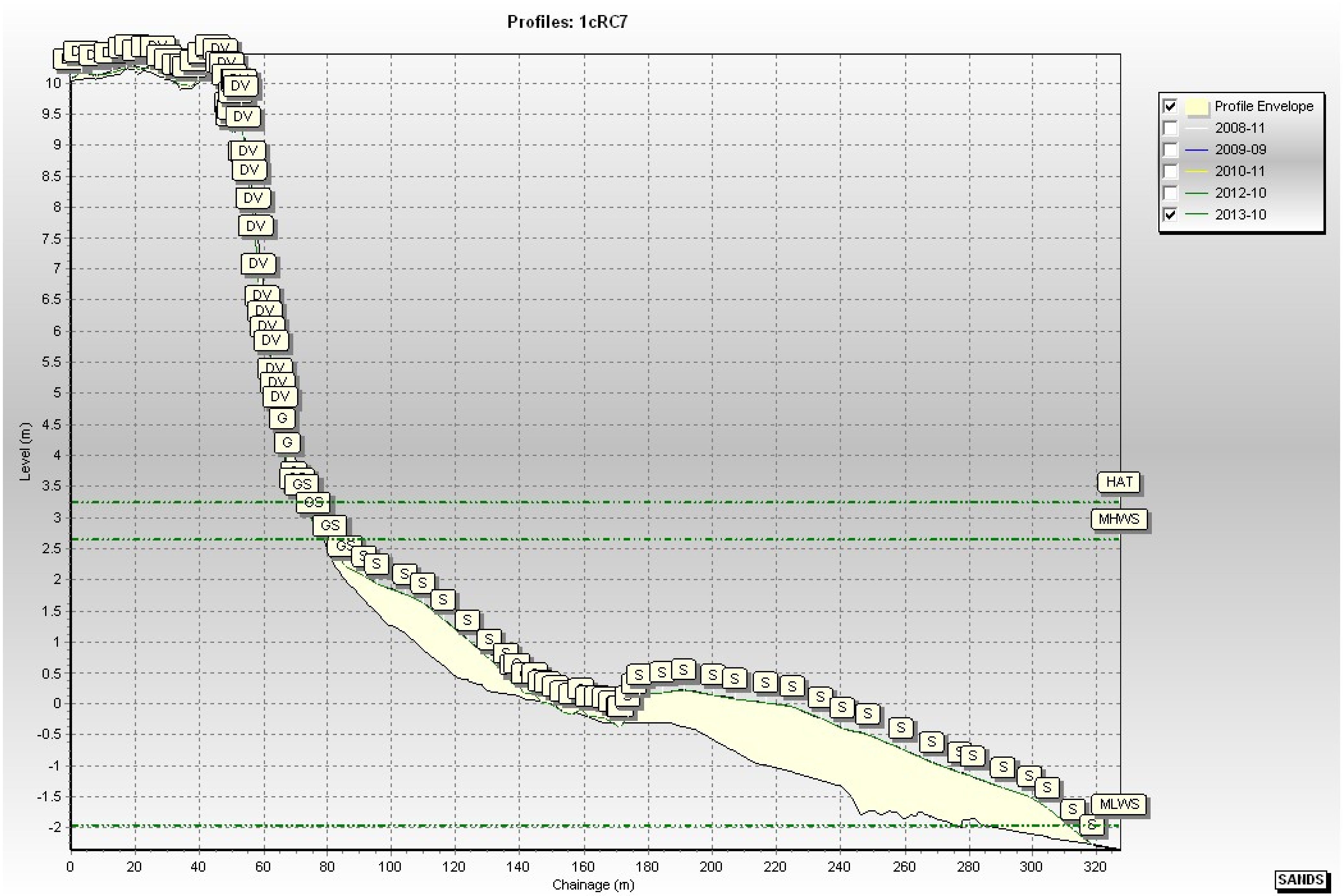


Profiles: 1cRC5

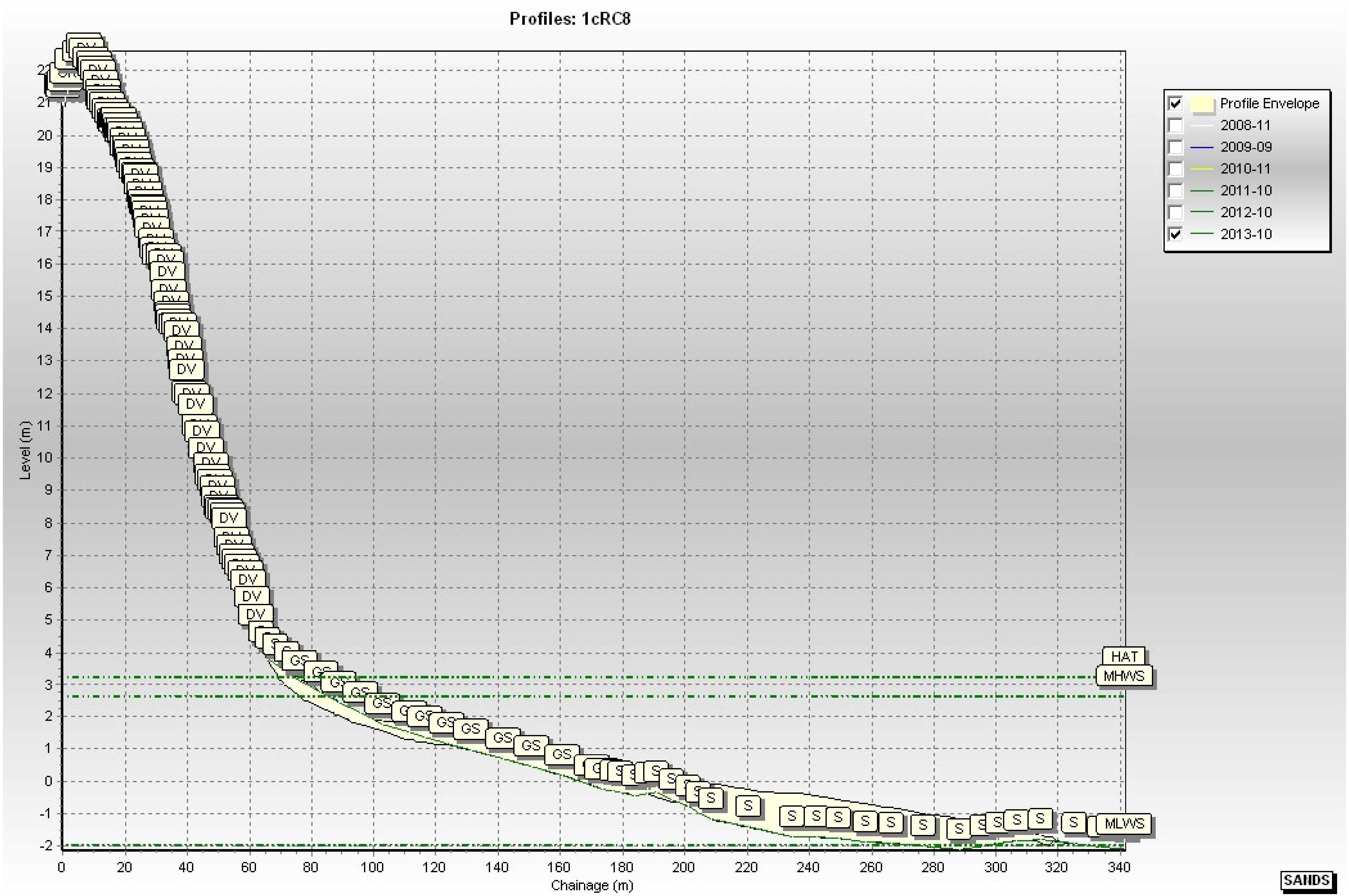


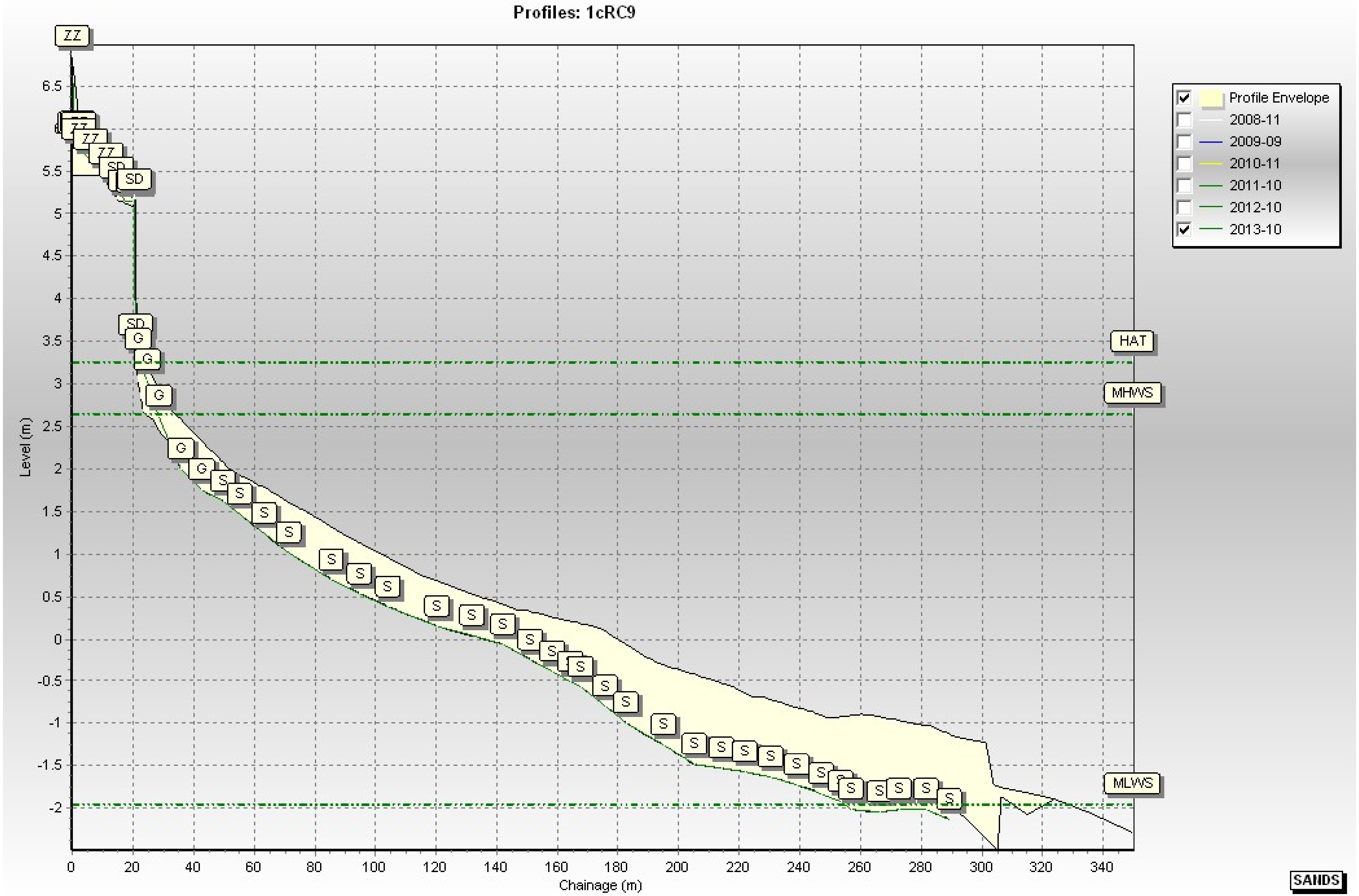


Profiles: 1cRC6
Profile Envelope
2008-11
2009-09
2010-11
2011-10
2012-10
2013-10
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS



Profiles: 1cRC7
Profile Envelope
2008-11
2009-09
2010-11
2012-10
2013-10
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS

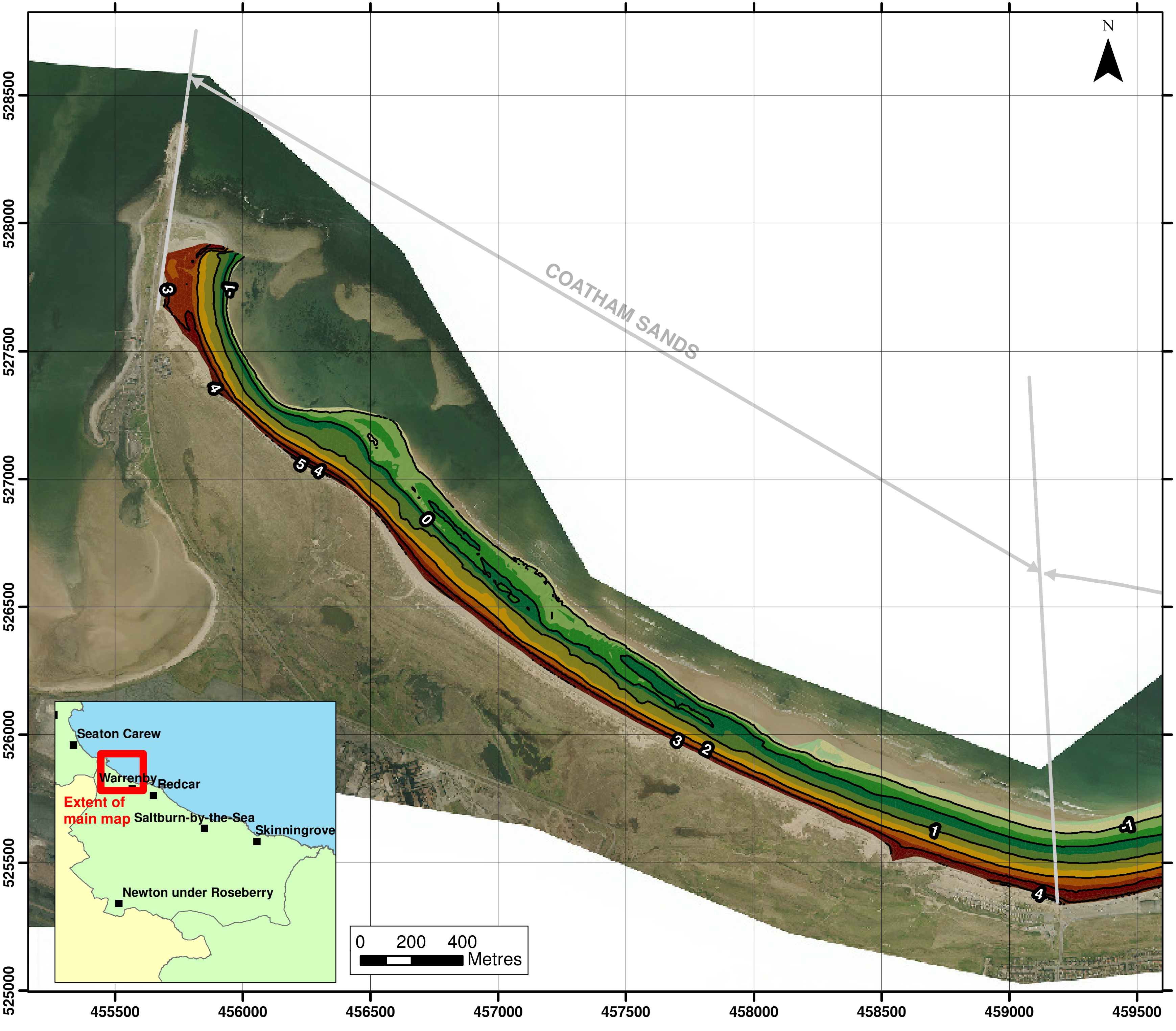

Profiles: 1cRC8
Level (m)
Chainage (m)
Profile Envelope
2008-11
2009-09
2010-11
2011-10
2012-10
2013-10
HAT
MHWS
MLWS
DV
GS
S
SANDS



Profiles: 1cRC9
Level (m)
Chainage (m)
HAT
MHWS
MLWS
Profile Envelope
2008-11
2009-09
2010-11
2011-10
2012-10
2013-10
SANDS

Appendix B

Topographic Survey



KEY

Elevation (m OD)

7.5 - 8
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 6
Full Measures Survey
Autumn 2013

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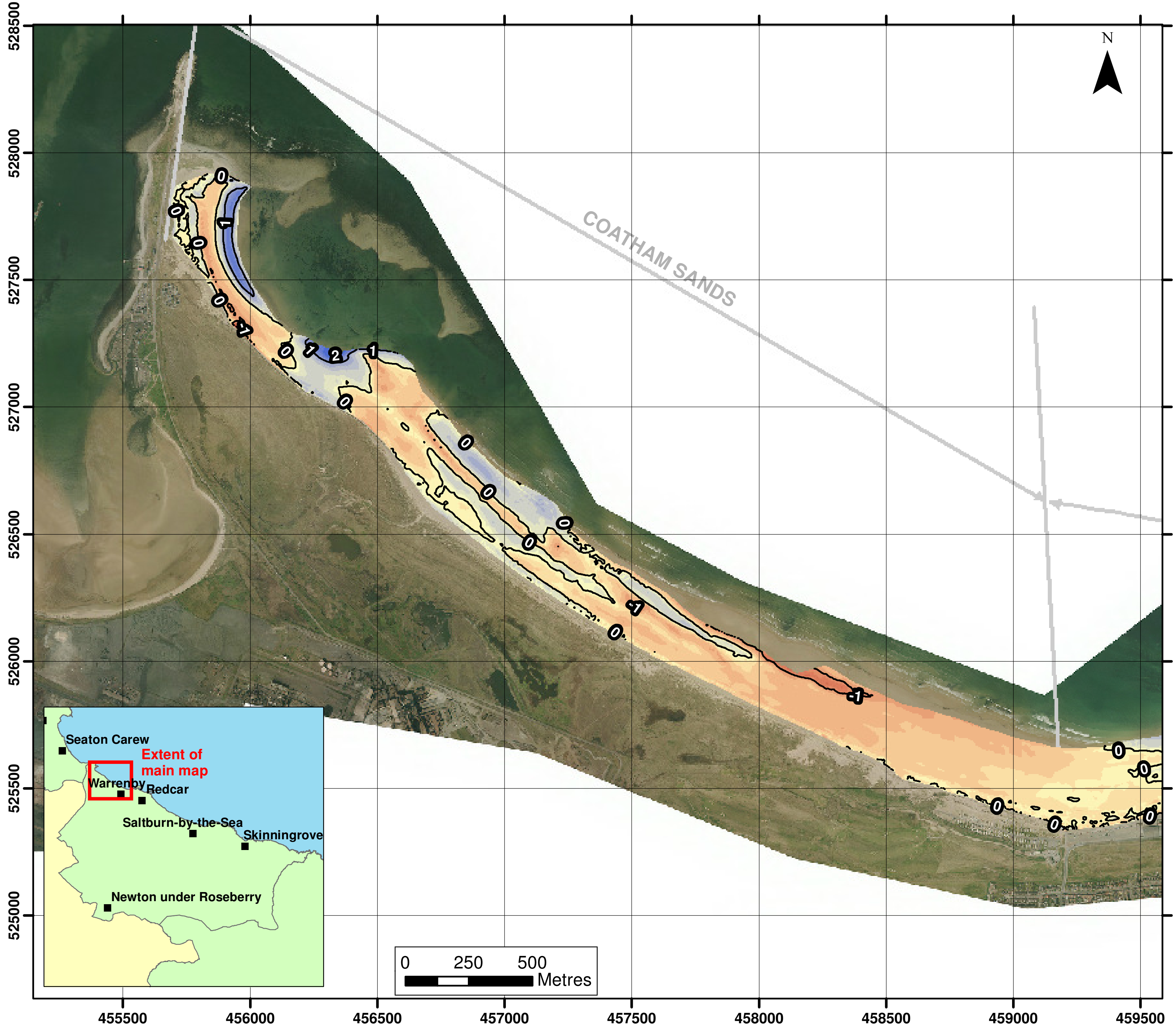

KEY **Autumn 2012 and Autumn 2013**
Change in elevation (m)

<-2
-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
0 - 0.1
0.1 - 0.25
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

Loss

Change < 0.1 m

Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1b
Short-term Elevation Change
Coatham Sands
Redcar & Cleveland Borough Council

Analytical Report 6
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Autumn 2013

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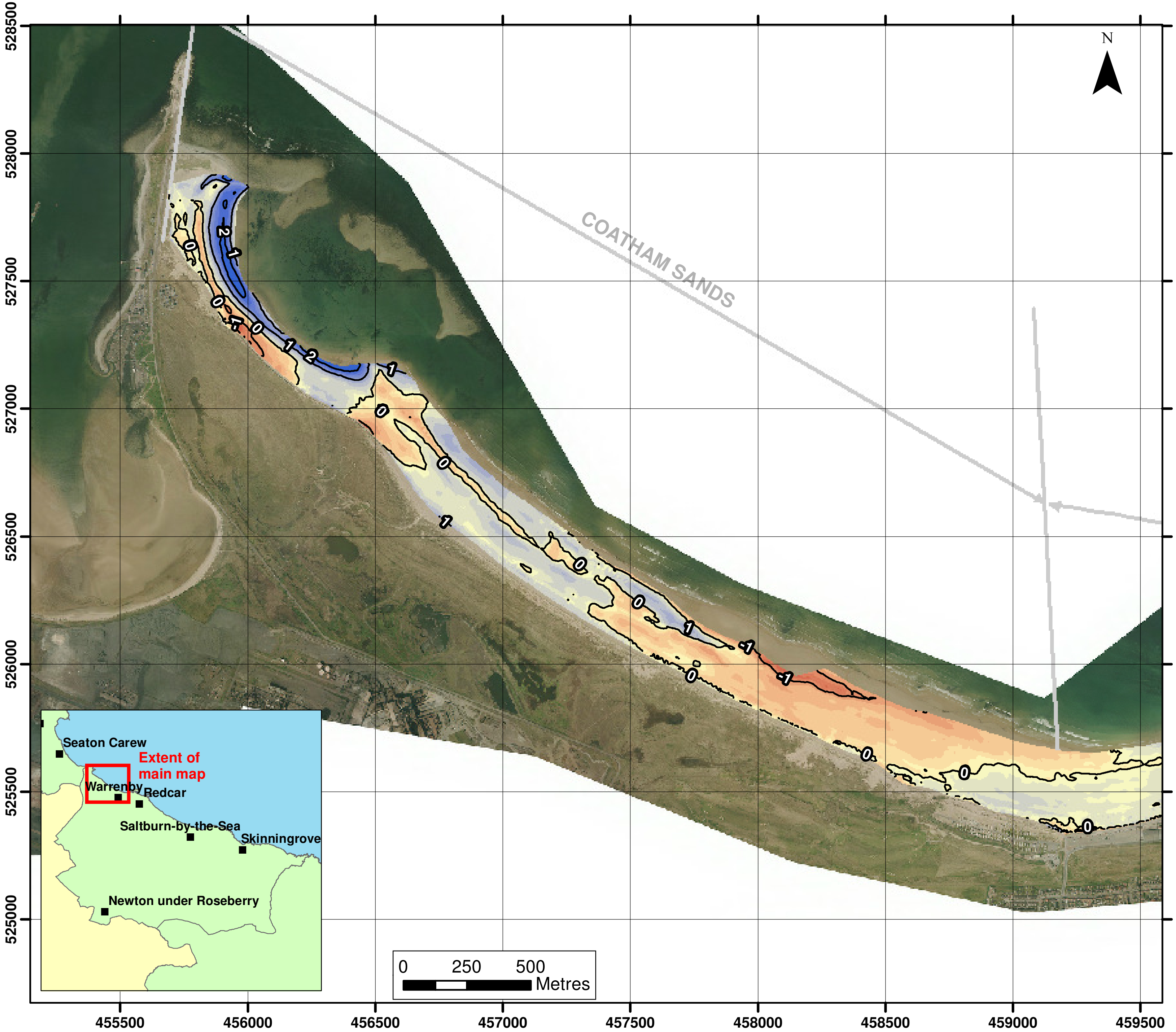

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

- <-2
- -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
- 0 - 0.1
- 0.1 - 0.25
- 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

Loss
Change < 0.1 m
Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1c
Long-term Elevation Change Coatham Sands Redcar & Cleveland Borough Council

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Autumn 2013

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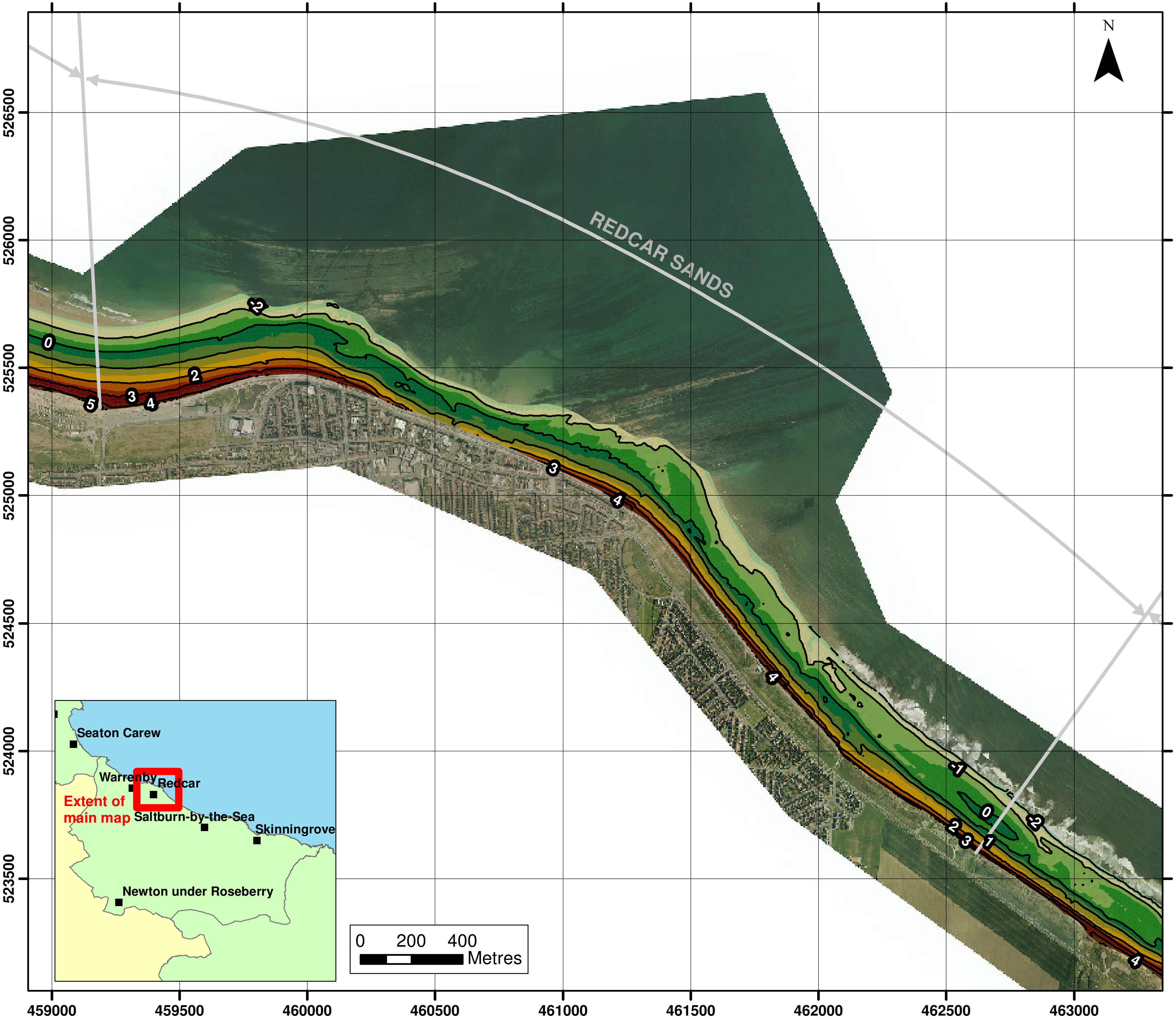

KEY

Elevation (m OD)

- 7.5 - 8
- 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
- -2.89 - -2.5
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

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

Analytical Report 6
Full Measures Survey
Autumn 2013

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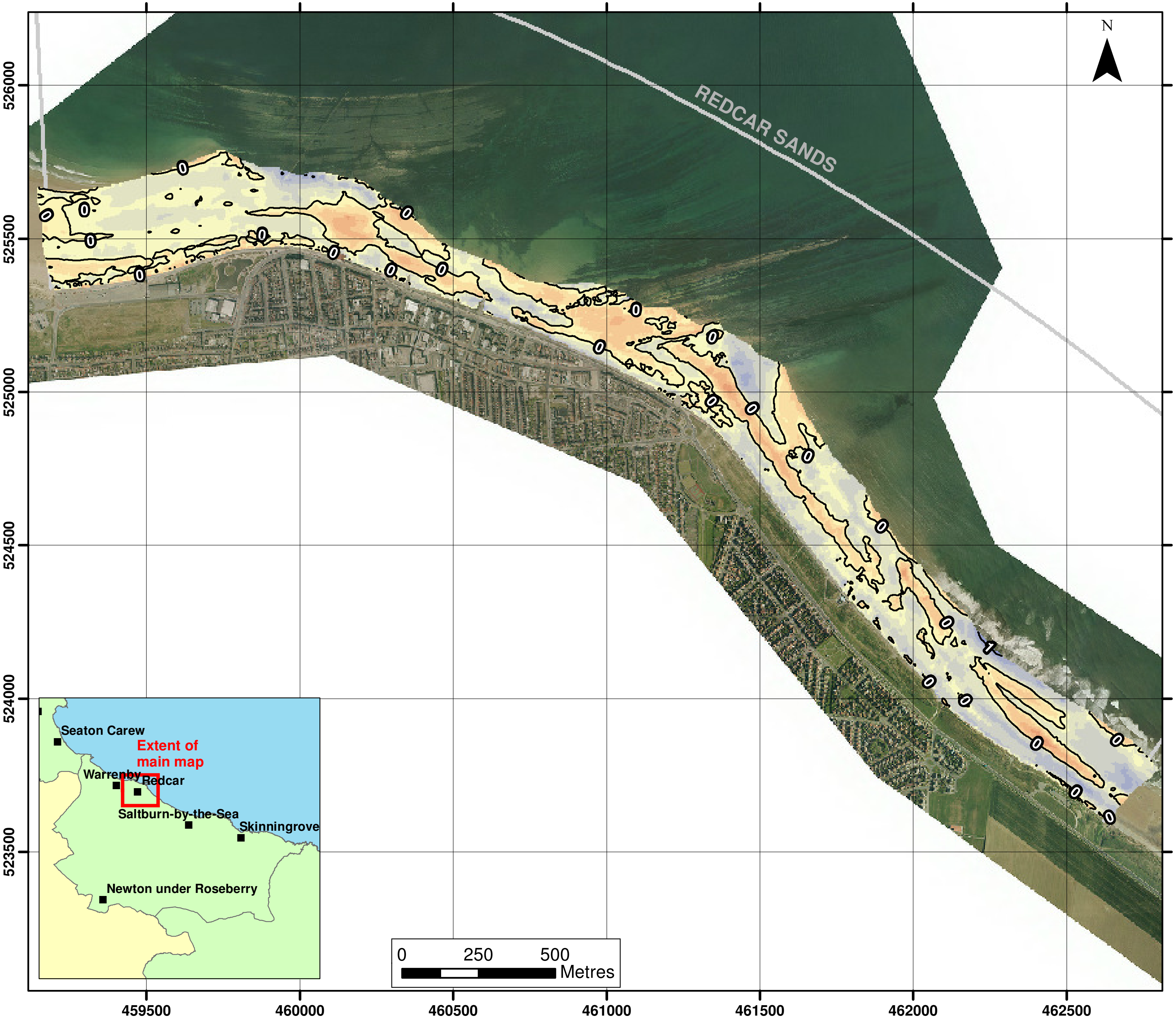

KEY Spring 2013 and Autumn 2013
Change in elevation (m)

<-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	

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 2b
Short-term Elevation Change Redcar Sands Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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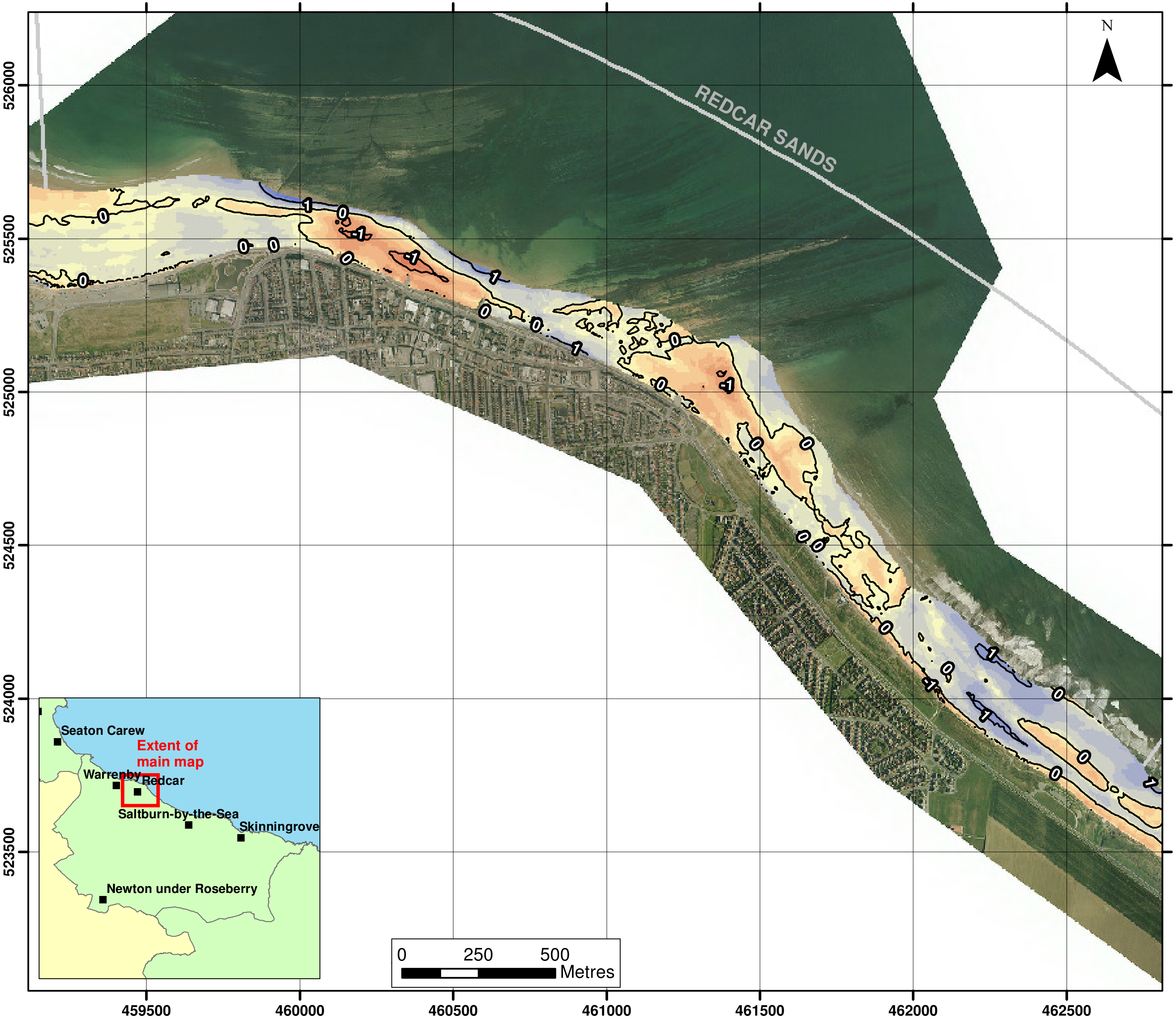

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

<-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	

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 2c
Long-term Elevation Change Redcar Sands Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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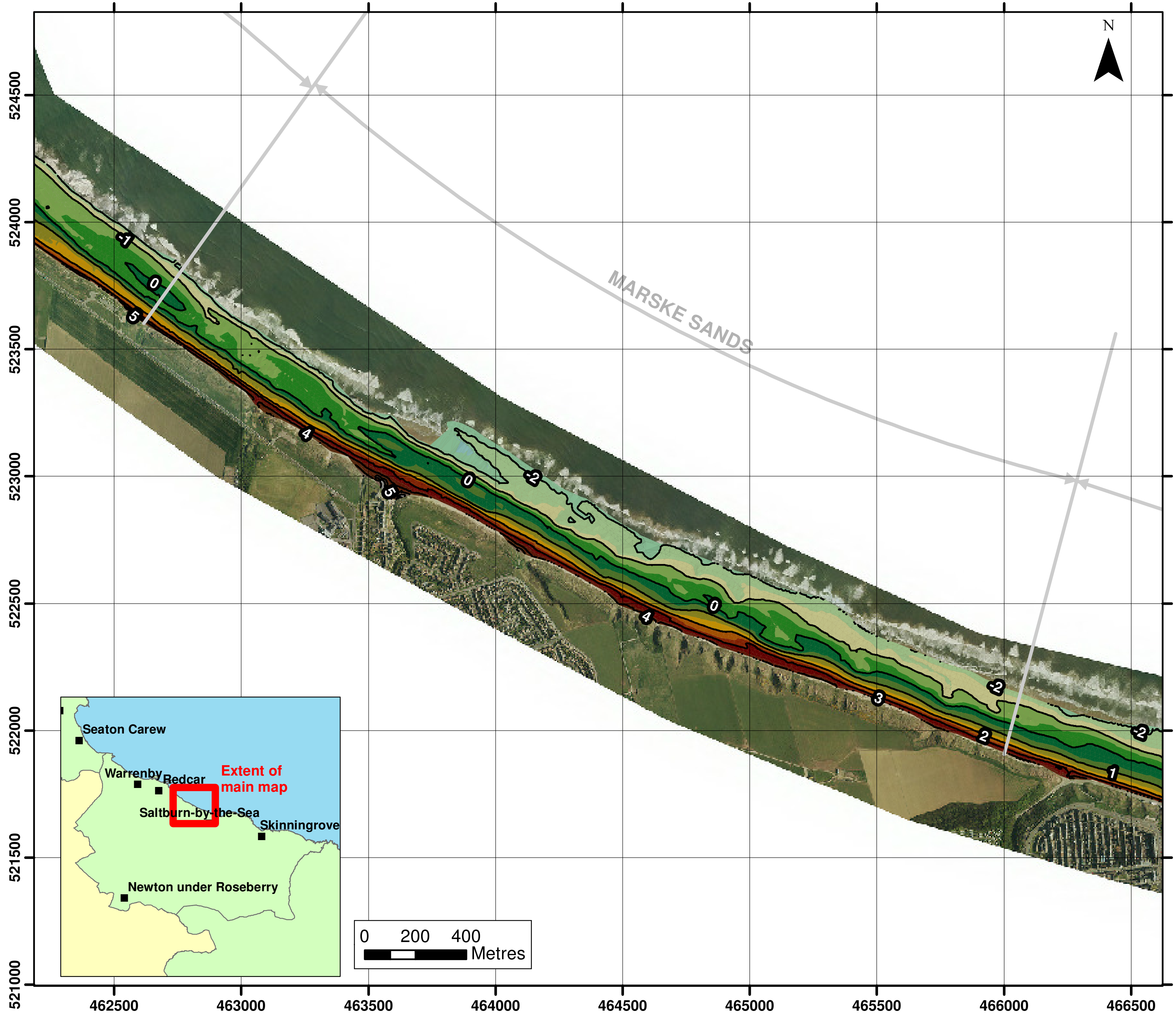

KEY

Elevation (m OD)

- 7.5 - 8
- 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 3a
Topographic Survey
Marske Sands
Redcar & Cleveland
Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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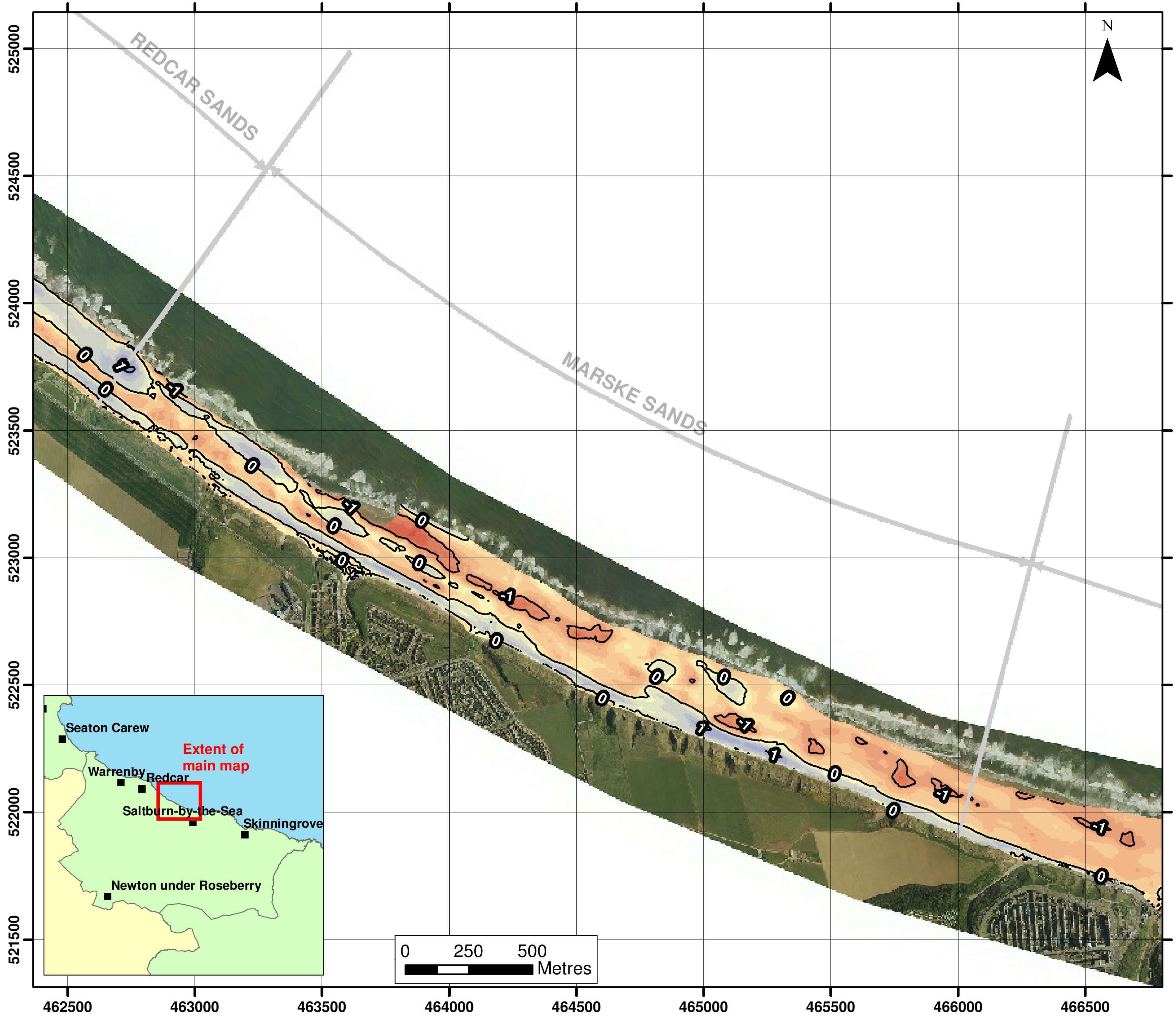

KEY Autumn 2012 and Autumn 2013
Change in elevation (m)

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

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 3b
Short-term Elevation Change Marske Sands Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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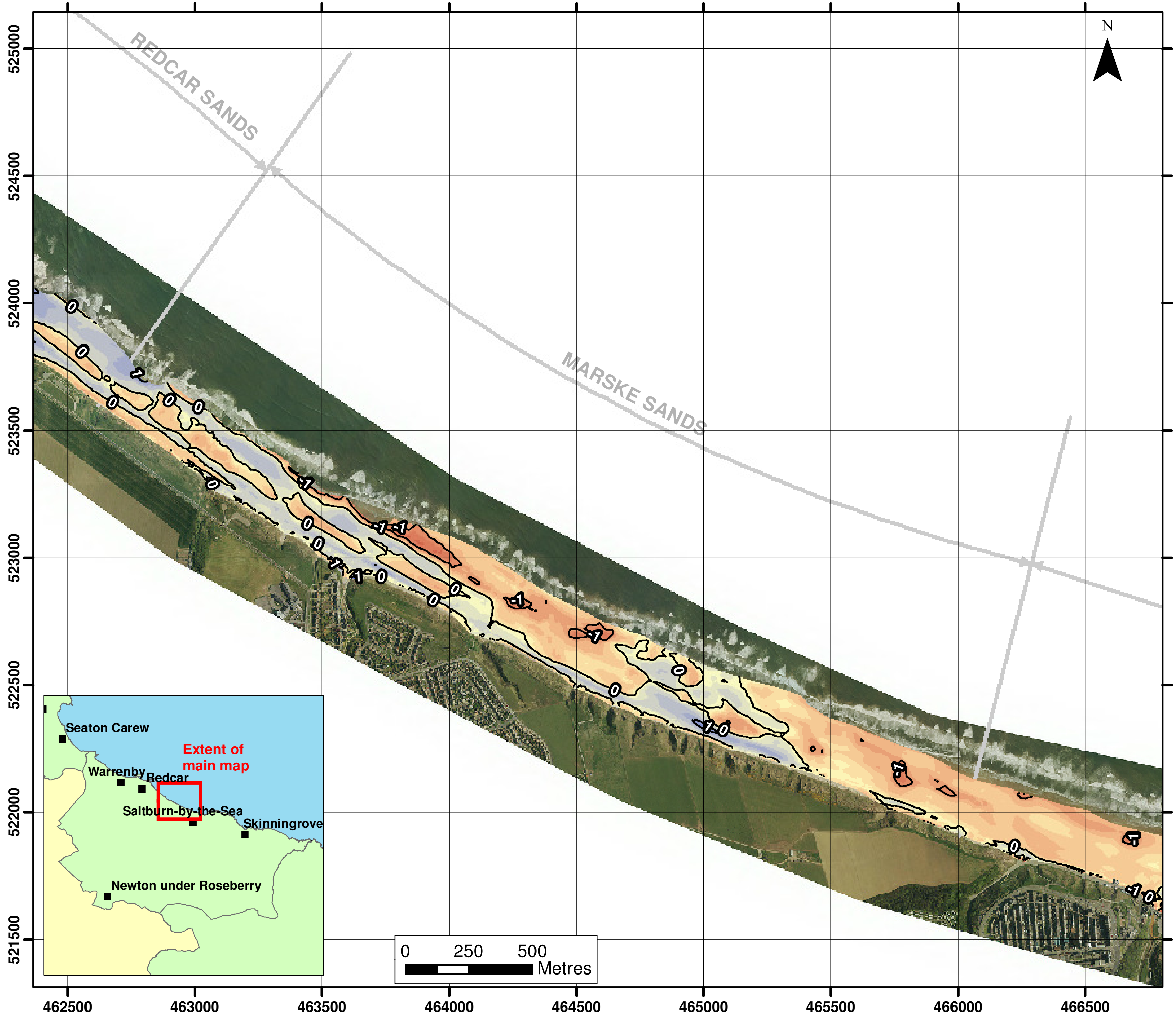

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

<-2
-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
0 - 0.1
0.1 - 0.25
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

Loss
Change < 0.1 m
Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 3c
Long-term Elevation Change
Marske Sands
Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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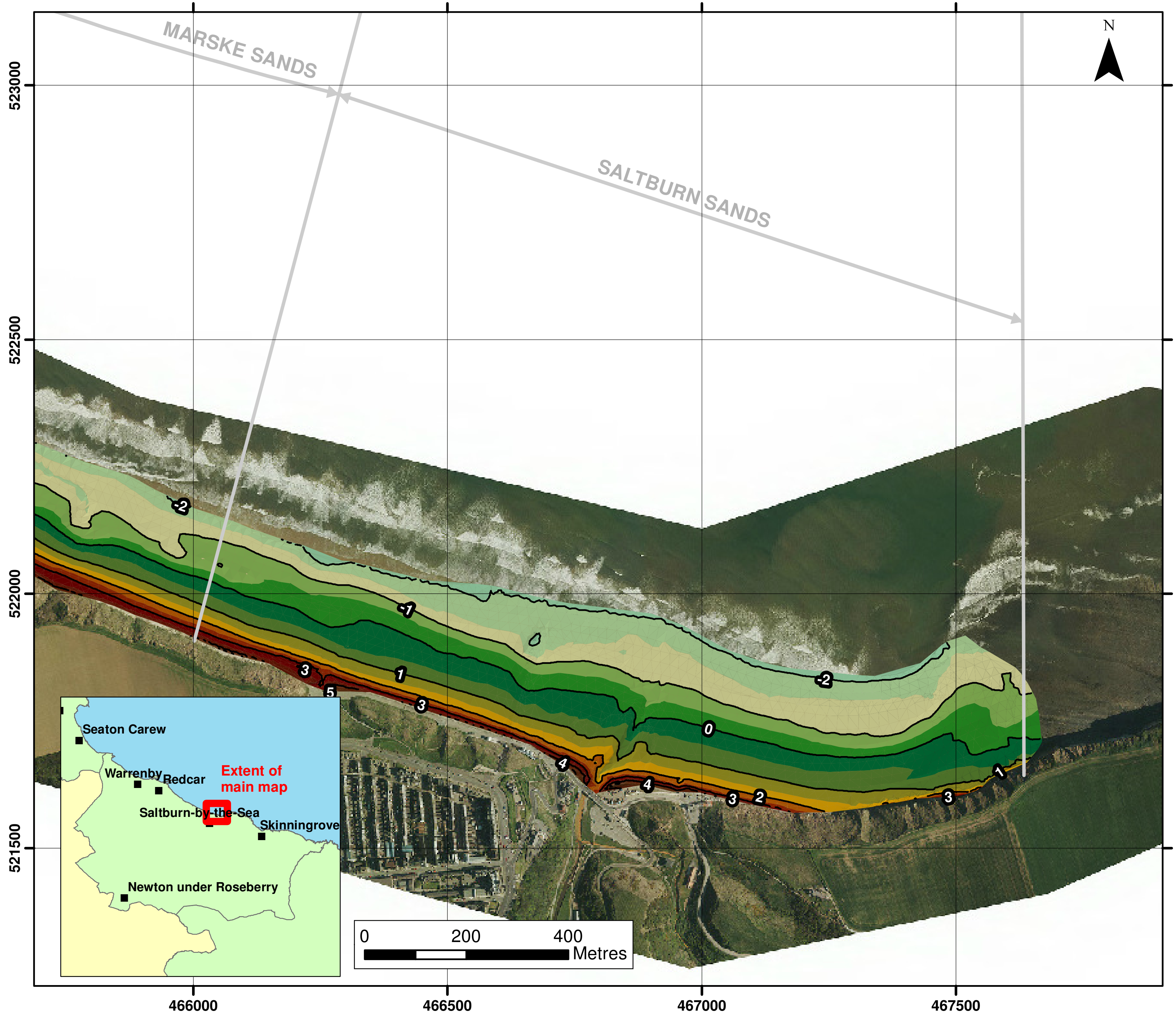

KEY

Elevation (m OD)

- 7.5 - 8
- 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 4a
Topographic Survey
Saltburn Sands
Redcar & Cleveland Borough Council

Analytical Report 6
FullMeasures Survey
Autumn 2013

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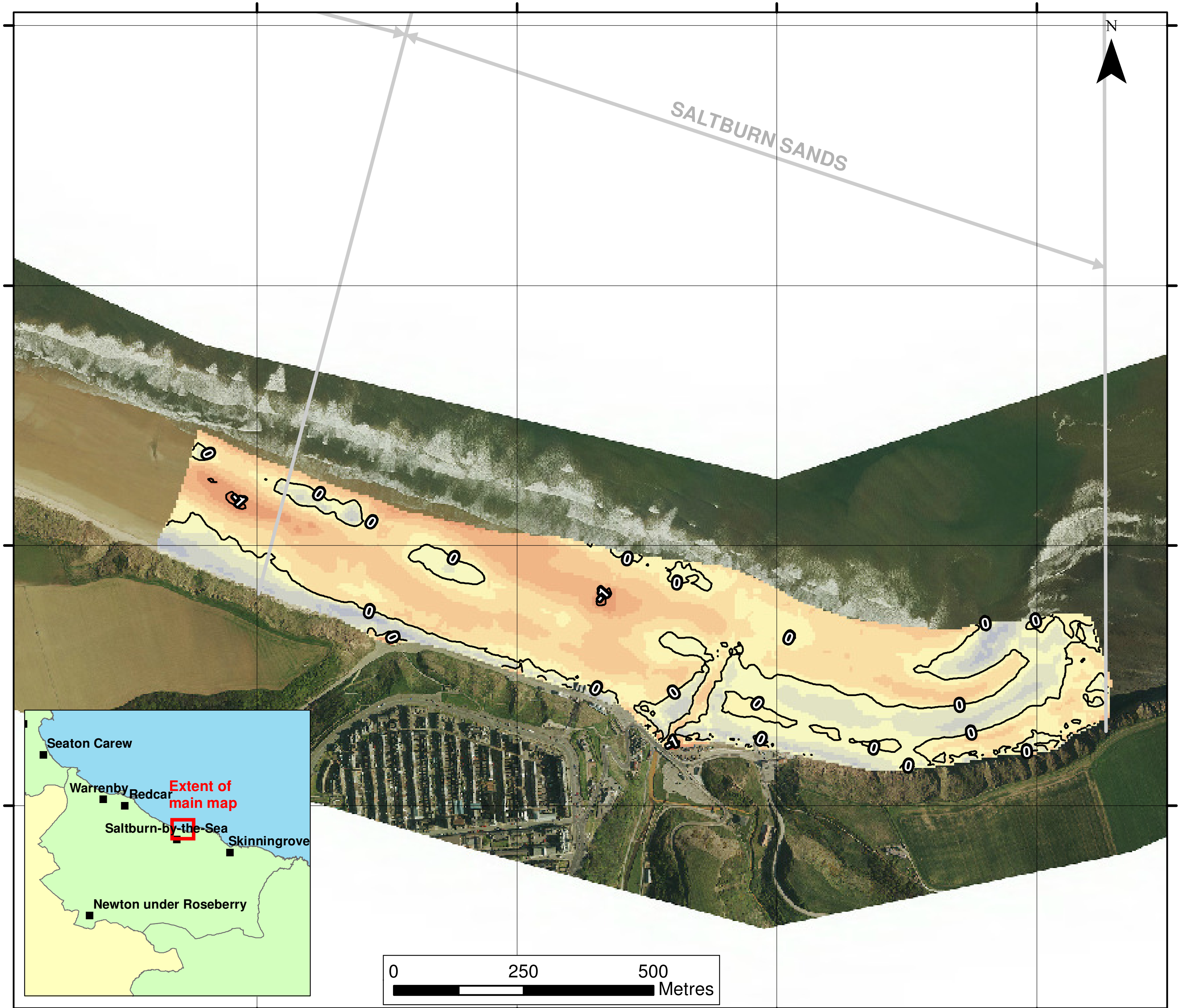

KEY Spring 2013 and Autumn 2013
Change in elevation (m)

- <-2
- -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
- 0 - 0.1
- 0.1 - 0.25
- 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

Loss

Change < 0.1 m

Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 4b Short-term Elevation Change Saltburn Sands Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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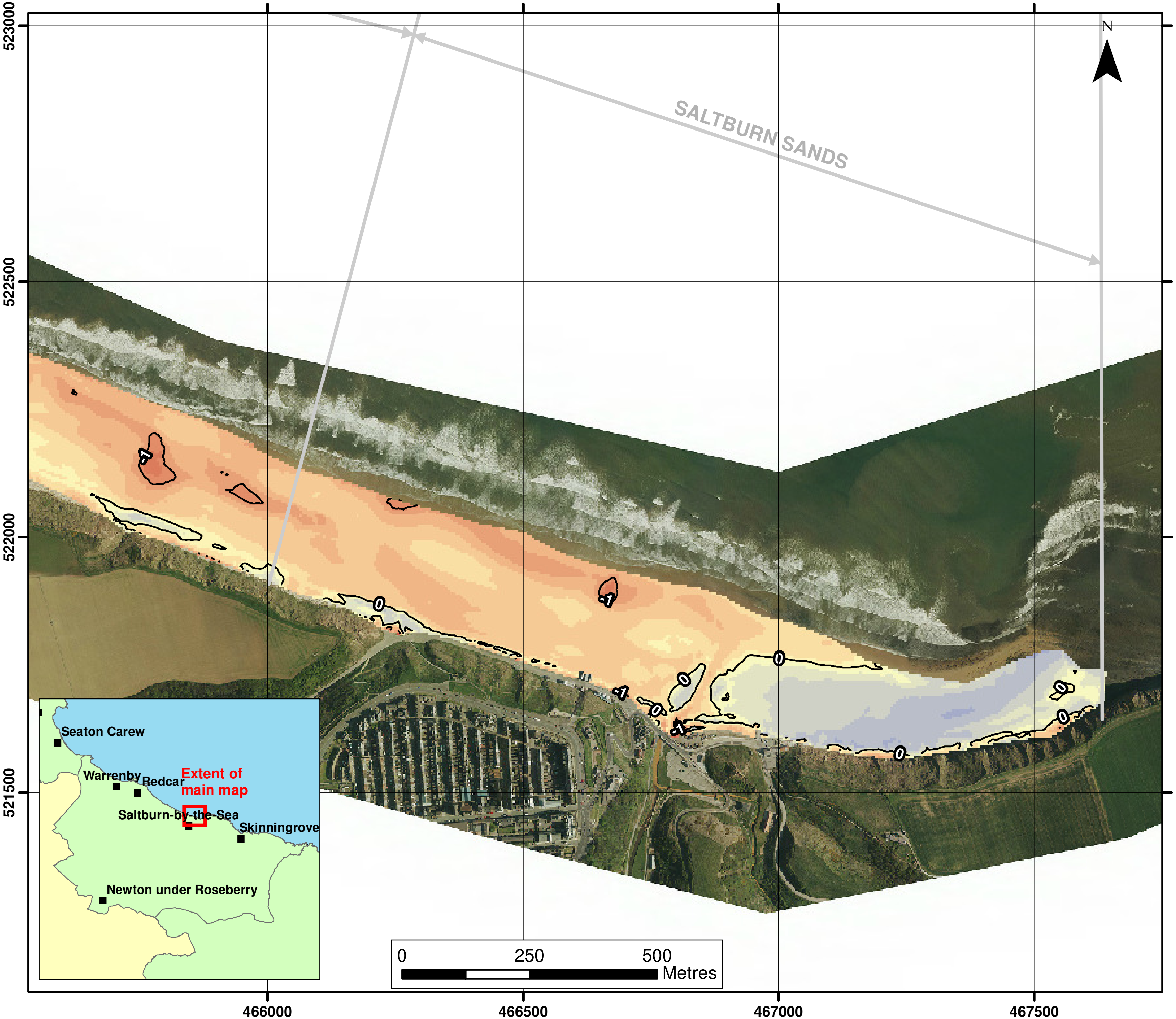

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

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

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 4c
Long-term Elevation Change Saltburn Sands Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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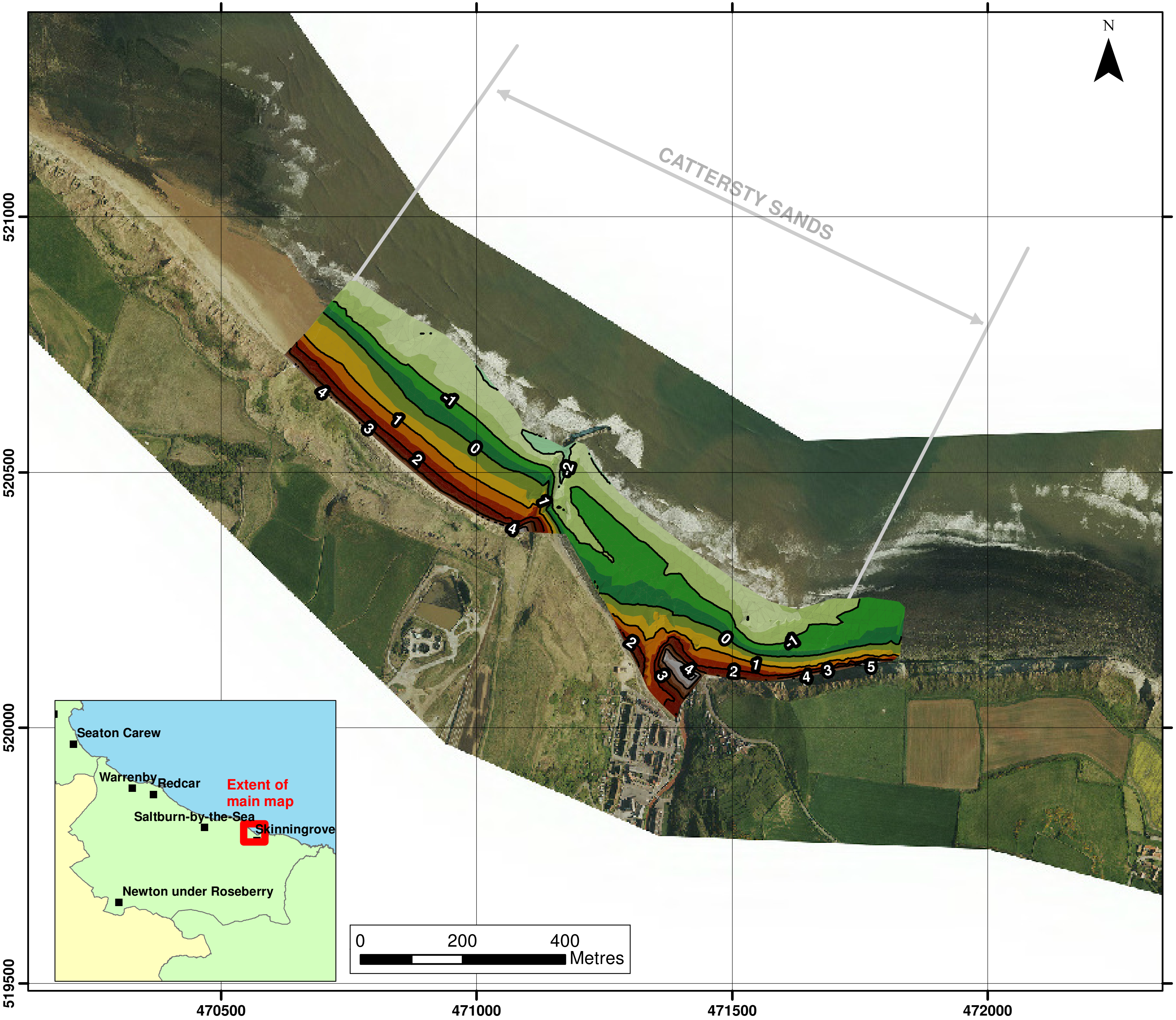
www.northeastcoastalobservatory.org.uk



KEY

Elevation (m OD)

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

Analytical Report 6
Fulll Measures Survey
Autumn 2013

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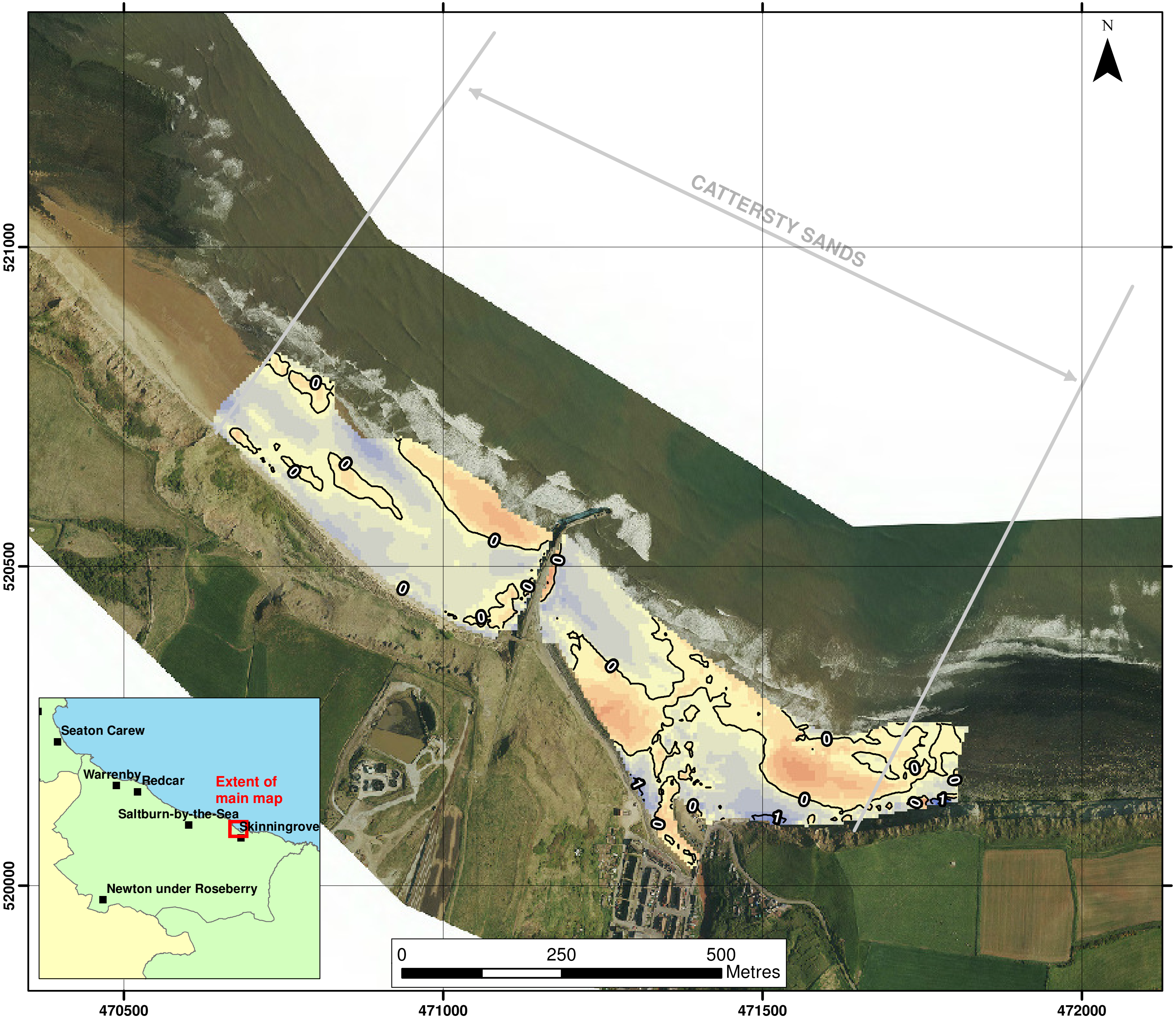

KEY Spring 13 and Autumn 13
Change in elevation (m)

Change in elevation (m)	
<-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	

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 5b
Short-term Elevation Change Cattersty Sands Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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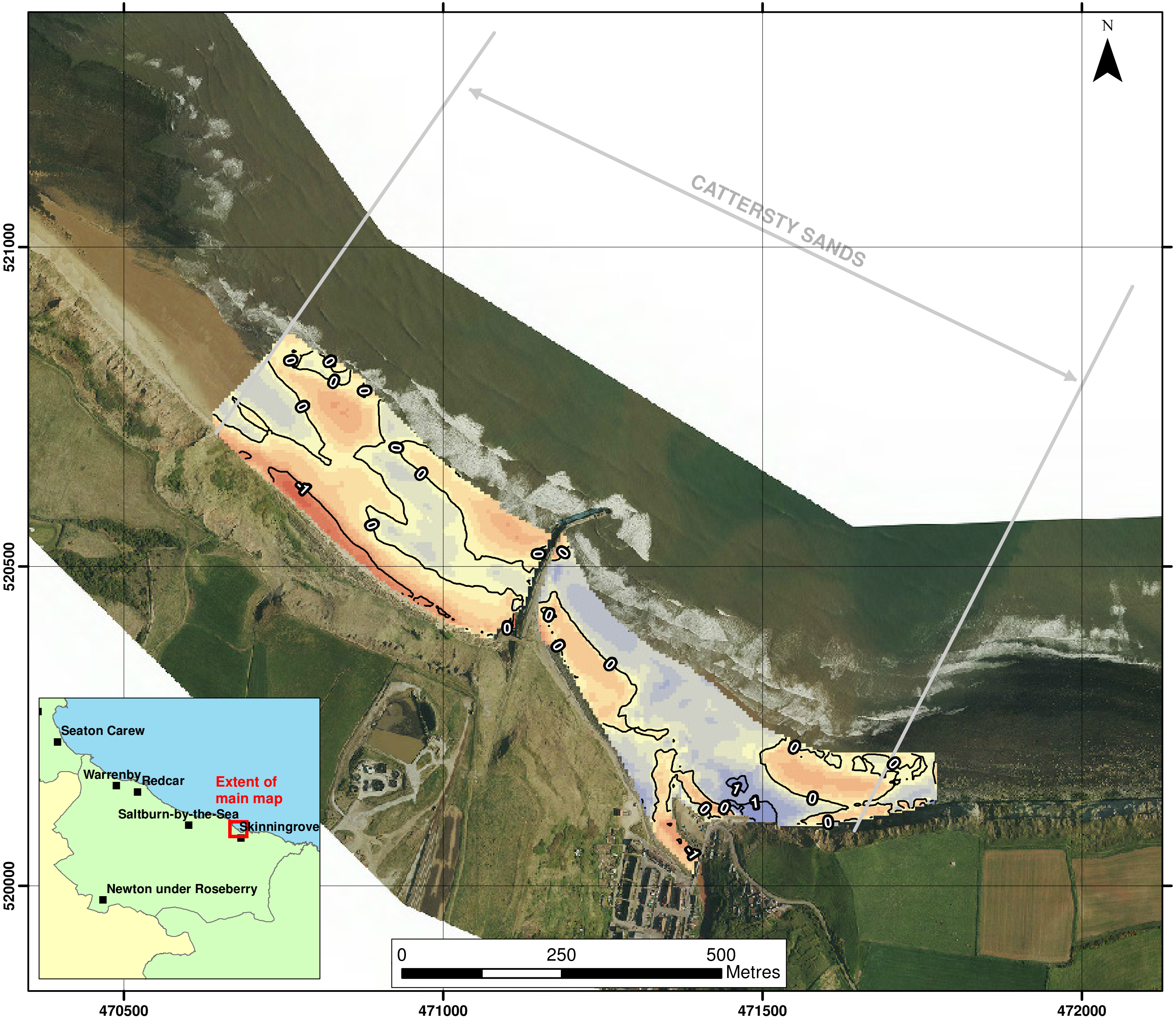

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 5c
Long-term Elevation Change Cattersty Sands Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
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Appendix C

Cliff Top Survey

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 bi-annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

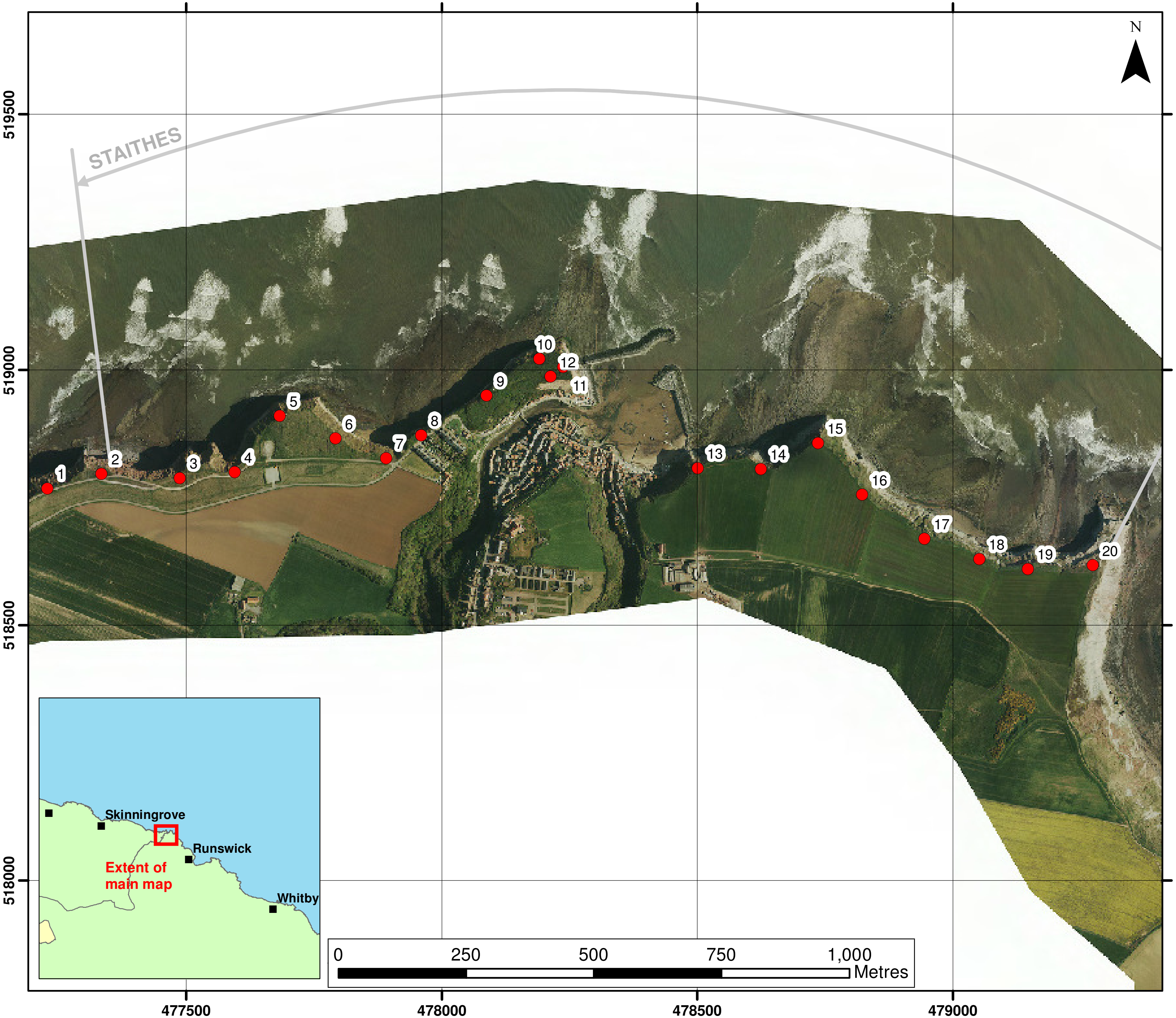
Table C1 provides baseline information about these ground control points and results from the 2008 (baseline) survey showing the position from the ground control point to the edge of the cliff top along the defined bearing. Future reports will show results from subsequent surveys and provide a means 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 2013)	Present Survey (Oct 2013)	Baseline (Nov 2008) to Present (Oct 2013)	Previous (April 2013) to Present (Oct 2013)	Baseline (Nov 2008) to Present (Oct 2013)
1	477228	518769	320	1.9	1.7	1.7	-0.2	0.0	0.0
2	477334	518798	0	10.9	10.8	10.8	-0.1	0.0	0.0
3	477487	518789	350	7.1	8.3	8.5	1.4	0.2	0.3
4	477594	518801	340	5.9	5.1	5.2	-0.7	0.0	-0.1
5	477683	518911	350	8.4	9.2	8.9	0.5	-0.3	0.1
6	477792	518867	30	8.6	8.5	8.5	-0.1	0.0	0.0
7	477891	518828	60	7.7	7.5	7.5	-0.2	0.0	0.0
8	477959	518873	350	8.7	9.8	9.9	1.2	0.0	0.2
9	478088	518950	350	7.6	8.3	8.3	0.7	0.1	0.1
10	478191	519023	340	8.4	8.8	8.8	0.4	0.0	0.1
11	478237	519007	60	6.9	6.7	6.7	-0.2	0.0	0.0

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 2013)	Present Survey (Oct 2013)	Baseline (Nov 2008) to Present (Oct 2013)	Previous (April 2013) to Present (Oct 2013)	Baseline (Nov 2008) to Present (Oct 2013)
12	478213	518988	150	6.1	6.5	6.2	0.1	-0.3	0.0
13	478501	518809	15	11.4	9.2	9.2	-2.2	0.0	-0.5
14	478624	518807	20	7.5	7.5	7.5	0.0	0.1	0.0
15	478737	518858	60	6.1	6.4	6.4	0.3	0.0	0.1
16	478823	518757	60	8	9.0	9.3	1.3	0.3	0.3
17	478944	518671	30	9.3	9.4	9.4	0.1	0.0	0.0
18	479052	518630	20	9.2	9.4	9.4	0.2	0.0	0.0
19	479147	518610	0	14.2	14.4	14.4	0.2	0.0	0.0
20	479274	518618	20	11.4	11.4	11.4	0.0	-0.1	0.0

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.



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
Staithes
Redcar & Cleveland Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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