Cell 1 Regional Coastal Monitoring Programme
Analytical Report 8: ‘Full Measures’ Survey 2015

Hartlepool Borough Council
Final Report

February 2016

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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) River Tyne to Frenchman's Bay	Frenchman's Bay to Souter Point	Souter Point to Chourdon Point	Chourdon Point to Hartlepool Headland
1 in 200 year	3.41	3.44	3.66	3.91
HAT	2.85	2.88	3.18	3.30
MHWS	2.15	2.18	2.48	2.70
MLWS	-2.15	-2.12	-1.92	-1.90
Water Level Parameter	**Water Level (m AOD) Hartlepool Headland to Saltburn Scar**	**Skinningrove**	**Hummersea Scar to Sandsend Ness**	**Sandsend Ness to Saltwick Nab**
1 in 200 year	3.87	3.86	4.1	3.88
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

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.

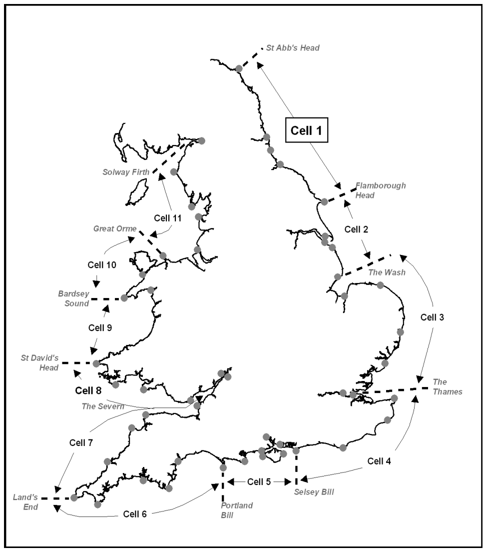


Figure 1 Sediment Cells in England and Wales

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 CH2M.

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	July 10	-
3	2010/11	Aug-Nov 10	Feb 11	Feb-April 11	August 11	Sept 11
4	2011/12	Sep-Oct 11	Oct 12	Mar-May 12	Feb 13	-
5	2012/13	Sep 2012	Feb 13	April 13	May 13	-
6	2013/14	Sep-Oct 13	Feb 14	March 14	July 14	
7	2014/15	Sep-Oct 14	Feb 15	April 15	June 15	
8	2015/16	August 2015	Feb 16 (*)			

(*) The present report is **Analytical Report 8** and provides an analysis of the 2015 Full Measures survey for Hartlepool 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 sections listed in 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

Hartlepool Borough Council's frontage extends from Crimdon Beck in the north, to the North Gare Breakwater in the south. For the purposes of this report, it has been sub-divided into four areas, namely:

- North Sands
- Hartlepool Headland
- Middleton
- Hartlepool Bay

1.2 Methodology

Along Hartlepool Borough Council's frontage, the following surveying is undertaken:

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along part of North Sands (referred to as Hartlepool North or 'HN')
    - Topographic survey along Middleton (referred to as Hartlepool Central or 'HC')
    - Topographic survey along Hartlepool Bay (referred to as Hartlepool South or 'HS')
- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 9 no. transect lines
- Additionally, every five years (starting with 2008 as the baseline year), the Full Measures topographic survey at Hartlepool North is extended to fully cover the whole of North Sands and Hartlepool Headland with a topographic survey. This extends across the boundary of jurisdiction between Hartlepool Borough Council and County Durham Council.

The location of these surveys is shown in Figure 2. The 2015 Full Measures survey was undertaken along this frontage on various dates between 28th August and 11th October. During this time weather were generally dry with light to moderate breezes from a range of directions. The sea state at all sites was either calm or moderate. The survey reports from Academy Geomatics document details of the weather conditions over this survey period.

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:

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

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 wave buoy located at Tyne and Tees deployed under the national monitoring programme and three Cell 1 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 BC as part of the Cell 1 monitoring programme.

An assessment of baseline wave data was presented in the Cell 1 2011 Wave Data Analysis Report, which reviewed all readily available wave data in the region. Wave data update reports for 2013-14 and 2014-15 provide an update to the baseline with analysis of the wave data collected under the programme between 2011 and March 2015. These wave data reports are also available from the reports page on the Cell 1 monitoring website:
http://www.northeastcoastalobservatory.org.uk/Default.aspx?view=pnlTexts&text=Reports

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 which includes storm analysis for data collected up to the end of November 2015, extending the wave analysis to cover the period prior to the Full Measure surveys.

An overview plot of wave height data from the three Cell 1 wave buoys is shown in Figure 2. Note that there were significant gaps in the data at both Scarborough and Whitby, but the record is nearly continuous from Newbiggin. There were a large number of small storms over the wither 2014-15 with the largest wave heights occurring in mid-October 2014 and beginning of February 2015. A storm with significant wave heights over 4m occurred in early September, after Middleton but before the other areas.

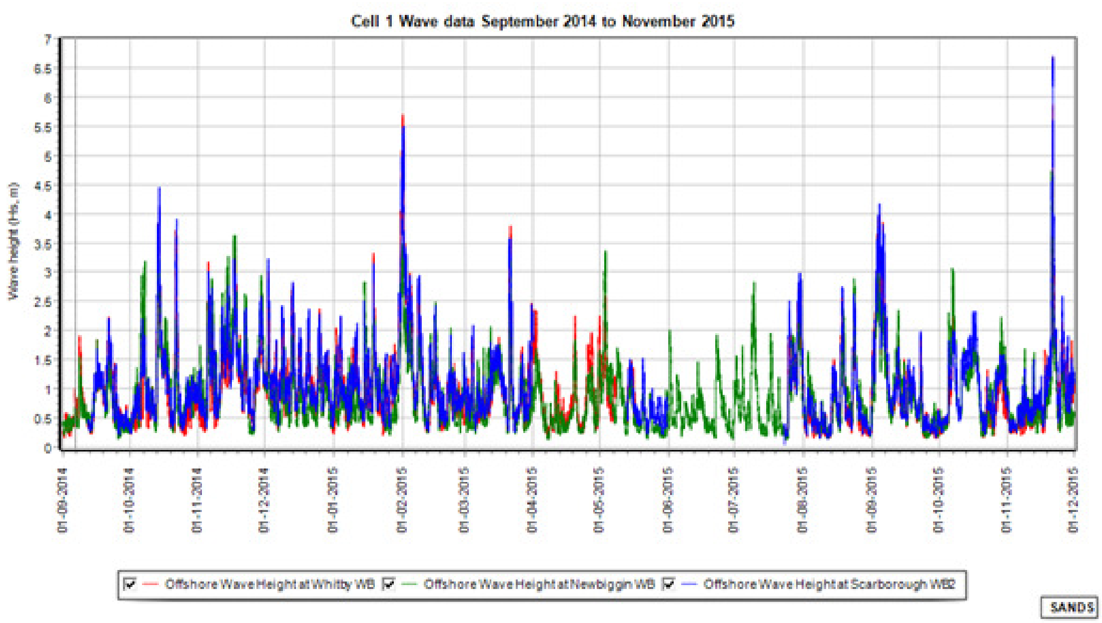


Figure 3, Wave monitoring data from the Three Cell 1 wave buoys

2.2 Tyne/Tees WaveNet Buoy storms analysis

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 and results of a SANDS Storms analysis is 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 2007 and 2008.

Table 4: SANDS Storm Analysis at Tyne/Tees WaveNet Buoy (updated to include data to Dec 2015)

General Storm Information							At Peak					
Start Time	**End Time**	**Dur (hr)**	**Peak of Storm**	**Mean Dir (°)**	**No Events**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Tz (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**	**Total Energy (KJ/m)**
19/03/2007 10:30	21/03/2007 05:30	43	20/03/2007 14:30	23	64	78.2	6.2	14.8	8.5	23	1.7E+04	1.4E+07
25/06/2007 20:30	26/06/2007 13:30	17	26/06/2007 10:00	54	18	77.3	4.4	10.3	7.2	23	4.0E+03	1.7E+06
26/09/2007 03:00	27/09/2007 05:00	26	26/09/2007 19:00	11	33	79.7	4.6	13.8	7.6	6	**7.8E+03**	3.6E+06
08/11/2007 20:00	**12/11/2007 15:00**	**91**	**09/11/2007 08:30**	**16**	**58**	**77.7**	**6.2**	15.9	**9.0**	**6**	**1.9E+04**	**1.6E+07**
19/11/2007 03:30	25/11/2007 21:30	162	23/11/2007 05:00	88	52	76.8	4.9	12.7	7.6	17	7.6E+03	6.8E+06
08/12/2007 03:00	10/12/2007 14:30	59.5	08/12/2007 03:30	106	8	82.9	4.1	12.8	7.6	17	5.4E+03	7.5E+05
03/01/2008 10:30	04/01/2008 01:30	15	03/01/2008 23:30	77	24	14.6	4.2	10.9	7.6	62	4.2E+03	2.5E+06
01/02/2008 15:00	02/02/2008 09:30	18.5	02/02/2008	41	30	80.1	6.0	16.4	9.0	17	1.9E+04	8.7E+06
10/03/2008 08:30	10/03/2008 12:30	4	10/03/2008 11:00	146	9	307.5	4.6	9.6	6.5	141	3.8E+03	7.3E+05
17/03/2008 15:00	**25/03/2008 03:00**	**180**	**22/03/2008 05:00**	**81**	**58**	**82.1**	**7.9**	14.8	**9.0**	**6**	**2.7E+04**	**1.7E+07**
05/04/2008 22:00	07/04/2008 05:00	31	06/04/2008 19:00	49	20	83.1	4.6	13.9	7.6	6	7.9E+03	3.0E+06
20/07/2008 16:00	21/07/2008 09:30	17.5	20/07/2008 23:30	15	8	76.0	4.2	11.8	7.6	11	4.9E+03	9.1E+05
03/10/2008 03:00	03/10/2008 20:30	17.5	03/10/2008 16:30	55	17	76.7	4.7	13.6	7.6	23	**8.1E+03**	2.8E+06
21/11/2008 04:00	25/11/2008 12:30	104.5	22/11/2008 11:30	15	112	75.8	6.0	15.6	8.5	11	1.7E+04	2.2E+07
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	109	37	332.1	4.9	10.0	7.2	129	4.7E+03	4.0E+06
31/01/2009 16:30	03/02/2009 09:00	64.5	02/02/2009 22:00	84	57	7.2	5.8	11.4	8.5	84	8.7E+03	8.1E+06
23/03/2009 22:30	28/03/2009 20:30	118	28/03/2009 16:30	217	14	89.4	5.3	10.0	7.6	6	5.4E+03	1.3E+06
10/07/2009 01:30	10/07/2009 02:30	1	10/07/2009 01:30	13	2	78.7	4.2	11.9	7.2	11	5.0E+03	2.3E+05
29/11/2009 20:30	**30/11/2009 15:00**	**18.5**	**30/11/2009 00:30**	**18**	**36**	**72.7**	**6.0**	11.2	**8.0**	**11**	**9.0E+03**	**5.9E+06**
17/12/2009 10:30	18/12/2009 05:00	18.5	17/12/2009 19:30	64	36	26.3	5.4	12.7	8.0	68	**9.4E+03**	5.7E+06
30/12/2009 09:00	30/12/2009 23:00	14	30/12/2009 12:30	84	24	7.7	5.1	9.0	7.2	90	4.1E+03	2.3E+06
06/01/2010 05:30	06/01/2010 11:00	5.5	06/01/2010 06:30	30	10	63.6	4.2	12.7	7.2	11	5.7E+03	1.1E+06
29/01/2010 10:30	30/01/2010 00:30	14	29/01/2010 22:30	9	21	81.9	5.4	10.2	8.0	6	6.0E+03	2.1E+06
26/02/2010 22:30	27/02/2010 02:30	4	27/02/2010 01:00	18	7	72.4	4.6	10.1	7.6	17	4.2E+03	7.0E+05
19/06/2010 07:00	20/06/2010 08:30	25.5	19/06/2010 20:00	21	49	69.2	5.4	12.7	7.6	23	**9.4E+03**	8.5E+06
29/08/2010 14:00	30/08/2010 06:30	16.5	30/08/2010 01:00	243	17	92.8	4.7	10.3	7.6	6	4.7E+03	1.6E+06
06/09/2010 22:30	07/09/2010 16:00	17.5	07/09/2010 15:30	101	22	353.2	4.6	10.5	8.0	90	4.5E+03	2.3E+06

General Storm Information							At Peak					
Start Time	End Time	Dur (hr)	Peak of Storm	Mean Dir (°)	No Events	Mean Dir Vector (°)	Hs (m)	Tp (s)	Tz (s)	Dir (°)	Energy @ Peak (KJ/m/s)	Total Energy (KJ/m)
17/09/2010 07:00	17/09/2010 18:30	11.5	17/09/2010 08:30	10	17	80.7	4.7	13.1	8.0	11	7.5E+03	2.9E+06
24/09/2010 03:00	26/09/2010	45	24/09/2010 10:00	21	80	71.6	5.3	12.1	8.0	11	8.0E+03	1.2E+07
20/10/2010 02:00	24/10/2010 16:30	110.5	20/10/2010 10:00	13	16	78.2	4.2	13.4	7.2	17	6.4E+03	1.8E+06
08/11/2010 14:00	**09/11/2010 20:30**	**30.5**	**09/11/2010 10:00**	**88**	**58**	**3.0**	**5.6**	10.5	**8.0**	**73**	**6.9E+03**	**7.8E+06**
17/11/2010 11:00	17/11/2010 18:30	7.5	17/11/2010 12:00	136	9	322.4	4.7	9.2	6.9	129	3.7E+03	8.1E+05
29/11/2010 19:30	02/12/2010 08:30	61	29/11/2010 21:00	80	45	11.8	5.1	11.2	7.6	56	6.3E+03	5.4E+06
16/12/2010 15:00	17/12/2010 06:30	15.5	17/12/2010 03:30	12	22	79.1	4.6	12.5	7.6	17	6.4E+03	2.8E+06
23/07/2011 14:00	**24/07/2011 11:00**	**21**	**24/07/2011 03:00**	**23**	**39**	**67.1**	**4.7**	12.8	**7.6**	**17**	**7.2E+03**	**5.8E+06**
24/10/2011 18:30	25/10/2011 09:30	15	25/10/2011 09:30	103	26	348.5	4.1	11.3	6.9	79	4.2E+03	2.6E+06
09/12/2011 08:30	09/12/2011 10:00	1.5	09/12/2011 08:30	7	3	84.0	4.1	14.2	8.0	6	6.7E+03	4.8E+05
05/01/2012 16:00	06/01/2012 05:00	13	06/01/2012 03:00	12	19	79.0	4.6	12.5	7.6	17	6.4E+03	2.6E+06
03/04/2012 13:30	04/04/2012 10:30	21	03/04/2012 17:30	66	38	25.1	5.6	9.7	7.6	56	5.9E+03	5.5E+06
24/09/2012 08:30	25/09/2012 10:30	26	25/09/2012 01:30	74	50	16.7	4.7	12.3	8.0	62	6.6E+03	7.4E+06
26/10/2012 16:30	27/10/2012 14:30	22	26/10/2012 23:00	12	34	79.4	4.9	15.3	7.6	11	1.1E+04	4.9E+06
05/12/2012 16:00	15/12/2012 01:30	225.5	14/12/2012 19:30	78	31	18.4	5.4	10.5	7.6	96	6.4E+03	4.5E+06
20/12/2012 06:00	**21/12/2012 14:30**	**32.5**	**20/12/2012 23:00**	**101**	**56**	**348.4**	**5.6**	11.3	**8.0**	**96**	**8.0E+03**	**8.8E+06**
18/01/2013 18:30	22/01/2013 06:00	83.5	21/01/2013 10:00	81	54	9.2	6.7	11.2	8.5	84	1.1E+04	1.1E+07
06/02/2013 08:00	07/02/2013 06:00	22	06/02/2013 12:30	47	38	81.6	5.4	11.9	7.6	11	8.2E+03	6.1E+06
07/03/2013 21:00	10/03/2013 21:30	72.5	08/03/2013 04:00	67	37	24.6	4.9	10.7	7.6	73	5.4E+03	4.3E+06
18/03/2013 09:00	25/03/2013 00:30	159.5	23/03/2013 14:30	85	153	5.1	6.0	12.1	8.0	90	1.0E+04	2.8E+07
23/05/2013 18:00	**24/05/2013 12:00**	**18**	**23/05/2013 22:30**	**13**	**32**	**77.5**	**6.7**	12.5	**8.5**	**17**	**1.4E+04**	**7.1E+06**
10/09/2013 13:00	10/09/2013 19:30	6.5	10/09/2013 14:00	11	14	79.3	4.4	11.0	7.2	11	4.6E+03	1.5E+06
09/10/2013 22:30	11/10/2013 09:00	34.5	10/10/2013 17:00	68	62	79.8	5.4	12.7	7.6	22	9.4E+03	1.2E+07
29/11/2013 22:30	30/11/2013 06:30	8	30/11/2013 00:30	42	17	84.5	5.6	12.7	8.0	11	1.0E+04	3.3E+06
05/12/2013 14:00	07/12/2013 04:30	38.5	06/12/2013 20:00	24	59	80.8	4.7	17.0	9.0	6	1.3E+04	1.2E+07
27/12/2013 09:30	27/12/2013 12:30	3	27/12/2013 10:00	218	3	249.3	4.1	7.3	6.5	202	1.8E+03	1.3E+05
05/02/2014 04:00	05/02/2014 18:00	14	05/02/2014 05:30	139	9	318.4	4.4	9.3	6.9	129	3.3E+03	7.2E+05
12/02/2014 20:00	**14/02/2014 19:00**	**47**	**12/02/2014 21:00**	**183**	**8**	**275.6**	**4.6**	8.9	**6.5**	**141**	**3.2E+03**	**7.8E+05**
21/10/2014 22:00	22/10/2014 01:30	3.5	21/10/2014 23:00	6	5	84.4	4.4	11.5	7.6	6	**5.0E+03**	6.0E+05
31/01/2015 08:30	01/02/2015 19:30	35.0	31/01/15 23:30	78	71	88.7	6.2	13.1	8.0	6	1.3 E+4	1.4 E+7
03/09/2015 05:30:00	04/09/2015 06:00:00	24.5	03/09/2015 18:30:00	13	15	78.1	4.4	10.5	6.8	11	4.2 E+3	1.6 E+6
21/11/2015 01:30:00	**21/11/2015 14:30:00**	**13.0**	**21/11/2015 05:30:00**	**72**	**27**	**85.9**	**7.1**	**11.8**	**8.5**	**356**	**1.4 E+4**	**5.7 E+6**

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.

Comparing the annual storm records it can be seen that 2010 had the most storms (13). In 2010 the largest storm had an incident direction of 73 degrees which is unusual. We might therefore expect that the alongshore drift on the Cell 1 beaches in 2010 may have been atypical with unusual changes from the storm conditions. This was noted in several of the 2010 Full Measures reports.

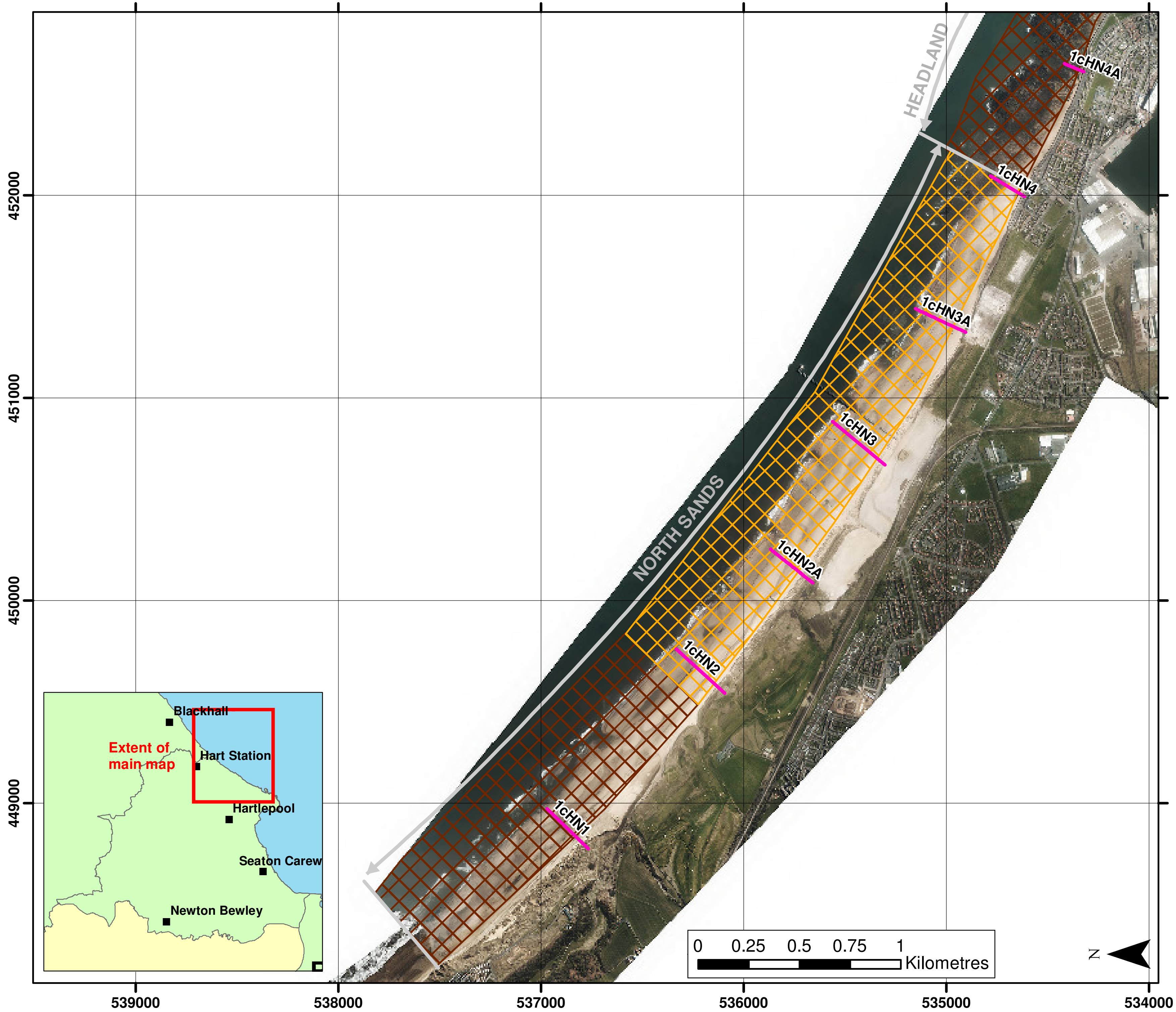
The years with the fewest storms was 2011, 2014 and 2015. In 2011 and 2014 this was reflected by a combination of accretion and overall stability recorded within the annual Full Measures reports.

The winter of 2012 to 2013 appears to have suffered with larger storms than usual, 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 and 6th December 2013, was particularly notable. Although this event did not have such 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 tides in some locations. The combined high water levels and large waves causing significant damage to many coastal defences and beaches in the north east.

The 2014 storms did appear to have an influence on beach behaviour, as shown by the profile analysis included within the 2014 Full Measures reports, with the movement of material across and along the beach. Dune toe erosion was more dominant than in previous years and could be explained by particularly high tides rather than storm erosion alone.

During 2015 there were only three storms with peak wave heights above the threshold, but all had large wave heights and much greater wave energy than the 2014 storms. The September storm was after the survey at North Sands and Middleton but the rest of the profiles show evidence of autumn storms with berms being lost from the beach.



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
North Sands
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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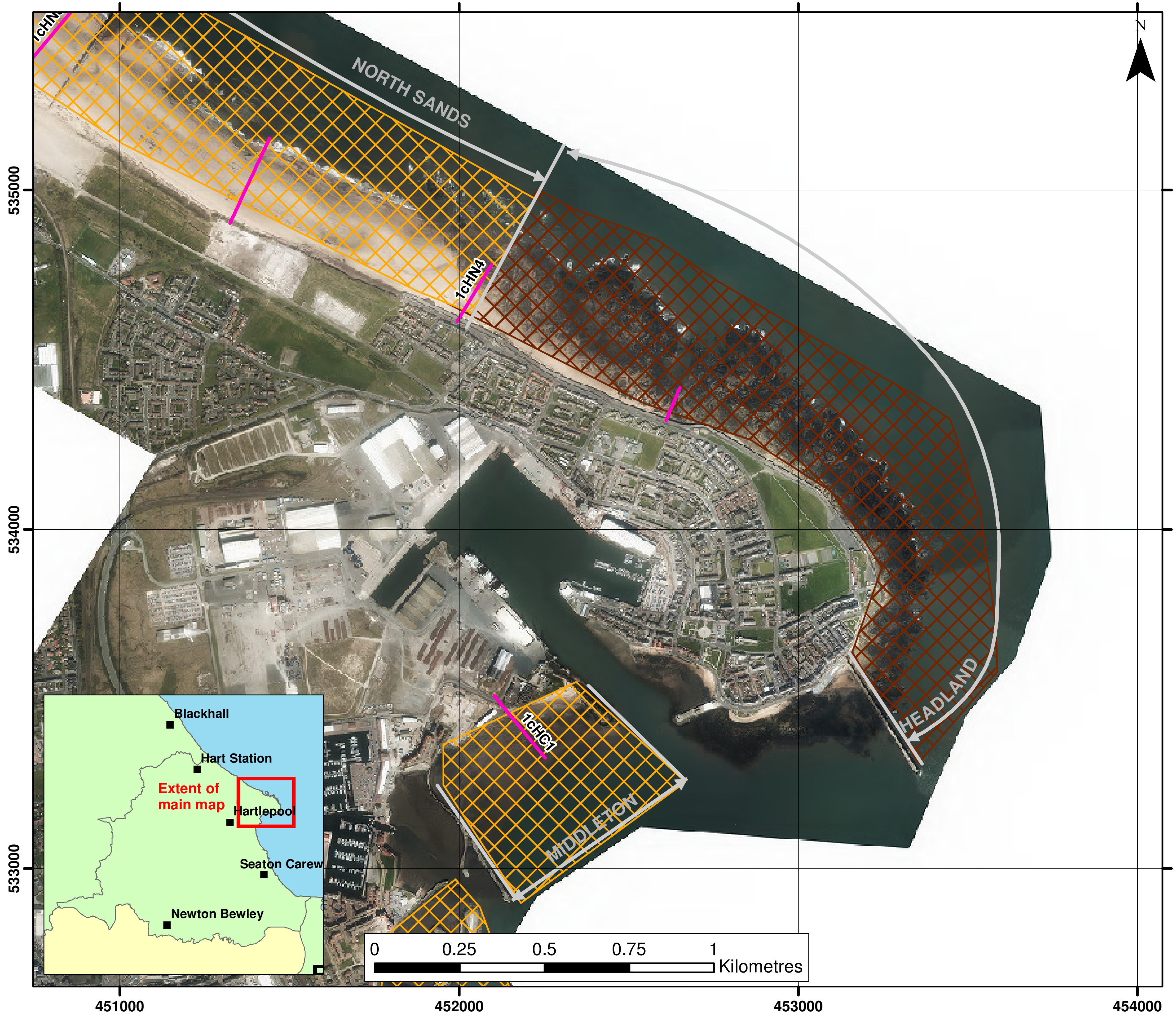
Photography courtesy of North East Coastal Observatory
www.northeastcoastalobservatory.org.uk



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
Headland and Middleton
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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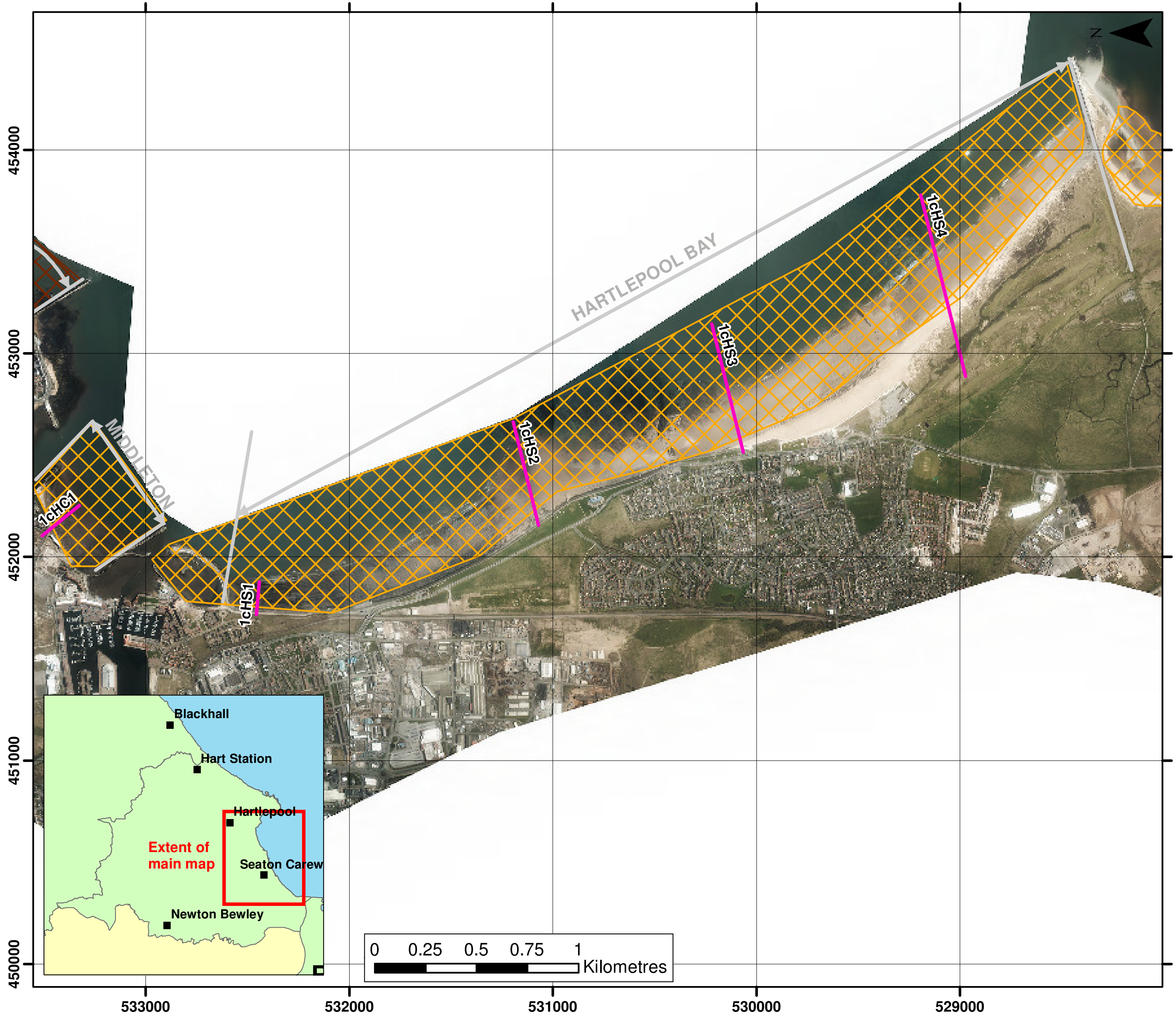

KEY

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
Hartlepool Bay
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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Photography courtesy of North East Coastal Observatory
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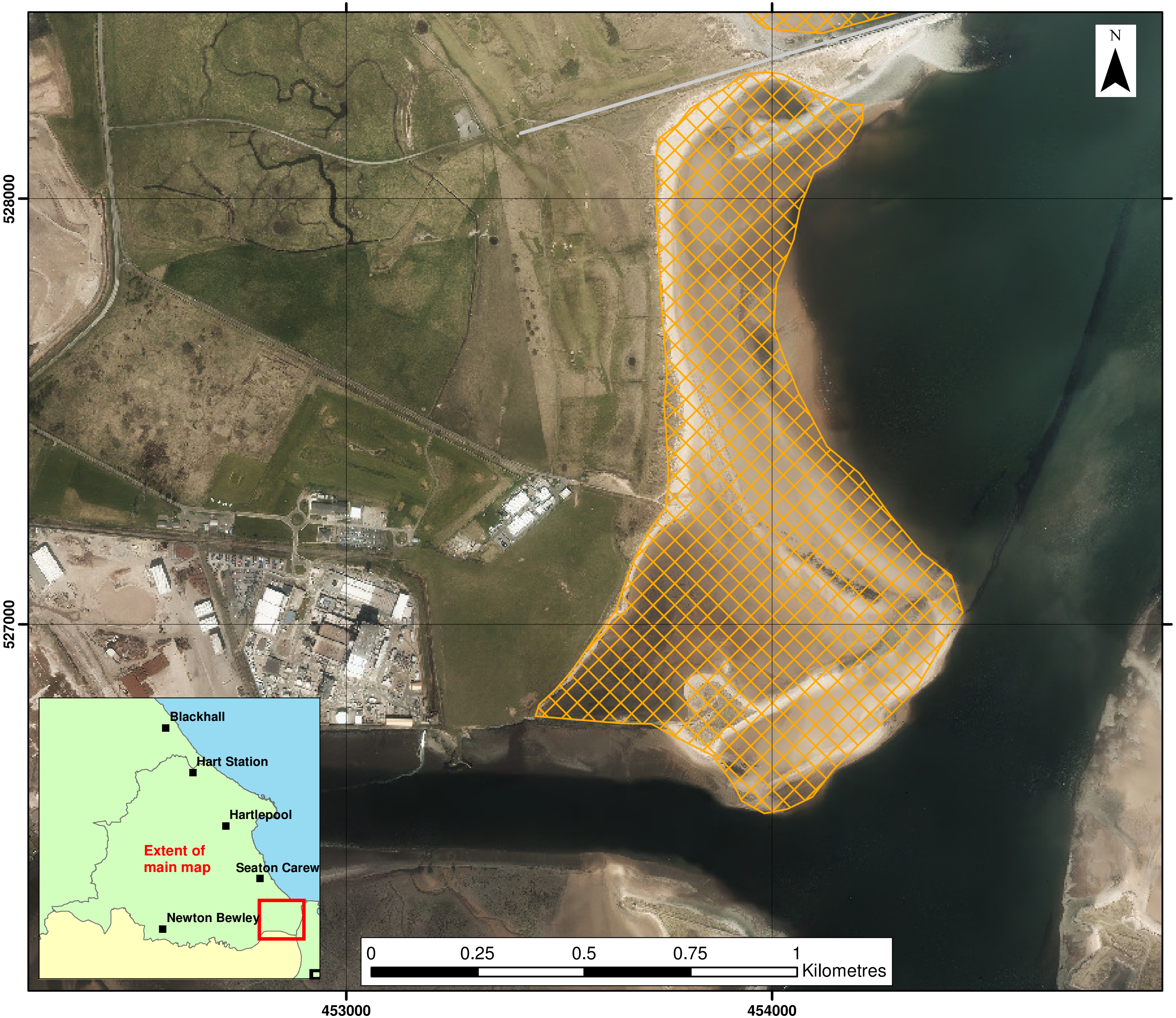

KEY

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
Hartlepool North Gare
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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Photography courtesy of North East Coastal Observatory
www.northeastcoastalobservatory.org.uk

3. Analysis of Survey Data

3.1 North Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
2nd Sept 2015	**Beach Profiles:** North Sands is covered by four beach profile lines during the Full Measures survey (Appendix A). They were last surveyed in April 2015. Profile **1cHN1** is located within Durham County Council's area of responsibility, about 400m north of the outfall of Crimdon Beck, is reported here so changes can be interpreted in association with those observed elsewhere along North Sands at HN2, HN3 and HN4. Overall at **1cHN1**, the beach is at its highest recorded level. The beach to 100m chainage and MHWS has changed little since April 2015. From 100m to 160m chainage there has been little change of ±0.2m. From 160m chainage to 200m the beach level has accreted by 0.4m as a berm has formed. Between 200m and 250m chainage the beach level has dropped by 0.4m as the lower beach berm has moved offshore. At Profile **1cHN2** the profile has not changed on the part with dunes, which is to 50m chainage since April 2015. On the upper beach between 50m and 130m chainage the beach level has remained stable between April and September 2015. From 130m to 180m chainage the beach had accreted a berm of 0.3m. Between 180m and 250m chainage the beach level has dropped by 0.6m over the summer as a berm was lost. **Profile 1cHN2a** was established in October 2011 and runs through the dunes close to North Sands. A foredune that had been accreting between 70m and 90m chainage since October 2011 was removed over the winter of 2013/14 (the period of the storm surge), but accretion has since restarted and there is a spike of 0.5m at 80m chainage. From 80m chainage to 110m there has been little change since April 2015. Between 110 and 160m chainage the beach has eroded by 0.2m since April 2015. From 160m to 210m a berm had eroded leading to the loss of 0.6m of material. From 210m to 260m 0.6m of material has accreted as a lower beach berm has formed. Profile **1cHN3** had developed a foredune since 2008. The crest of the fore-dune at 35m chainage	In the west of the bay the profiles HN1 to HN2a show modest accretion with beach berms moving. In the centre of the bay at HN3 and 3a there is stability and the profiles are in the middle of the range previously recorded. At the east of the bay the profiles are low and have been for some time. There was a clear division of behaviour on each side of the pier in the North Sands plot. The changes were more marked in the west than in the east. The surveys were carried out before the early September storm. As a result the profiles show the effect of the summer months on the beach and sediment build up, potentially with a westward sediment drift. **Longer term trends**: The difference plot and beach profiles show that there has been accretion in the west, stability in the middle of the bay and erosion in the east. **Autumn 2008 to Autumn 2015 trends** In the long-term difference plot, erosion dominates. The beach has dropped by up to 1m, particularly in the lower beach and the upper beach in the eastern half of the frontage. There was limited accretion in the mid-beach of the western half and over the rocks in the

Survey Date	Description of Changes Since Last Survey	Interpretation
	remains unchanged since October 2013. Although the front of this foredune was substantially eroded over the winter of 2013/14 it has recovered. From 40m to 80m chainage the beach has remained stable. Between 80m and 110m chainage the beach has accreted by 0.1m. From 110m to 220m chainage the beach has eroded by 0.3m. Between 220m and 270m chainage the beach level has accreted by 0.2m as a berm has formed. From 270m to the end of the survey at 330m chainage there was little change in beach level over the summer of 2015. At Profile **1cHN3a** there has been stability down to the dune face at 20m chainage. Between 20m and 40m chainage the beach level has dropped by 0.5m over the summer where the upper beach has steepened. From 40m and 80m chainage the beach has remained stable. From 80m and 150m chainage the beach has dropped by 0.2m. Between 150m and 220m chainage the beach level has increased by around 0.2m as a lower beach berm has formed. Overall the level is in the mid-to-low range of the previous profiles. At Profile **1cHN4** the whole profile is competitively low and similar to the September 2014 and April 2015 profiles. At 15m chainage there is a rock protrusion which has resulted as a spike in the profile. From 15m to 40m chainage the beach level has dropped by up to 0.3m and rocks are exposed on the beach. Between 40m and 75m chainage the beach has remained stable. From 75m and 110m chainage the rocks on the bottom of the beach are exposed due to a loss of 0.2m of material. The beach level is similar to September 2014. From 110 to the end of the survey at 220m the rocks on the bottom of the beach are exposed in the April and September 2015 profiles. At Profile **1cHN4a** the rocky shore platform is exposed and little has changed since September 2014 and April 2015, except for some intermittent accumulation of sand between high points in the shore platform. The beach here is low compared to profiles recorded in 2012 when sediment covering the shore platform.	eastern half of the plot. **Extended Survey Autumn 2008 to 2015** The dominance of accretion in the north of the survey area ties in with observations that the northern profiles have been accreting and lately have been near their highest levels. Given the erosion present in the annually surveyed area, this indicates a northwards migration of sand from further south in the bay which has exposed the rocky foreshore at Throston. The mixture of limited erosion and accretion on the rocky headland is likely due to movements of relatively small pockets of sand on the predominantly rocky foreshore.
	Topographic Survey: North Sands is covered by an annual topographic survey. Data from the 2015 Full Measures survey have been used to create a DGM (Appendix B – Map 1a) using a GIS package. The majority of the frontage is characterised by shore-parallel contours, except in the vicinity of outfalls, groynes and the pier where contours change direction. The GIS has also been used to calculate the differences between the Autumn 2014 and Autumn 2015	

Survey Date	Description of Changes Since Last Survey	Interpretation
	topographic surveys, as shown in Appendix B – Map 1b, to identify areas of net erosion and accretion. There are two parts to this area of interest with the beach on each side of the central pier behaving differently. On the west of the pier the changes are severe with up to 1m of accretion on the upper beach and 1m of erosion on the lower beach. East of the groyne the changes are more modest with a patchy distribution of change limited to ±0.75m. There was no clear pattern of change but accretion tended to be towards the upper beach and erosion on the lower beach and over the rocks on the shore. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The long term difference plots (Appendix B – Map 1c (i)) provide information on net of change in beach levels between Autumn 2008 and Autumn 2015 at North Sands. The long term difference plot shows the behaviour of the beach is different on the two sides of the pier. On the west there is accretion of up to 0.75m on the upper beach, this is the main area of accretion that was recorded. On the lower beach there has been erosion of more than 1m in a continuous strip along the bottom of the survey. The eastern side of the beach has been dominated by erosion with over 1m of material lost in palaces, there was limited stability over the rocks on the eastern extent of the survey. **North Sands and Headland Extended Survey 2008 to 2015** Appendix B – Map 1a(ii) shows the topography of an extended survey area at North Sands, which includes the beach to the north-west of the annual survey area as far as Crimdon Dene Holiday Park, Appendix B – Map 1c (ii) shows the difference in elevation between the Autumn 2008 and Autumn 2015 survey. The difference plot shows a patchy distribution with more erosion in the east and accretion in the west.	

3.2 Middleton

<table>
<tr><th>Survey Date</th><th>Description of Changes Since Last Survey</th><th>Interpretation</th></tr>
<tr><td rowspan="2">28th Aug 2015</td><td>Beach Profiles:

Middleton is covered by one beach profile line during the Full Measures survey (Appendix A). The upper beach at Profile 1cHC1 between the seawall at 50m chainage and 80m chainage has recovered since the erosion shown in September 2014. Between 80m and 110m chainage the beach level has remained stable. From 110m to 190m chainage the beach has eroded by 0.4m since September 2014. The beach is steep compared to previous profiles and the lower beach is among the lowest level recorded.</td><td rowspan="2">The beach profile showed a gain in the upper beach and a loss in the lower beach and steepening overall. The difference plot for Middleton shows a zone of erosion across the mid beach. In front of the headland the difference plots show a patchy distribution of change due to the thin but mobile cover of sand here.

Longer term trends:

The beach is in the mid-range of the previously recorded levels but is relatively steep. The fact that the profile was recorded in the end of August means that the beginning of the autumn storms would not have had an effect of lowering this beach.

Autumn 2008 to Autumn 2015 trends

The long term plot of change between 2008 and 2015 shows erosion for the whole of Middleton Beach, with modest accretion close to the harbour arm but severe erosion in the centre of the bay. The erosion in the middle of the bay is likely to be due to the refraction and reflection of waves on the hard defences focussing energy onto the central beach.</td></tr>
<tr><td>Topographic Survey:

The frontage is covered by an annual topographic survey between Middleton Jetty and North Pier. Data from the 2015 Full Measures survey have been used to create a DGM (Appendix B – Map 2a) using GIS software. Beach contours indicate a steeper beach in the east than the west, with the contours locally affected by pipelines and groynes. In the Autumn 2013 survey, differences between the eastern and western ends of the beach were less marked. Earlier years show a similar topography to 2014 and 2015.

The GIS has also been used to calculate the differences between the Autumn 2014 and Autumn 2015 topographic surveys, as shown in Appendix B – Map 2b, to identify areas of net erosion and accretion. The beach near the Headland shows a patchy, almost equal distribution of accretion and erosion. At Middleton there is a swath of erosion running diagonally (NE to SW) across the centre of the beach with accretion on both sides. The changes observed at Middleton beach over the year are modest at less than ±0.75m.

Long Term Topographic Trends Autumn 2008 to Autumn 2015:

The long term plot of change at Middleton (Appendix B – Map 2c) shows around 0.75m erosion in the middle of the beach with less than 0.5m accretion close to the groynes and hinterland, most changes in the bay are limited to ±0.25m.</td></tr>
</table>

3.3 Hartlepool Bay

<table>
<tr><th>Survey Date</th><th>Description of Changes Since Last Survey</th><th>Interpretation</th></tr>
<tr><td>10th Nov 2015</td><td>

Beach Profiles:

Hartlepool Bay is covered by four beach profile lines during the Full Measures survey (Appendix A). The profiles were last surveyed in March 2015. Sea coalers had been banned from driving onto the beach in 2013 but on 28th March 2015 the gates were opened and they were allowed to remove coal from the beach again (Hartlepool Mail).

Profile **1cHS1** is located approximately 150m south of the root of the South Pier. The profile starts at the wall to the rear of the promenade and extends across the promenade, over the fronting concrete splash wall and down the sloping face of the rock armour revetment before reaching the beach. Overall the level is similar to the 2014 level. Between 40 and 70m chainage 0.2m has been lost from the upper beach. The upper to mid beach level is high and is at its highest level since monitoring began and has been getting progressively higher.

Profile **1cHS2** is similar to the October 2014 and April 2015 profiles, Which are among the highest recoded. The 2015 profiles ae among the highest recorded and there has been progressive accretion. In October 2014 there was a lower beach berm between 200m and 300m chainage which has been eroded.

At profile **1cHS3** no change has occurred as far as 30m chainage at the base of the sea defences since March 2013. The November profile is very similar to the October 2014 and April 2015 profiles and is among the highest profiles with this area also showing progressive accretion, although the April 2015 profile is up to 0.2m higher in the upper beach. In previous reports the works to the seawall at Seaton Carew and the car park to the south where the alignment of the seawall has been advanced have been discussed. There were also excavations on the beach carried out by the water company. These works now appear to be complete, but will have impacted interim surveys and the behaviour of the beach to some degree.

The profile **1cHS4** is located further south, around 1km north of the North Gare breakwater in an area of undefended dunes at Seaton Sands. The profile covers approximately 325m of dunes before the beach. The dune section is stable, with a foredune continuing to accrete at around 320m chainage with 0.4m of

</td><td>

The profiles in Hartlepool Bay are all similar to the levels shown in the October 2014 and April 2015 surveys. This is likely to be due to the beach accreting more in the summer the levels are dropping back down following the autumn storms.

Profiles HS1-HS3 have all shown progressive accretion since the beginning of the surveys. The beach levels are high. The high beaches may be due to the northward transport of sediment from the dunes.

Longer term trends: The profiles have shown stability over 2015. The accretion of the northern three profiles continues. On the southern profile, HS4, the beach had steepened which could be a precursor to erosion. The foredune continues to develop although footfall may be damaging it and leading to erosion.

Autumn 2010 to Autumn 2015 trends

The small bay north of the promontory at Carr House Sands has been accreting through the survey programme. This is likely to be due to the fact that it is sheltered, locally by South Pier and also by the Headland. It is possible that the promontory at Carr Sands is eroding and material goes to the north bay. In the southern sub-bay there is an almost equal split of accretion in the north and erosion in the south. If this continues the erosion will impact the stability of the southern dunes soon.

</td></tr>
</table>

Survey Date	Description of Changes Since Last Survey	Interpretation
	growth since April 2015. However, the depression landward of this has deepened by around 0.2m since October 2014. Overall the beach is steep with the upper beach comparatively high and the lower beach was one of the lowest levels recorded. Between 350m and 430m chainage the berm which was present in the October 2014 and April 2015 has been lost, resulting in a drop of 0.5m.	
	Topographic Survey: Hartlepool Bay is covered by an annual topographic survey between the South Pier and the North Gare Breakwater. Data from the 2015 Full Measures survey have been used to create a DGM (Appendix B – Map 3a) using a GIS software package. The plot shows the two smaller bays within the larger Hartlepool Bay frontage. These smaller bays are separated by a slight promontory at Carr House Sands between Hartlepool and Seaton Carew. The beach contours are generally shore parallel, except where linear features (e.g. outfalls) and rock outcrops are present, such as in the northern part of Seaton Sands. Elevations at the rear of the beach are lowest in the north of the survey area near South Pier and higher further south. The GIS has also been used to calculate the differences between the Autumn 2014 and Autumn 2015 topographic surveys, as shown in Appendix B – Map 3b, to identify areas of erosion and accretion. The changes recorded over 2015 show a patchy distribution dominated by erosion. The promontory which divides the frontage into two bays had erosion in the north and accretion in the south. The changes in the northern part of the plot were small and with some accretion in the mid to lower beach, this supports the beach profile information. As you move south there is more severe erosion, with the largest change being at the southern extent of the plot where up to 2m has been lost on the upper beach. The distribution of change over 2015 was patchy in the southern part of the bay with erosion on the upper and mid beach and some modest accretion of up to 0.5m on the lower beach. **Long Term Topographic Trends Autumn 2010 to Autumn 2015:** The net changes observed between the first full measures survey in 2010 and the most recent in Autumn 2015 are shown in Appendix B – Map 3c. The plot shows four distinct areas in the two smaller bays which make up this section. Accretion of up to 0.5m in the northern bay, which is supported by the beach profile data for HS1-3. There was erosion of around 0.25m in front of Carr House Sands. In the middle of the southern bay there was accretion of up to 0.5m although there is also a shore parallel strip of erosion. The southern extent of the study area has the largest change, up to 2m of erosion at the top	

Survey Date	Description of Changes Since Last Survey	Interpretation
	of the beach at the southern extent, although the southern part of this survey has been subject to erosion of around 0.75m.	

3.4 North Gare

Survey Date	Description of Changes Since Last Survey	Interpretation
3rd Sept 2015	**Topographic Survey:** North Gare is covered by an annual topographic survey between the North Gare Breakwater and the Seaton on Tees Channel. The area is designated as the Teesmouth National Nature Reserve. Surveys have been carried out since Autumn 2011. Data from the 2015 Full Measures survey have been used to create a DGM (Appendix B – Map 4a) using GIS software. The beach contours recorded in 2015 show the promontory and the contours run shore parallel to the beach in the north. In the south of the study area the contours diverge from the shore line and there is an extensive flat area between the shoreline and MHW. However, the lower beach and foreshore are much steeper in the south of the survey area than in the north. The GIS has also been used to calculate the differences between the Autumn 2014 and Autumn 2015 topographic surveys, as shown in Appendix B – Map 4b, to identify areas of net erosion and accretion. The difference plot shows that overall there has been erosion of around 0.25-0.5m. There was particularly severe erosion of 0.75m on the beach fronting the dunes near the North Gare breakwater. There was a metre of accretion on the seaward side of the promontory but there was also a metre of erosion almost directly north of it. The majority of the accretion was just landward of the promontory but it was mostly modest at less than 0.75m. **Long Term Topographic Trends Autumn 2011 to Autumn 2015:** The long term plot of change at North Gare (Appendix B – Map 4c) is very similar to the plot for Autumn 2014 to Autumn 2014. The long term difference plot is similar to the plot for 2015 because the trends of erosion and accretion in 2014 and 2014 were similar also the number of years of data is limited. The majority of the change is erosion which gets progressively more severe as you move from the estuary side to the coast. The most severe erosion is 1m close to the North Gare Breakwater. There is accretion of up to 1m on the tip of the promontory and immediately landward, including a strip running shore parallel to the coastal side.	The changes seen in the 2015 Full Measures survey is the continuation of the trends seen in the previous survey, with the more discernible areas of shore parallel erosion and accretion in the north of the survey area now showing the reverse trend. This relates to movement of sand bars across the shore face. **Autumn 2011 to Autumn 2015 trends** The longer-term change plot shows a similar pattern to that experienced over the past 12 months suggesting stability of this landform. With more data, the persistence of this pattern will become clearer.

4. Problems Encountered and Uncertainty in Analysis

Beach profile HN1 is located within Durham County Council's area of responsibility but has been reported here so changes can be interpreted in association with those observed elsewhere along North Sands, along HN2, HN3 and HN4.

At Hartlepool North Start of section HN1 was previously a dry river bed, now has water flowing. Bird sanctuary fence installed approximately 20 yards south of HN1.

At North Gare the area south of breakwater difficult to survey due to very soft sand. In the embankment top in south east of survey area difficult to measure as sand dune would collapse when approaching edge, the sand dune is approximately 1.7 metres high.

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

No changes are needed at the present time.

6. Conclusions and Areas of Concern

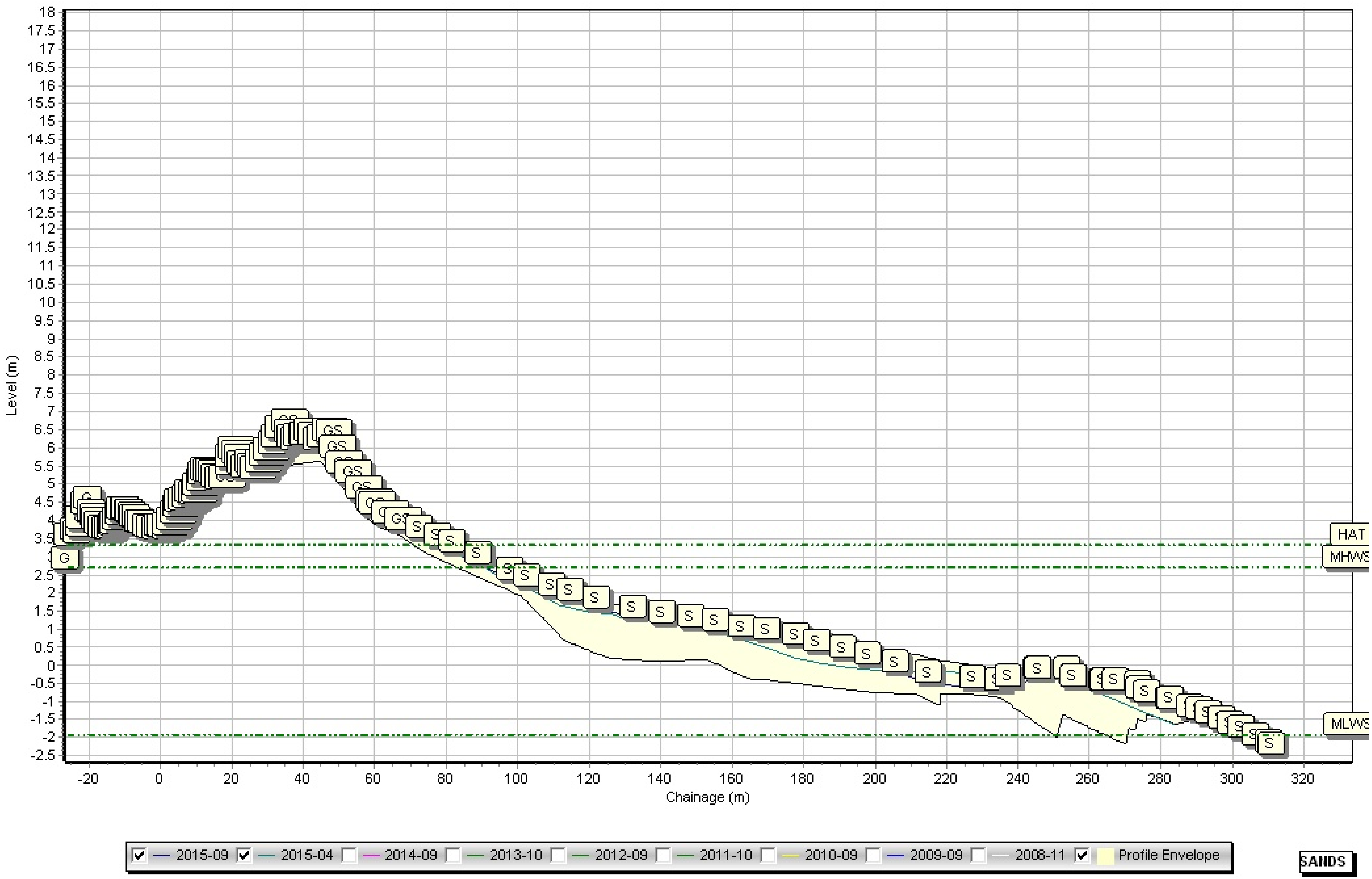
- At North Sands, the beach profiles and topographic plots show that the beach is comparatively low in the south of the survey area and high in the north, and it is likely that sediment is moving northwards in the bay. The long term difference plot supports this, with the southern half showing erosion and the northern half showing accretion on the upper beach.
- At Middleton, the centre of the bay has eroded over 2015 and the long term difference plot shows erosion overall with the centre of the beach having the largest change of 0.75m. The continuing erosion of the beach is expected because there are no sources of sediment to the Middleton frontage. The beach in front of the headland had a patchy distribution of change in 2015.
- The majority of changes through 2015 in Hartlepool Bay were modest. Profiles HS1-3 show progressive accretion, which is also supported by the long term difference plot. The long term difference plot also showed erosion at the southern extent of the bay, which could impact on the stability of the dunes if it continues.
- The topographic plots show a continuation of the elevation changes observed in 2013 to 2014 at North Gare. Through 2015 there was modest erosion overall with some accretion at the tip of the promontory.
- There is no cause for concern at any of these areas.

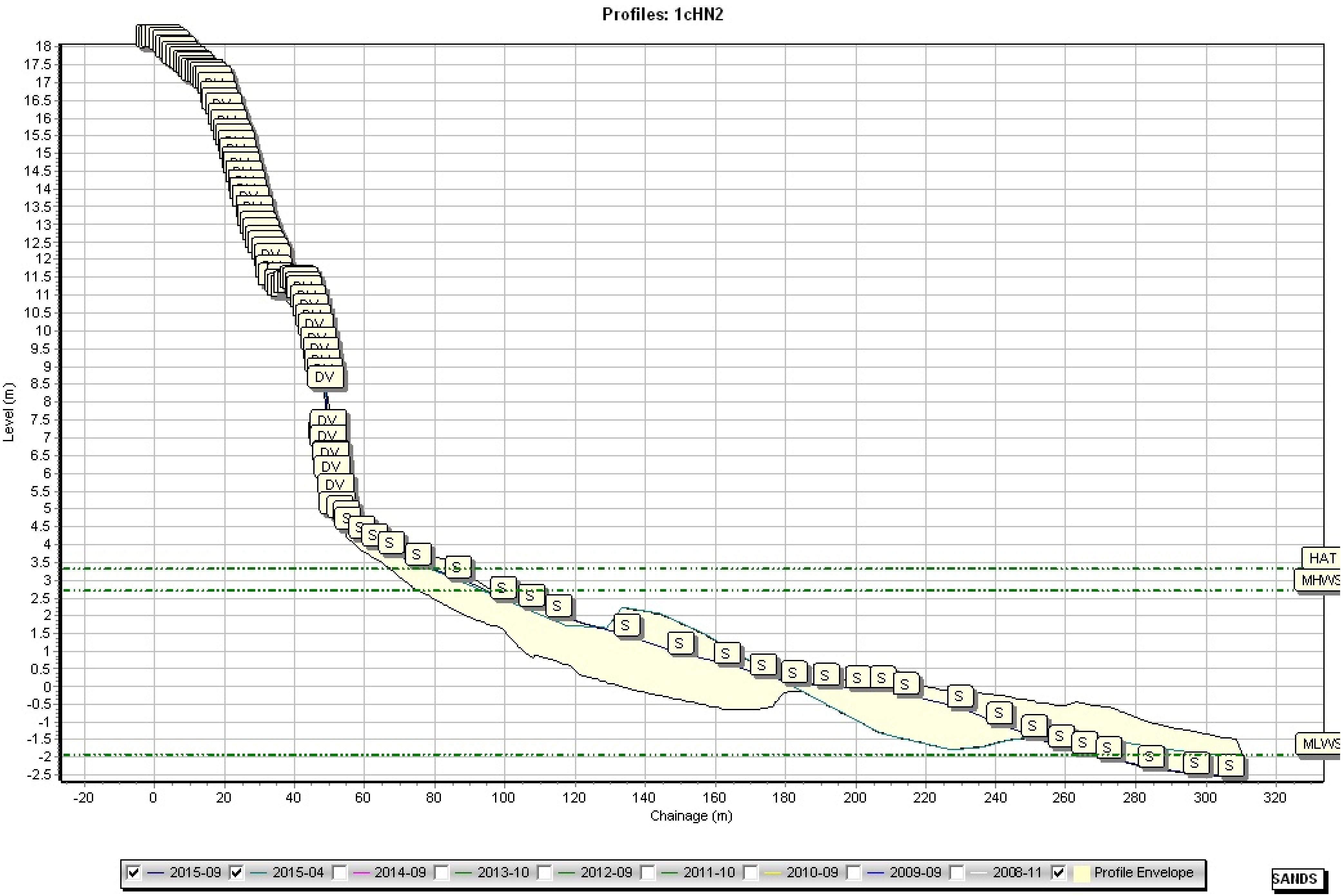
Appendices

Appendix A

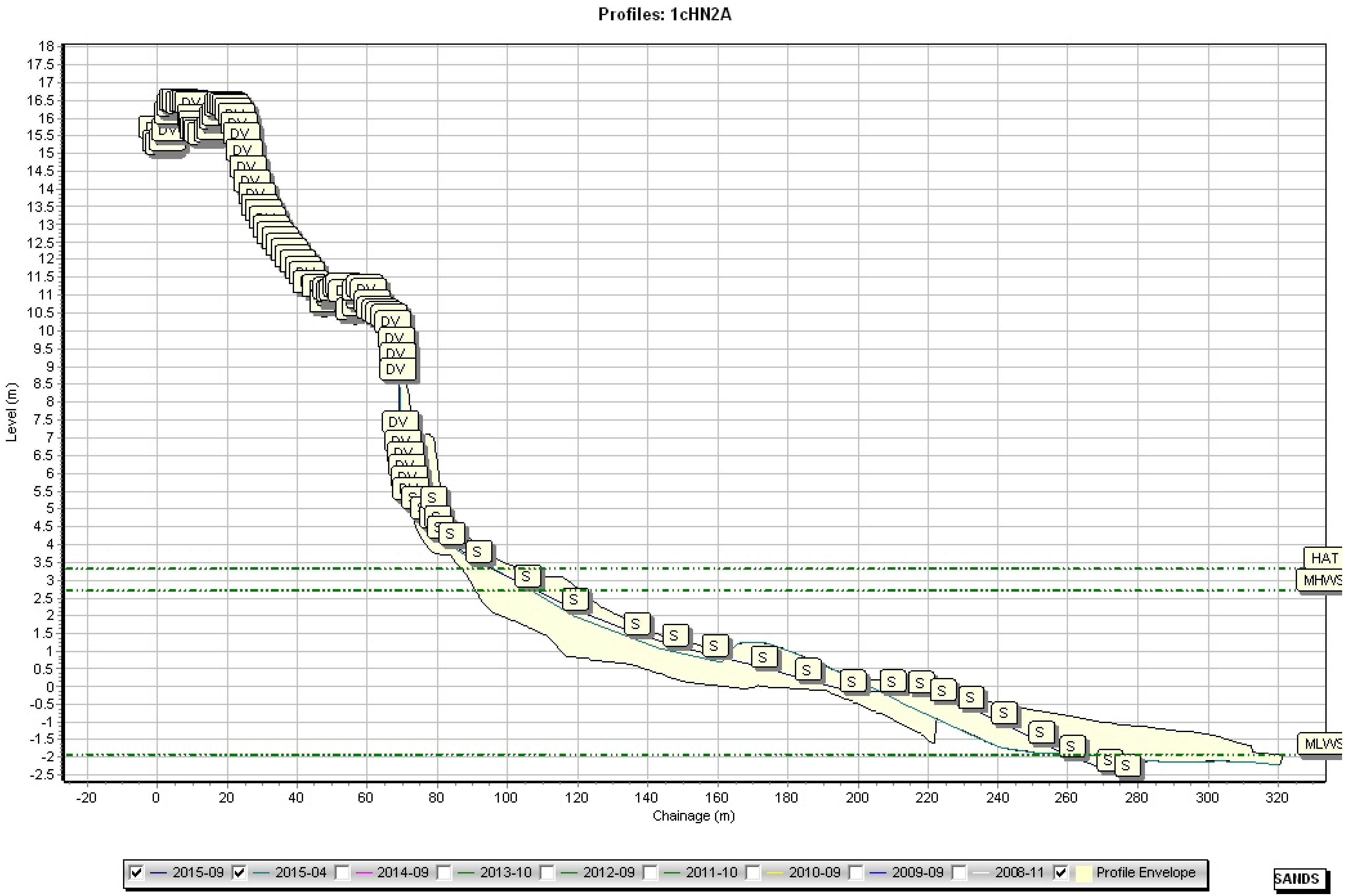
Beach Profiles

Profiles: 1cHN1

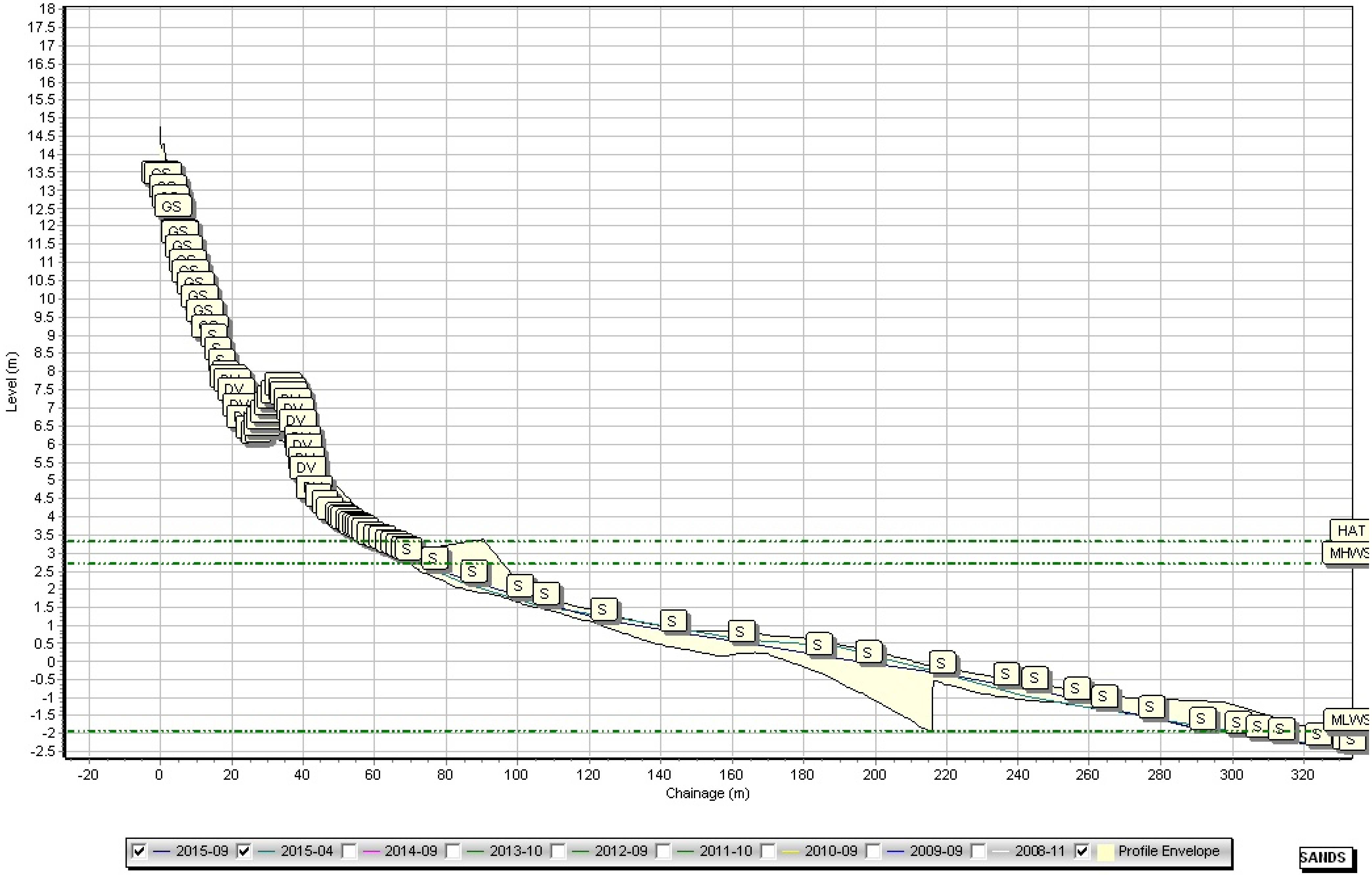




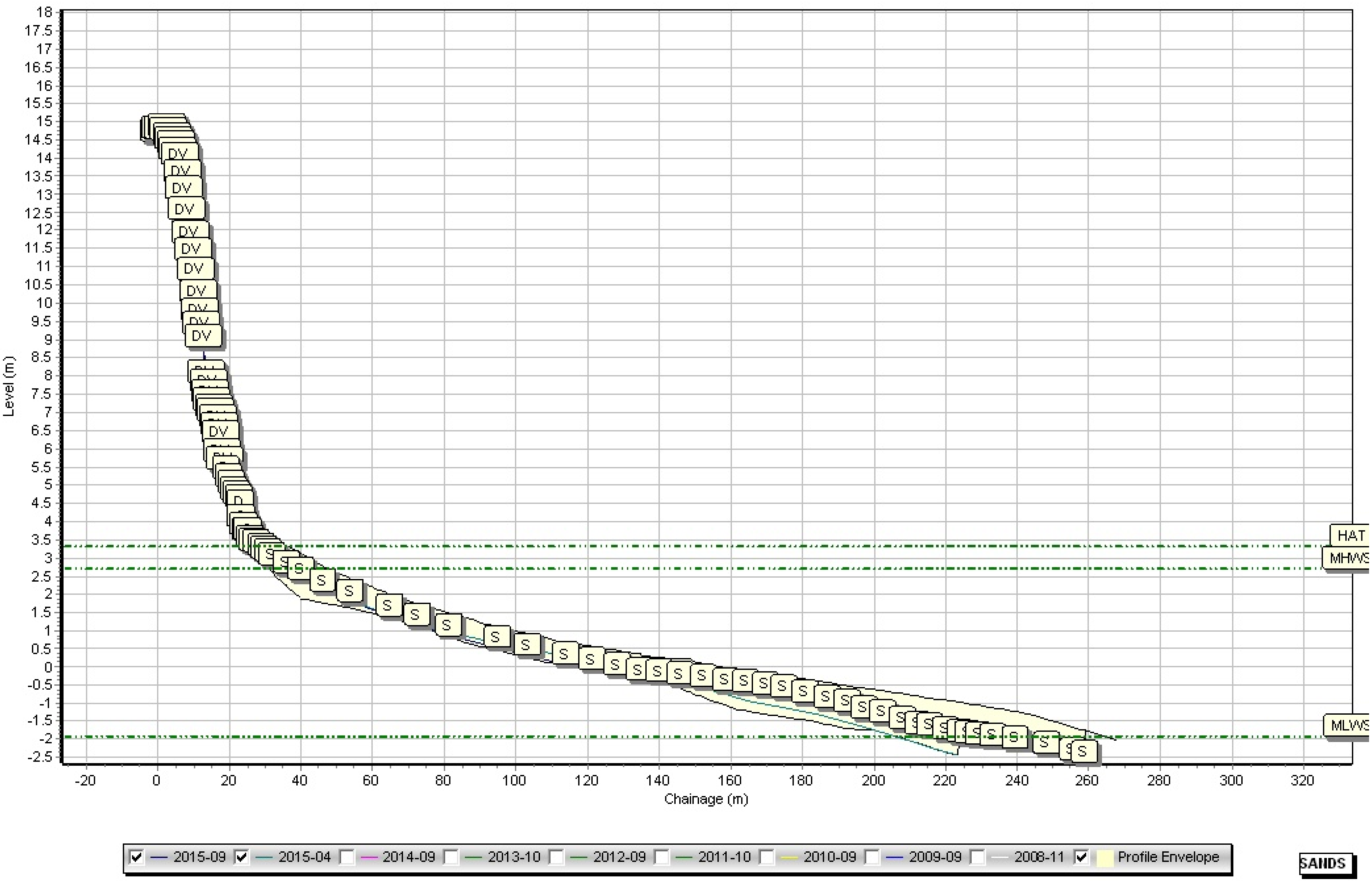
Profiles: 1cHN2
Level (m)
Chainage (m)
HAT
MHWS
MLWS
DV
S
2015-09
2015-04
2014-09
2013-10
2012-09
2011-10
2010-09
2009-09
2008-11
Profile Envelope
SANDS

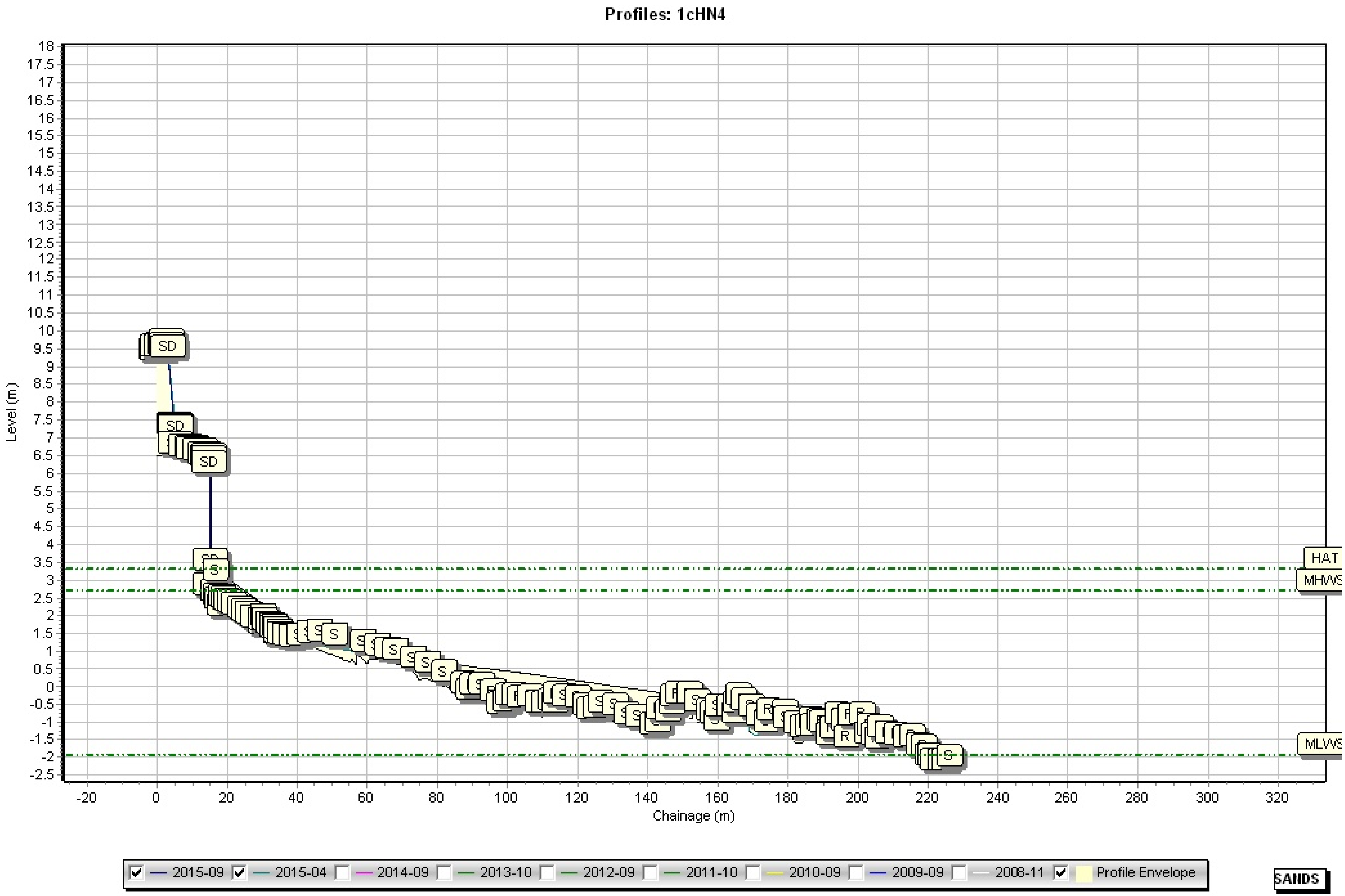

Profiles: 1cHN2A
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-09
2015-04
2014-09
2013-10
2012-09
2011-10
2010-09
2009-09
2008-11
Profile Envelope
SANDS

Profiles: 1cHN3

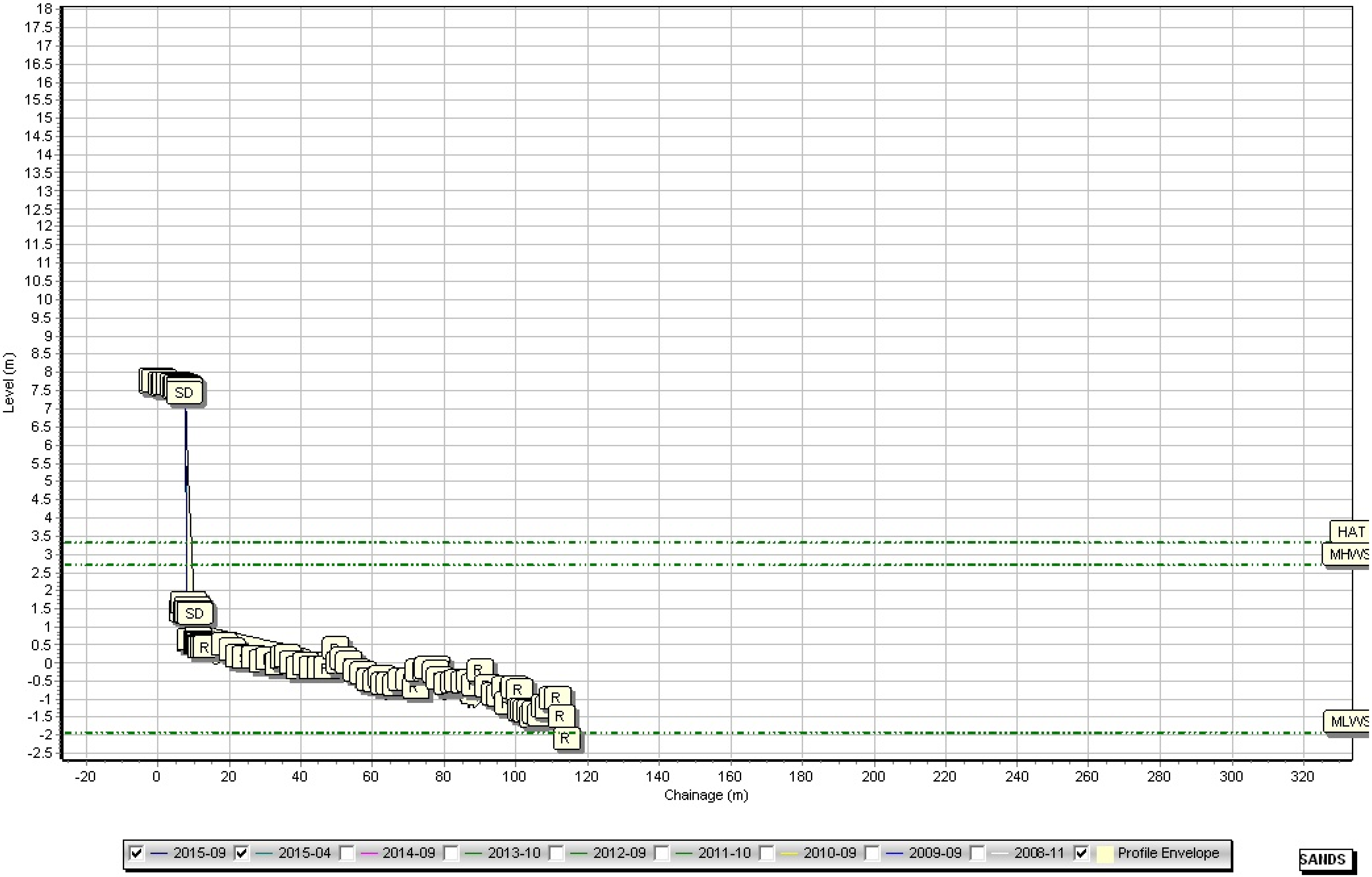


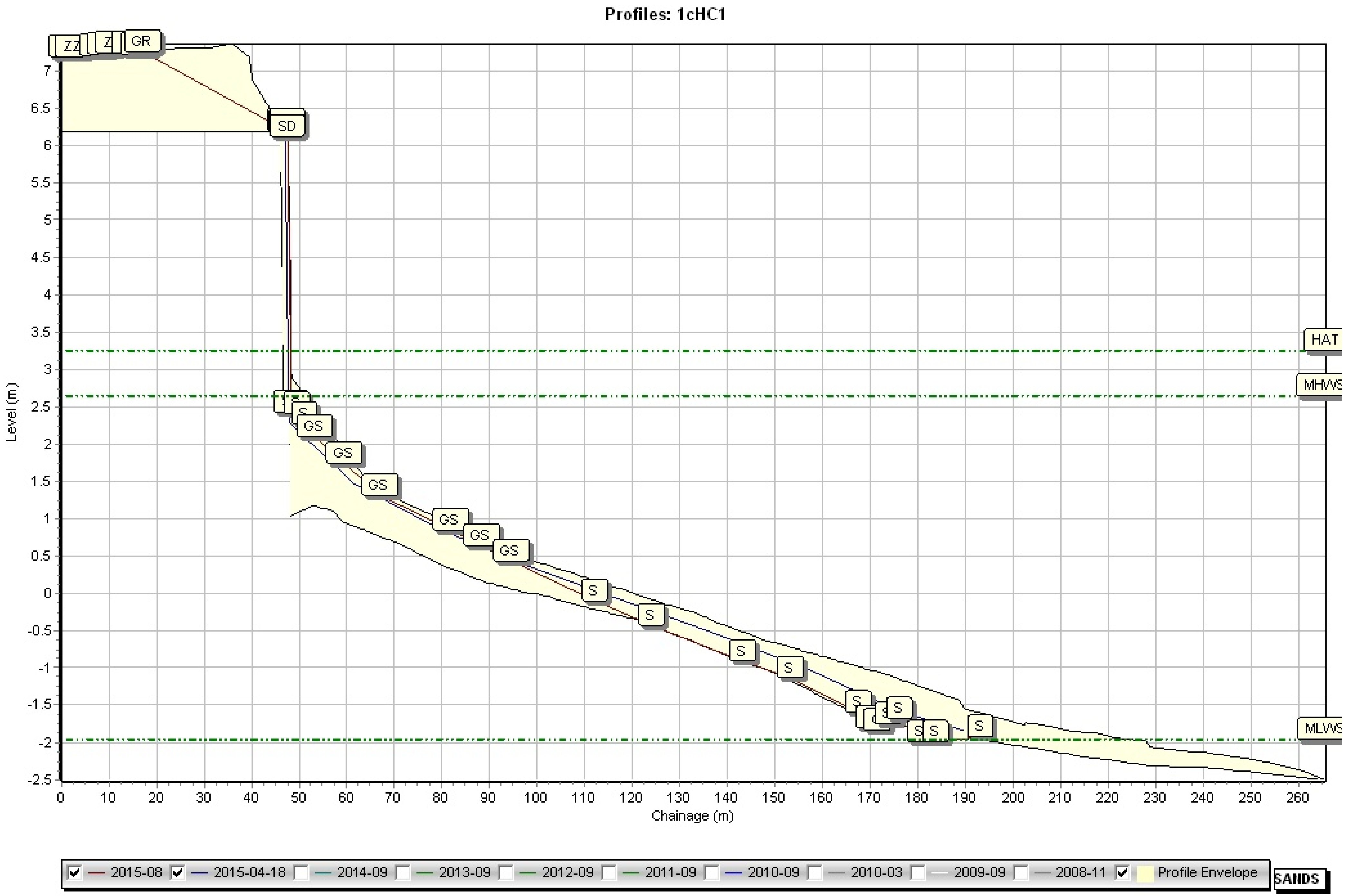
Profiles: 1cHN3A



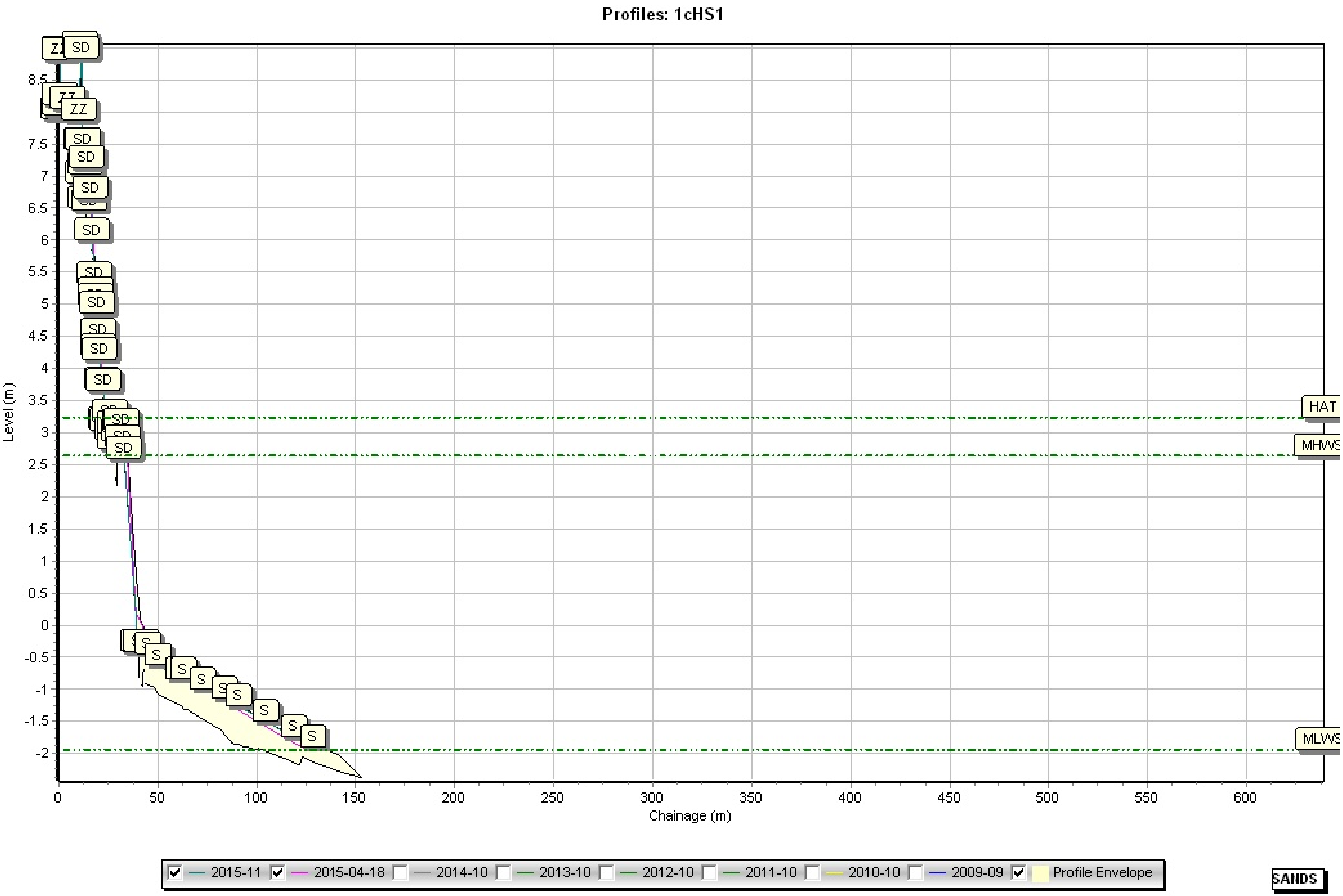

Profiles: 1cHN4
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-09
2015-04
2014-09
2013-10
2012-09
2011-10
2010-09
2009-09
2008-11
Profile Envelope
SANDS

Profiles: 1cHN4A

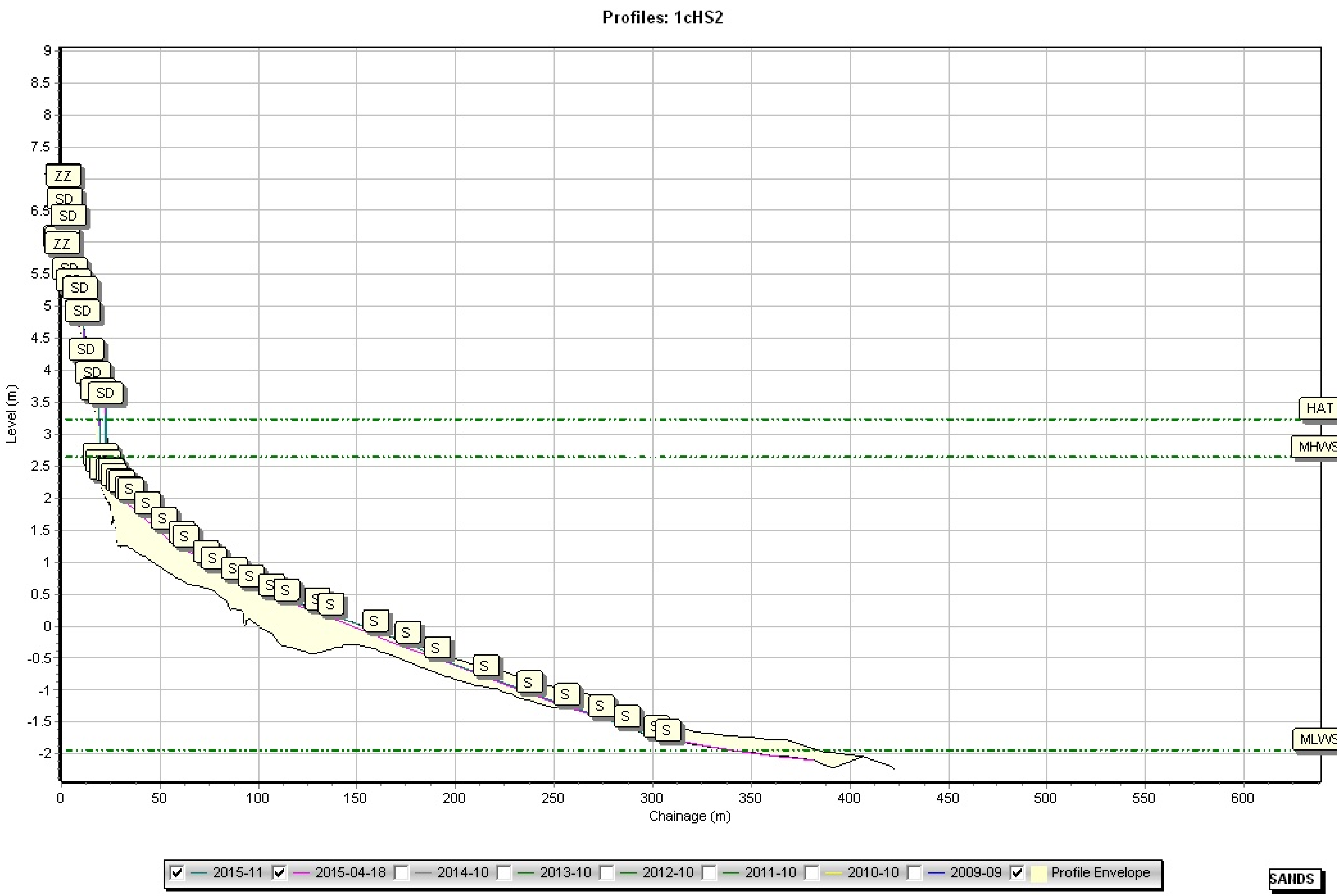


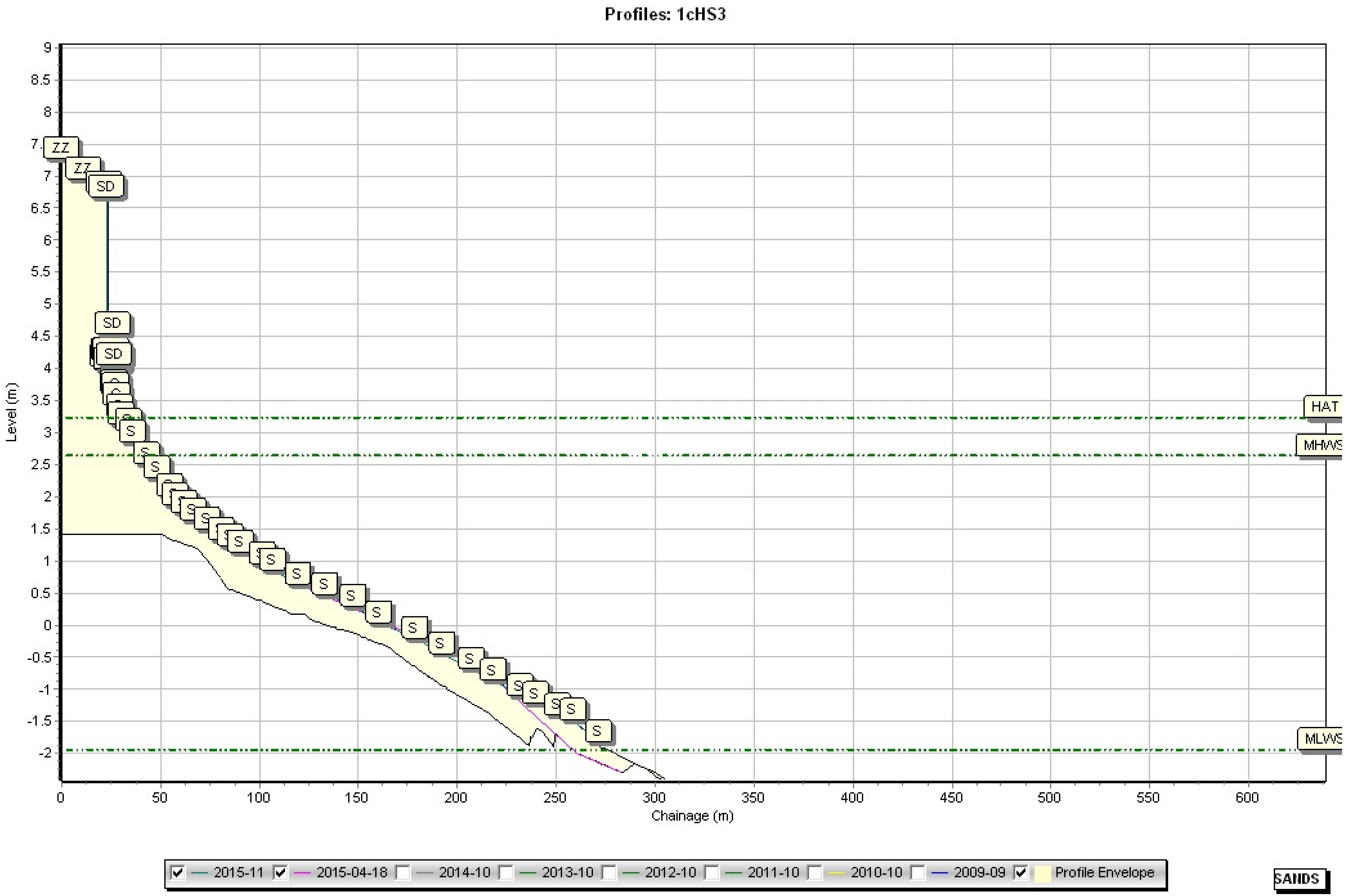


Profiles: 1cHC1
Level (m)
Chainage (m)
ZZ
Z
GR
SD
S
GS
HAT
MHWS
MLWS
2015-08
2015-04-18
2014-09
2013-09
2012-09
2011-09
2010-09
2010-03
2009-09
2008-11
Profile Envelope
SANDS

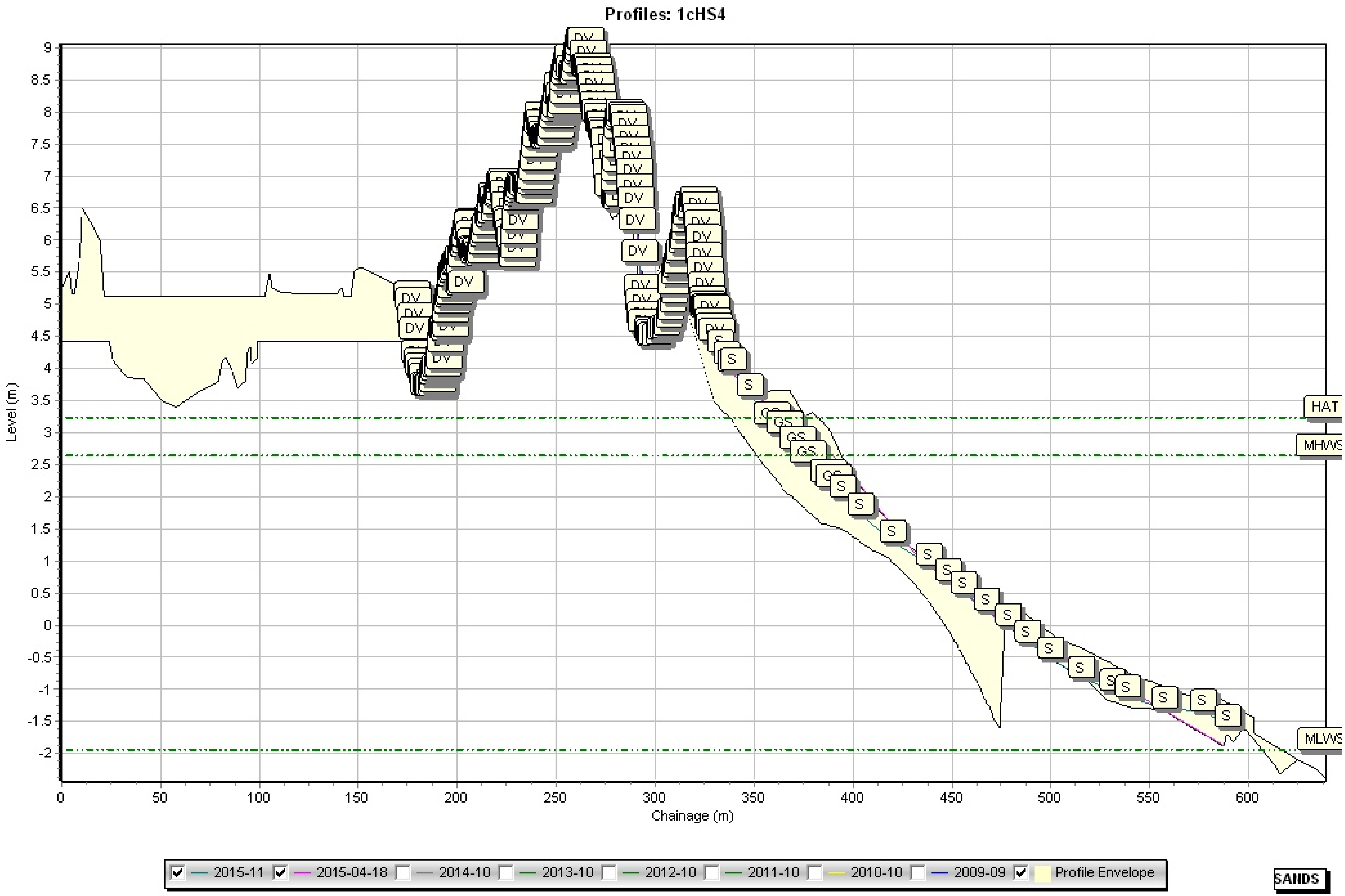


Profiles: 1cHS1
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
ZZ
S
2015-11
2015-04-18
2014-10
2013-10
2012-10
2011-10
2010-10
2009-09
Profile Envelope
SANDS


Profiles: 1cHS2
Level (m)
Chainage (m)
ZZ
SD
S
HAT
MHWS
MLWS
2015-11
2015-04-18
2014-10
2013-10
2012-10
2011-10
2010-10
2009-09
Profile Envelope
SANDS



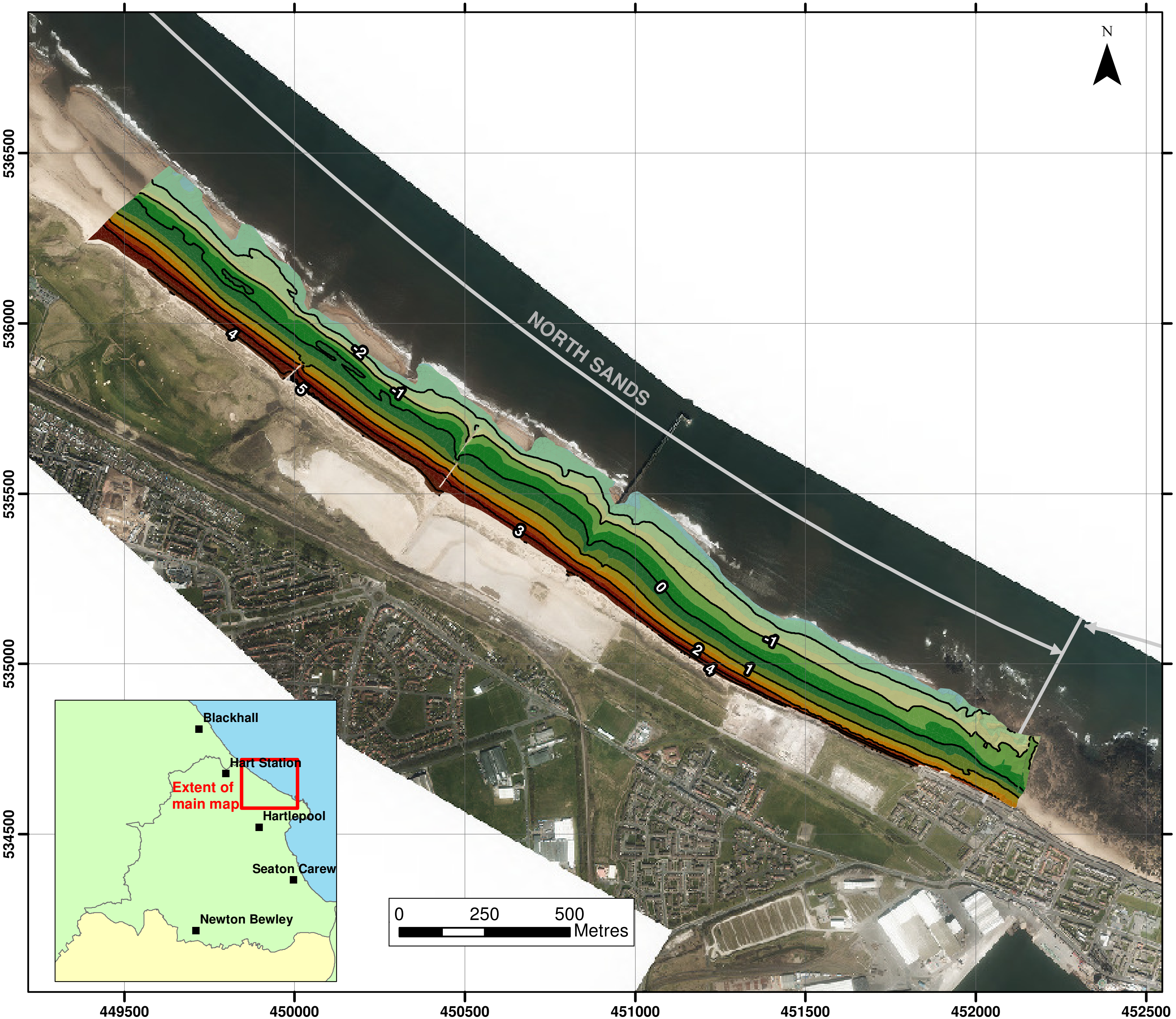
Profiles: 1cHS3
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2015-04-18
2014-10
2013-10
2012-10
2011-10
2010-10
2009-09
Profile Envelope
SANDS



Profiles: 1cHS4
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2015-04-18
2014-10
2013-10
2012-10
2011-10
2010-10
2009-09
Profile Envelope
SANDS

Appendix B

Topographic Survey



KEY

Elevation (m OD)

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

Contour 1m

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

Appendix B - Map 1a(i)
Topographic Survey
North Sands
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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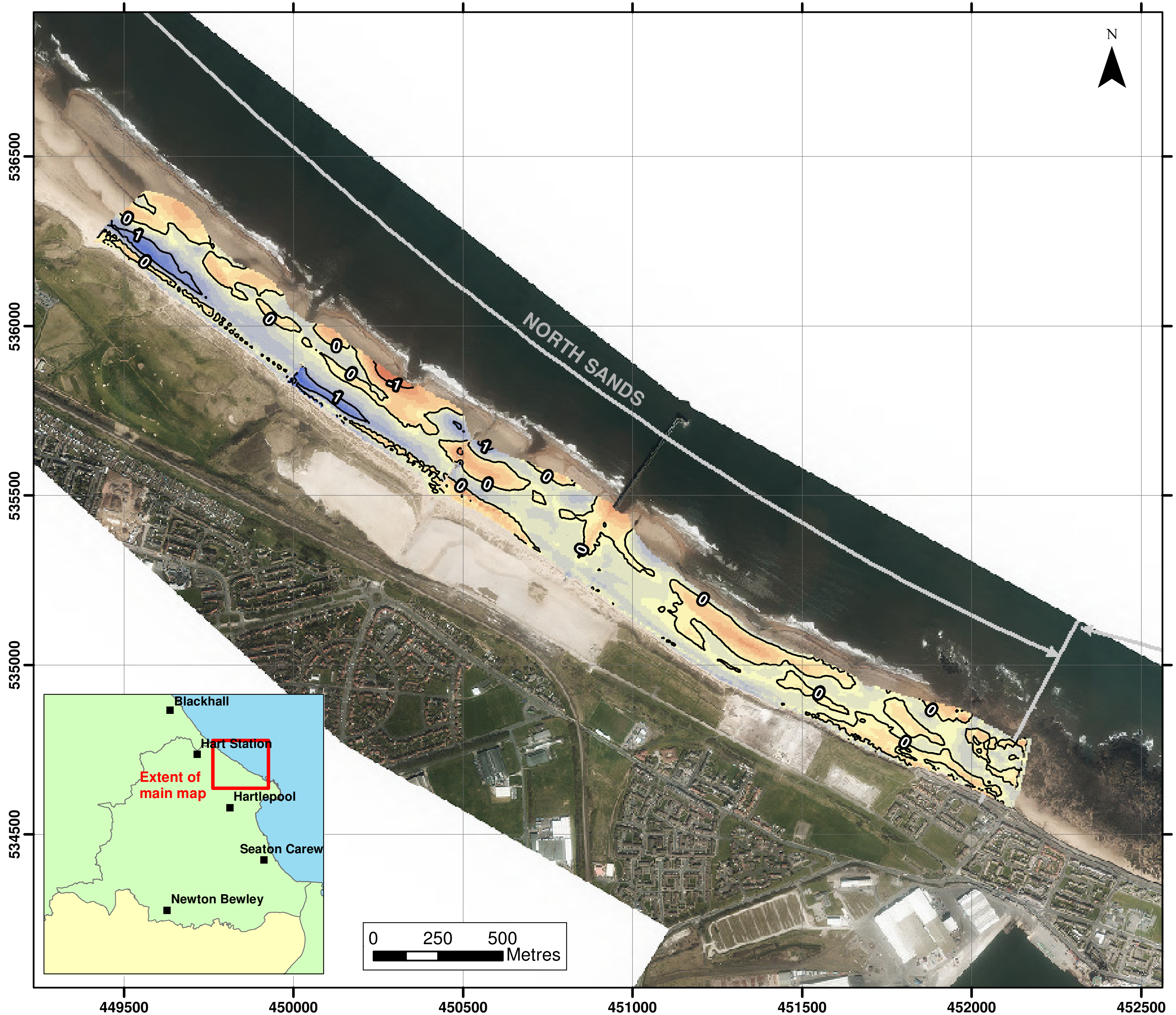

KEY Autumn 2014 and Autumn 2015
Change in elevation (m)

<-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 1b
Short-term Elevation Change North Sands Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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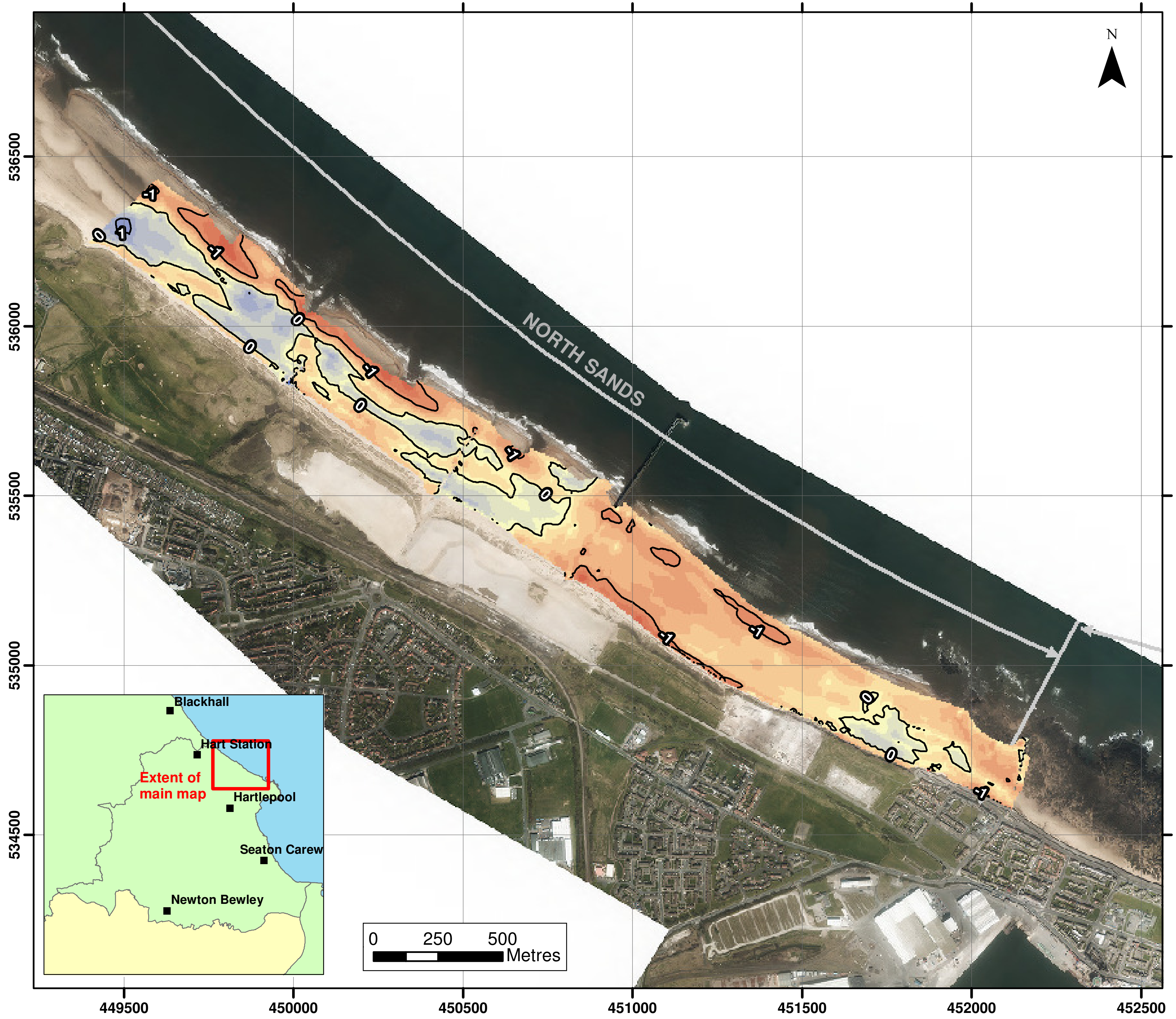

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

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 1c
Long-term Elevation Change North Sands Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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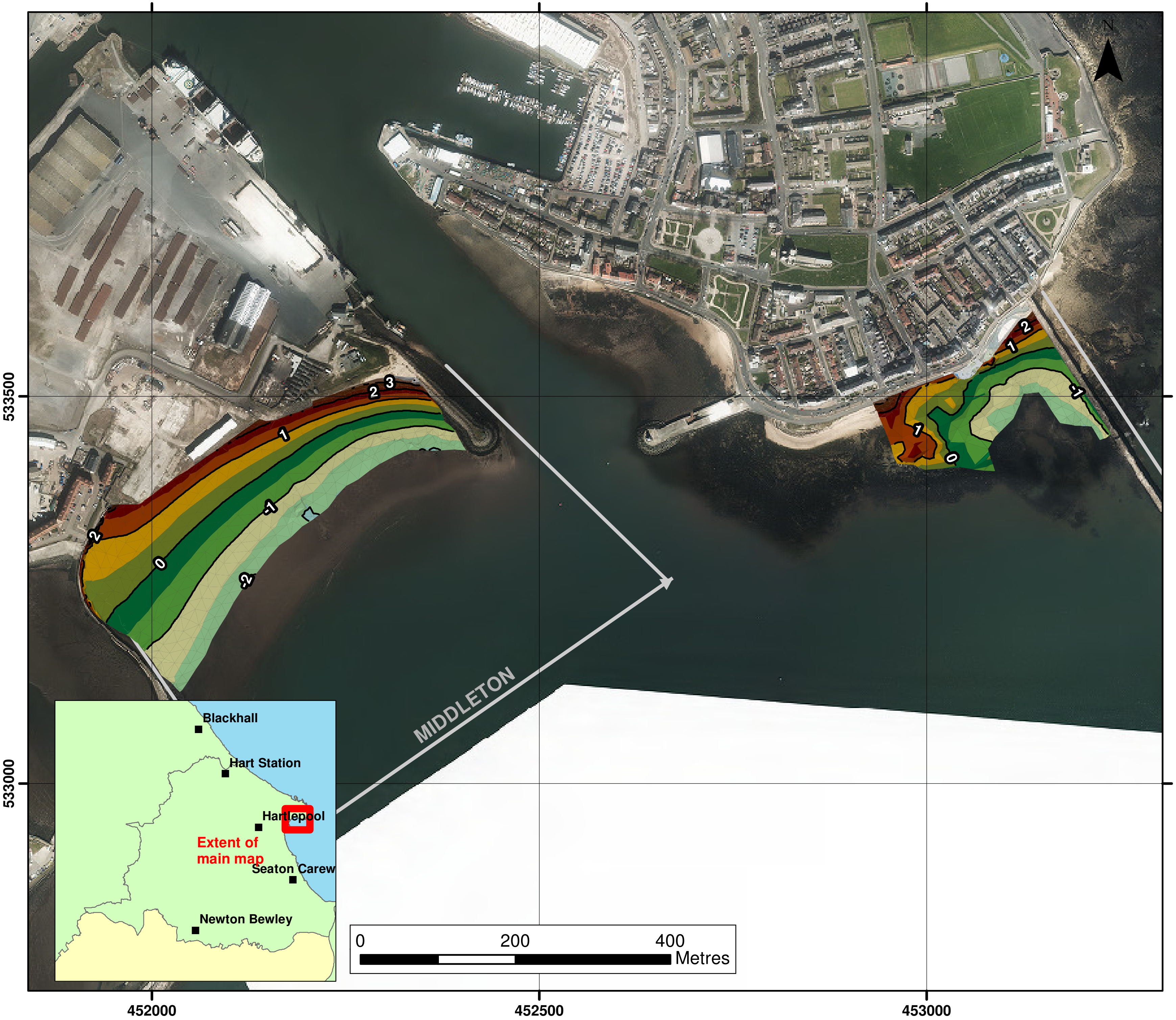

KEY

Elevation (m OD)

- 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 2a
Topographic Survey
Headland and Middleton
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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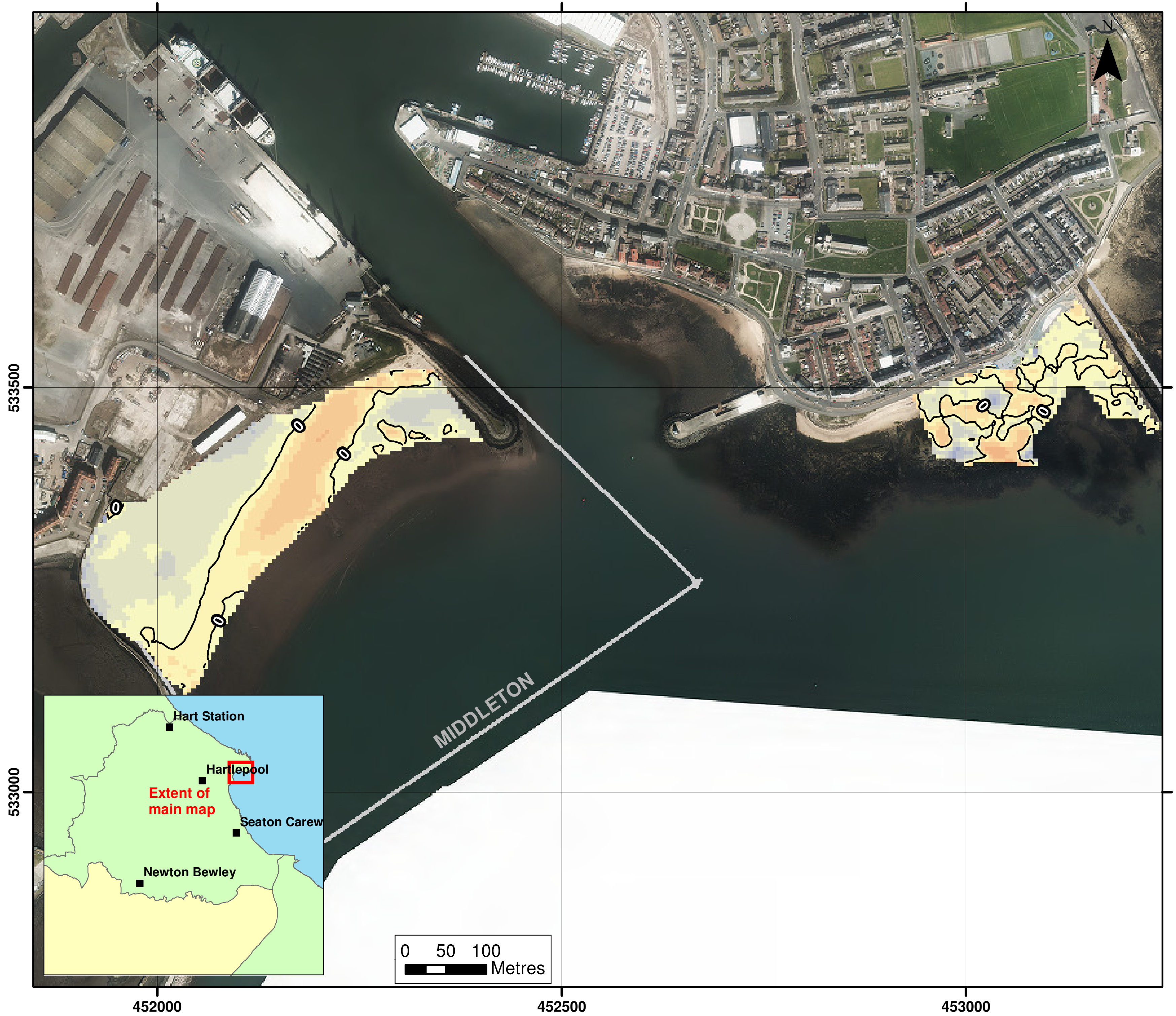

KEY Autumn 2014 and Autumn 2015
Change in elevation (m)

<-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
Middleton and Headland
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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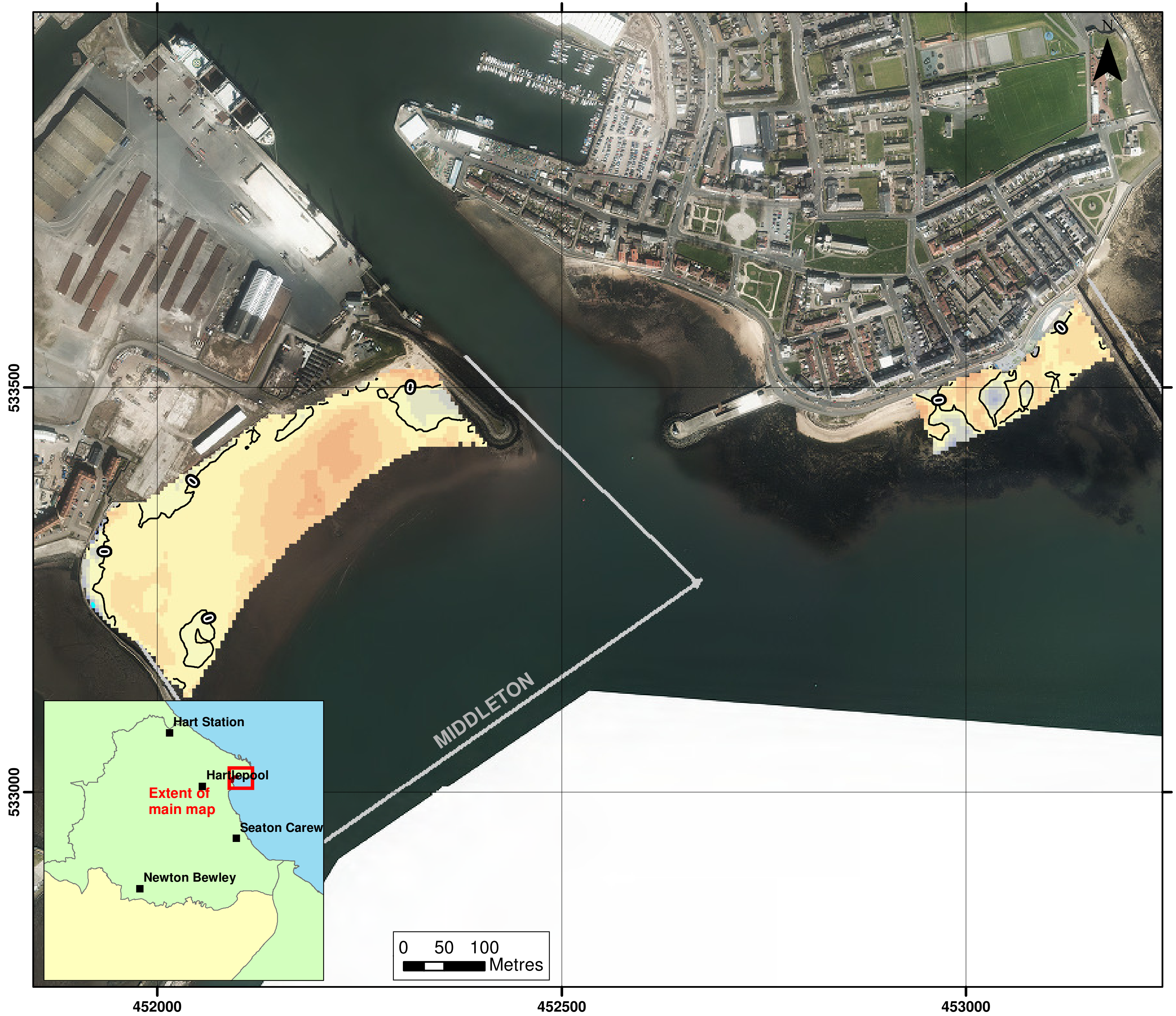

KEY Autumn 2008 and Autumn 2015

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 2c
Long-term Elevation Change Headland and Middleton Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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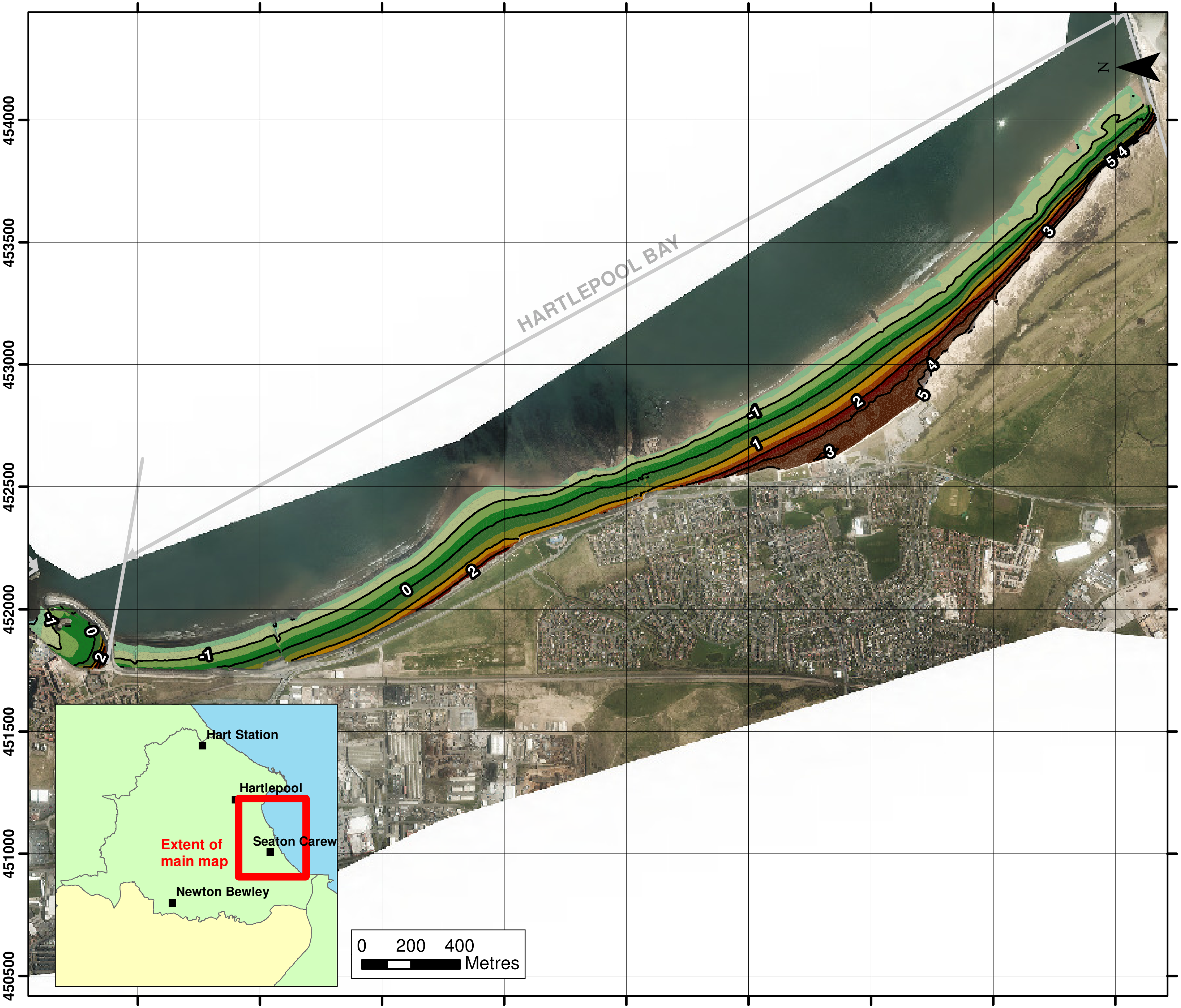

KEY

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
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 3a
Topographic Survey
Hartlepool Bay
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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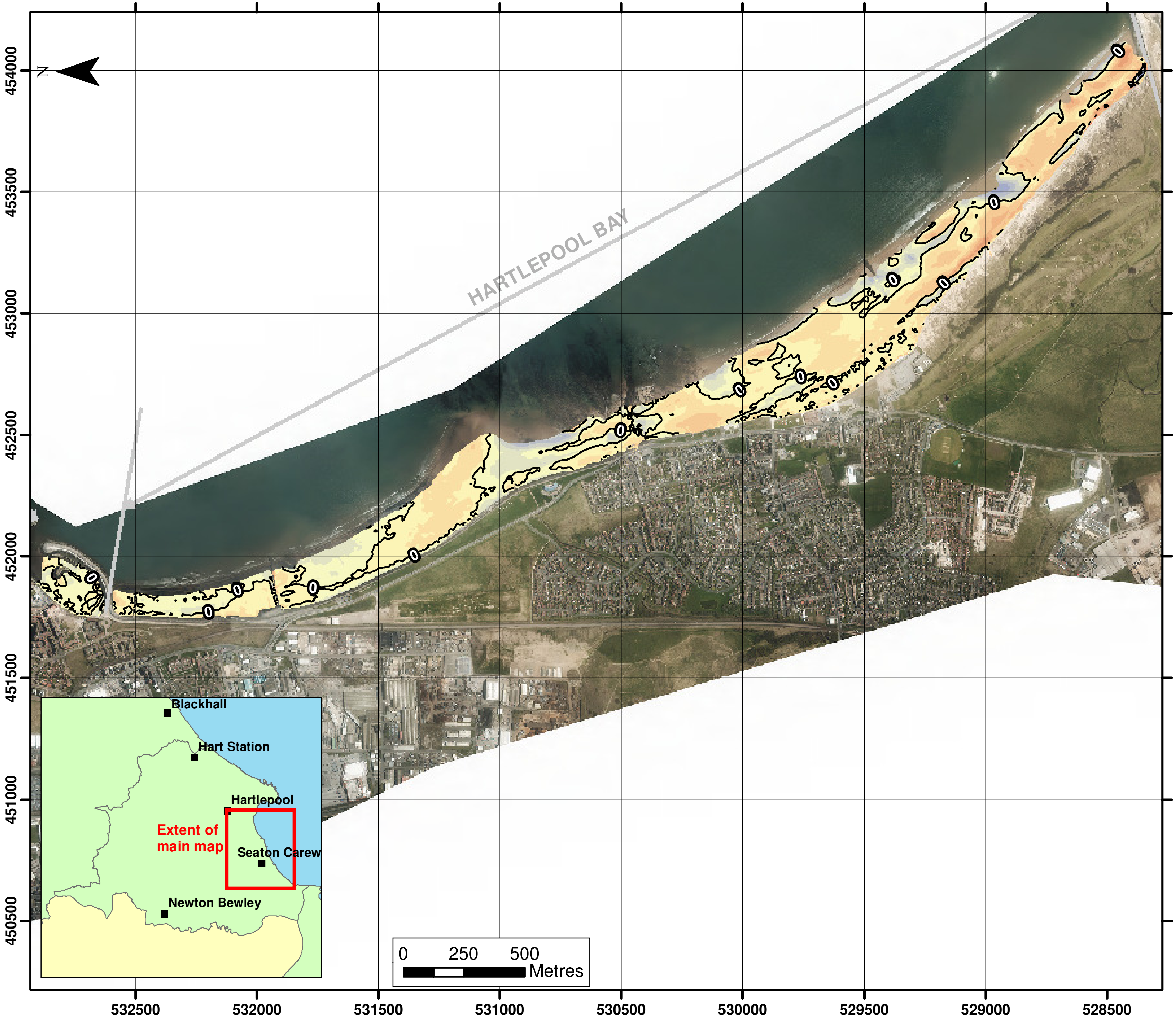

KEY Autumn 2014 and Autumn 2015
Change in elevation (m)

- <-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 3b Short-term Elevation Change Hartlepool Bay Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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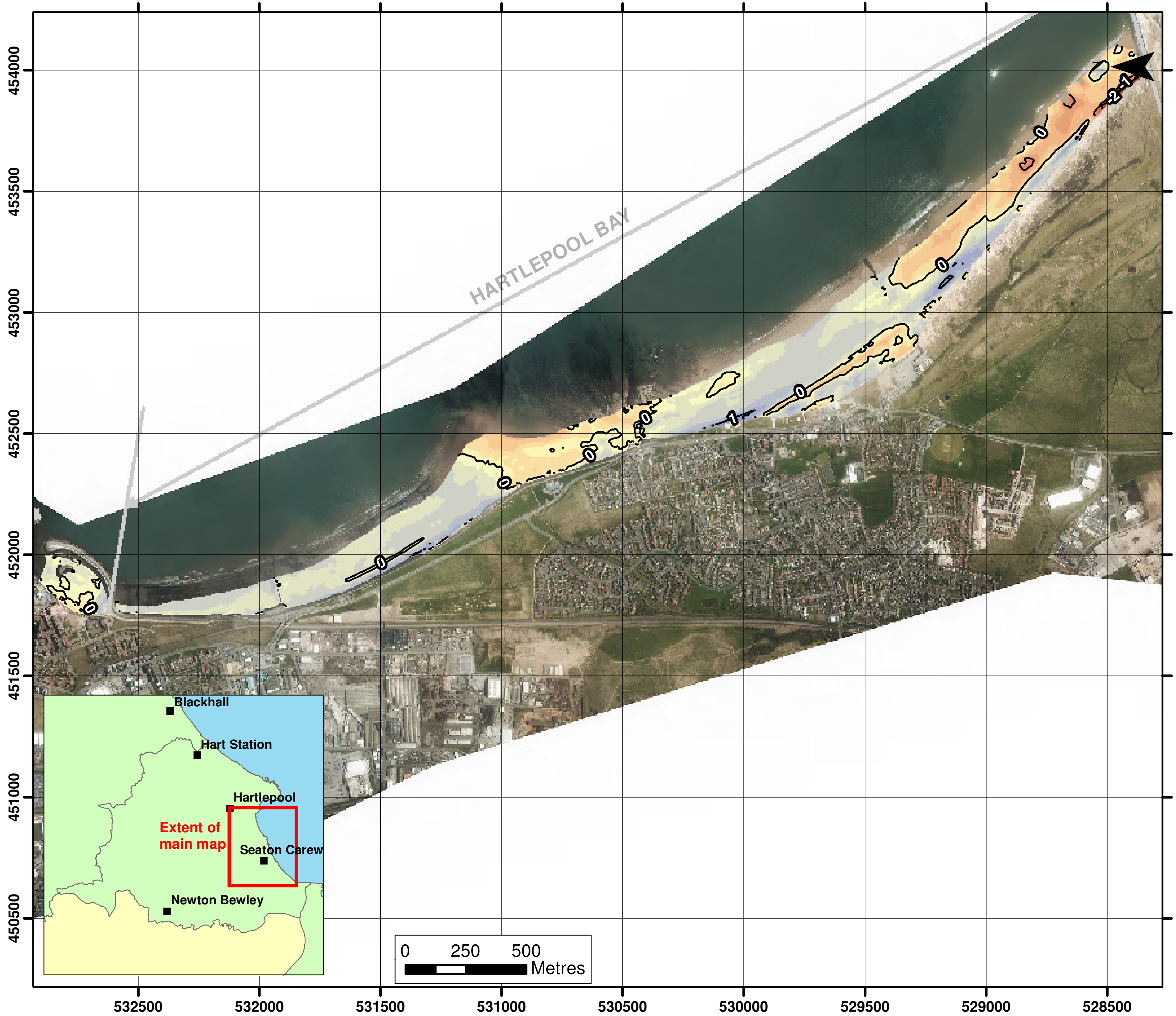

KEY **Autumn 2010 and Autumn 2015**
Change in elevation (m)

- <-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 Hartlepool Bay Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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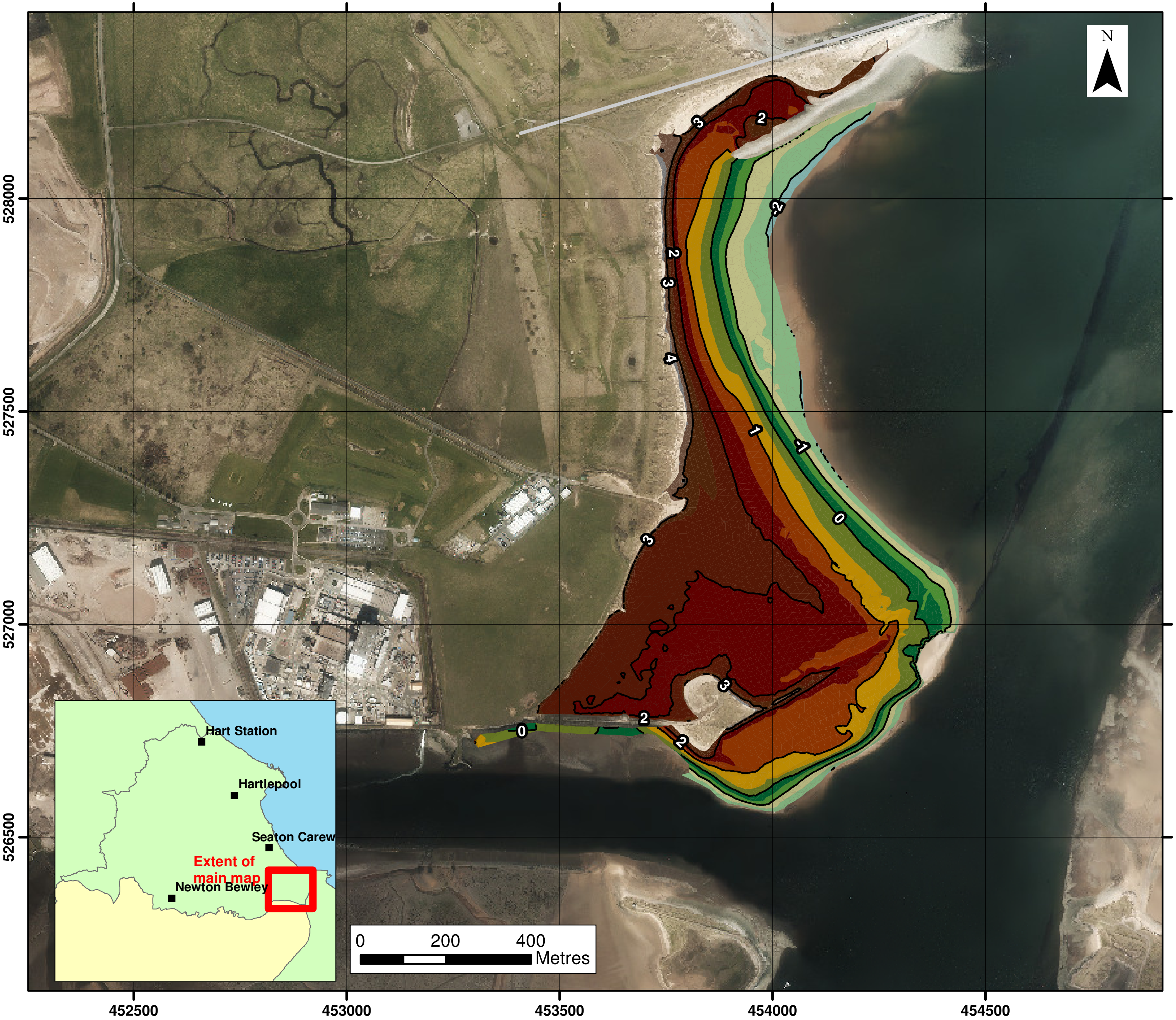

KEY

Elevation (m OD)

- 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 4a
Topographic Survey
Hartlepool North Gare
Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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KEY Autumn 2014 and Autumn 2015
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 4b Short-term Elevation Change Hartlepool North Gare Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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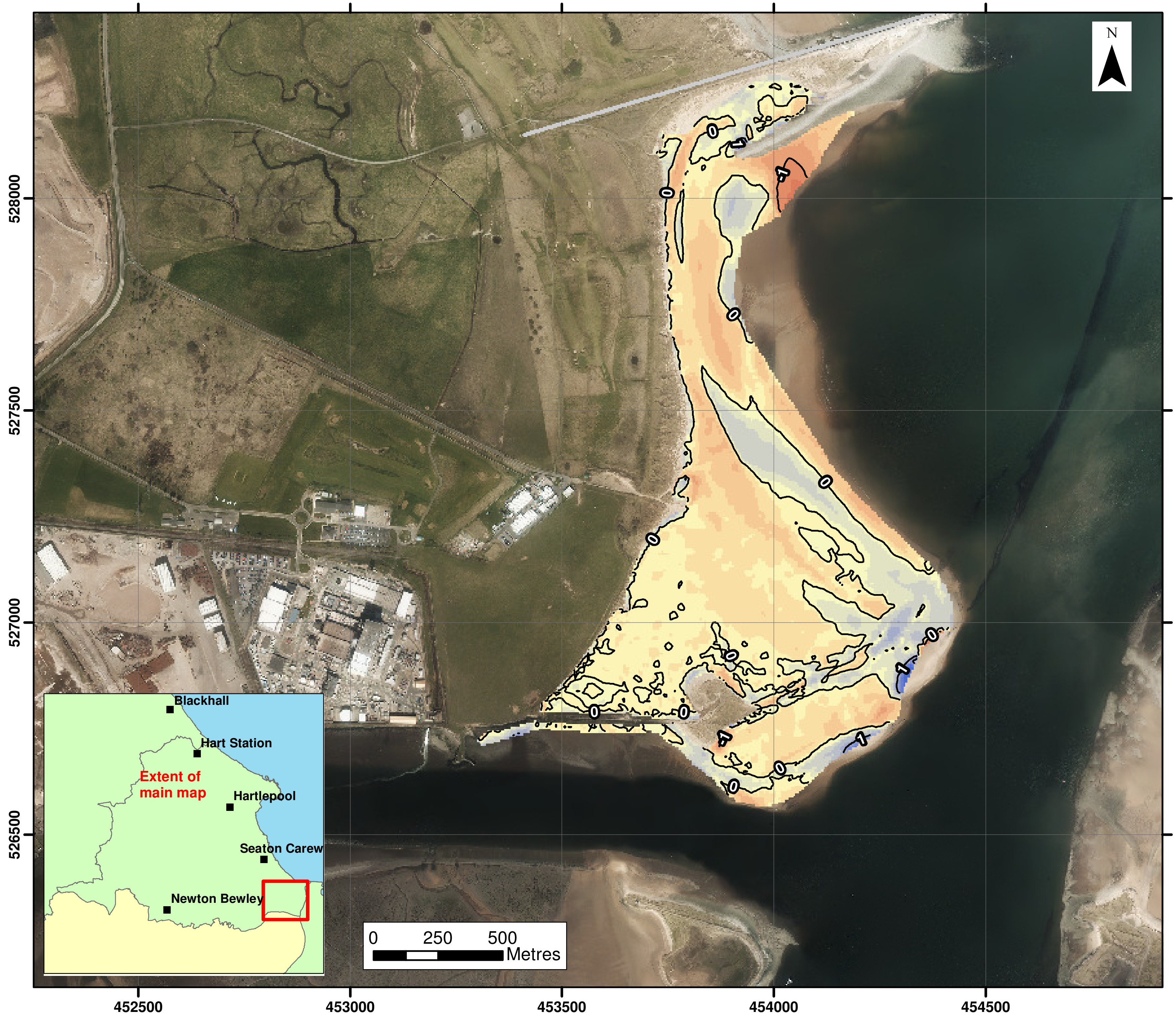

KEY Autumn 2011 and Autumn 2015
Change in elevation (m)

- <-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 4c
Long-term Elevation Change Hartlepool North Gare Hartlepool Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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