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# Cell 1 Regional Coastal Monitoring Programme
# Analytical Report 4 Full Measures Survey 2011

## Scarborough Council
## Final Report

## October 2012

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## Abbreviations and Acronyms

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

## Water Levels Used in Interpretation of Changes

| | Water Level (m AOD) | | | |
|---|---|---|---|---|
| **Water Level Parameter** | **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 |
| **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** |
| 1 in 200 year | 3.88 | 3.93 | 3.93 | 4.04 |
| 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 northeast England 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.

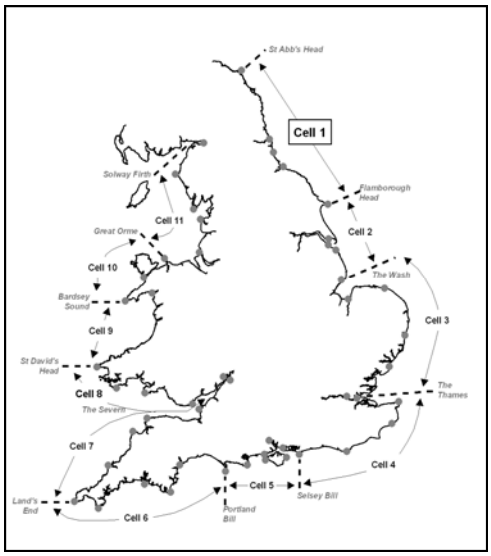



**Figure 1 Sediment Cells in England and Wales**

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 AONB
Sunderland City Council
Durham County Council
Redcar & Cleveland Borough Council
Hartlepool Borough Council
Whitby Scarborough Filey 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.

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.

A Cell 1 Overview Report is also produced regularly to provide 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 | Sept 11 | Aug 12 (*) | | | |

(*) The present report is **Analytical Report 4** and provides an analysis of the autumn/winter 2011 Full Measures survey for Scarborough 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. Areas covered in the current report are highlighted

**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

Scarborough Borough Council's frontage extends from Staithes Harbour to Speeton, in Filey Bay. For the purposes of this report, it has been sub-divided into eight areas, namely:

- Staithes
- Runswick Bay
- Sandsend Beach, Upgang Beach and Whitby Sands
- Robin Hood's Bay
- Scarborough North Bay
- Scarborough South Bay
- Cayton Bay
- Filey Bay

## 1.2 Methodology

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

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along 20 transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey along the Sandsend to Whitby frontage
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Scarborough North Bay
    - Topographic survey at Scarborough South Bay
    - Topographic survey at Cayton Bay
    - Topographic survey at Filey Bay

- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 20 transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Filey Bay (Town coverage)

- Cliff top survey annually at:
    - Staithes
    - Robin Hood's Bay (added Spring 2010)
    - Scarborough South Bay (added Spring 2010)
    - Cayton Bay
    - Filey

The location of these surveys is shown in Figure 2. The Full Measures survey was undertaken along this frontage between 16th and 29th September 2011. The weather for Runswick, Robin Hoods Bay, Scarborough North and Scarborough South surveys was Fine and dry with a calm sea state. When Cayton and Filey Bay were surveyed the weather was windy, bright and dry with a moderate sea state. During the 2011 Whitby Survey the weather was hot and dry with a calm sea state.

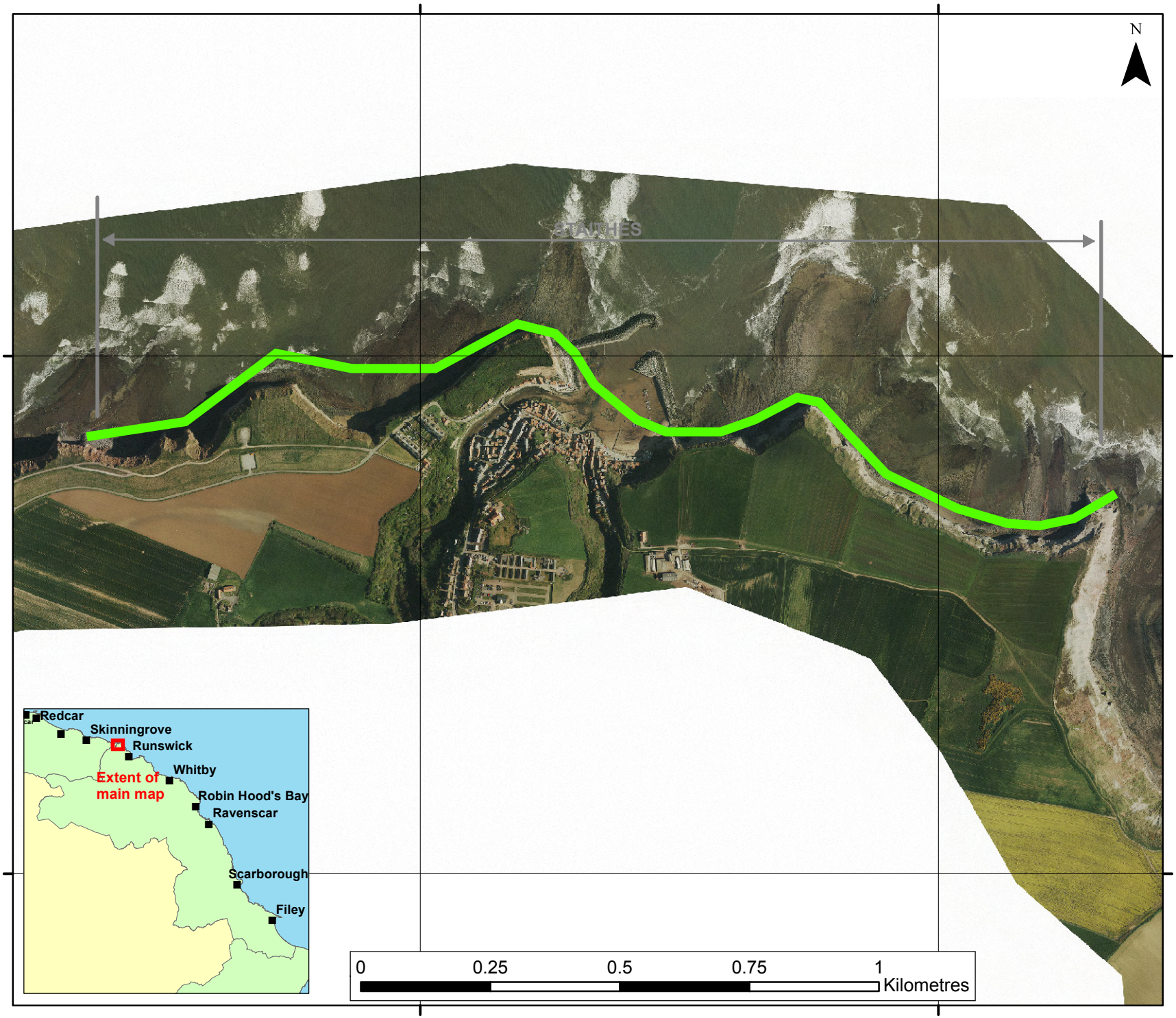
All data have been captured in a manner commensurate with the principles of the Environment Agency's *National Standard Contract and Specification for Surveying Services* and stored in a file format compatible with the software systems being used for the data analysis, namely SANDS and ArcGIS. This data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

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

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

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

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




## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 1
# Survey Locations
# Staithes
# Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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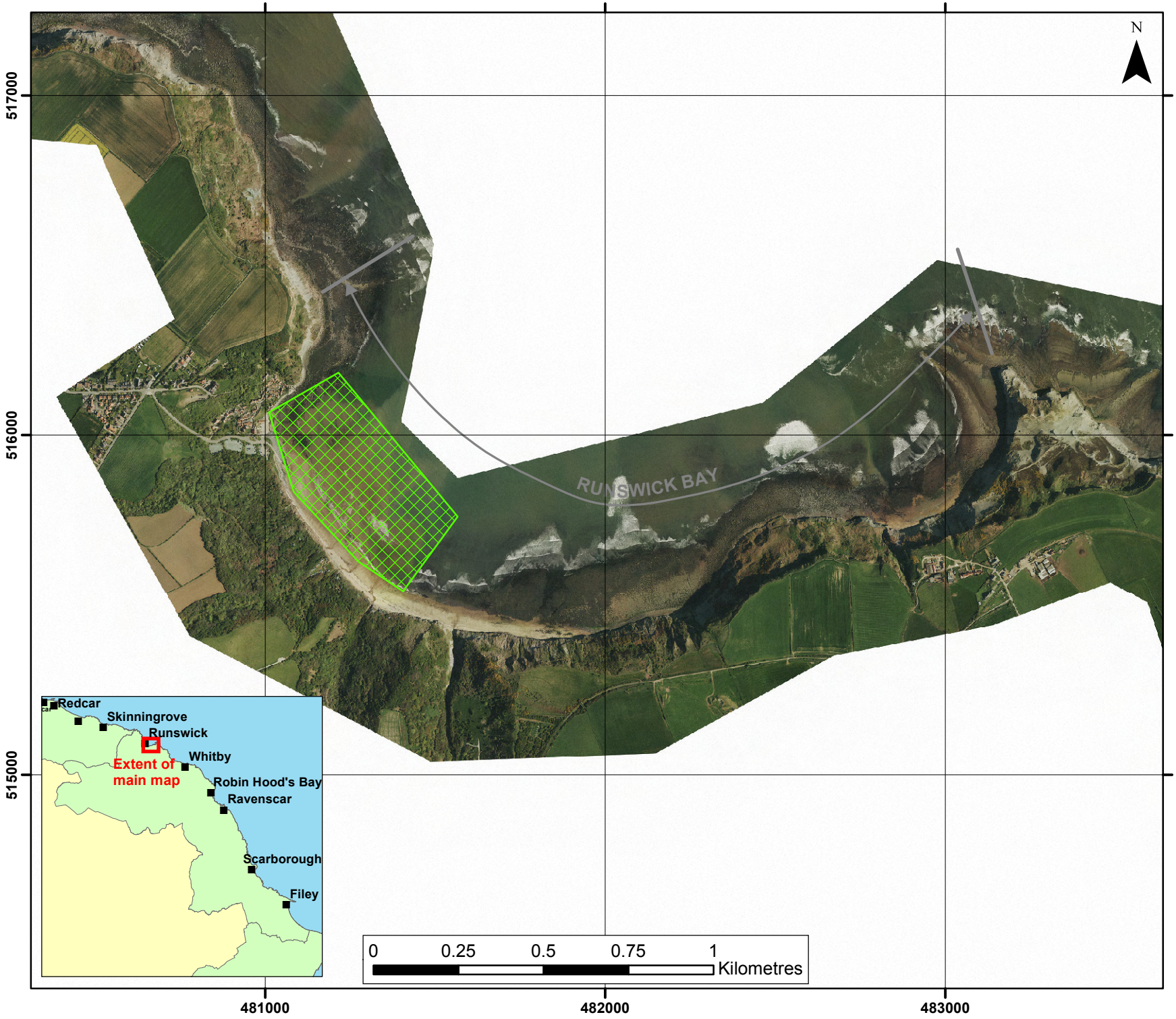


## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 2
# Survey Locations
# Runswick Bay
# Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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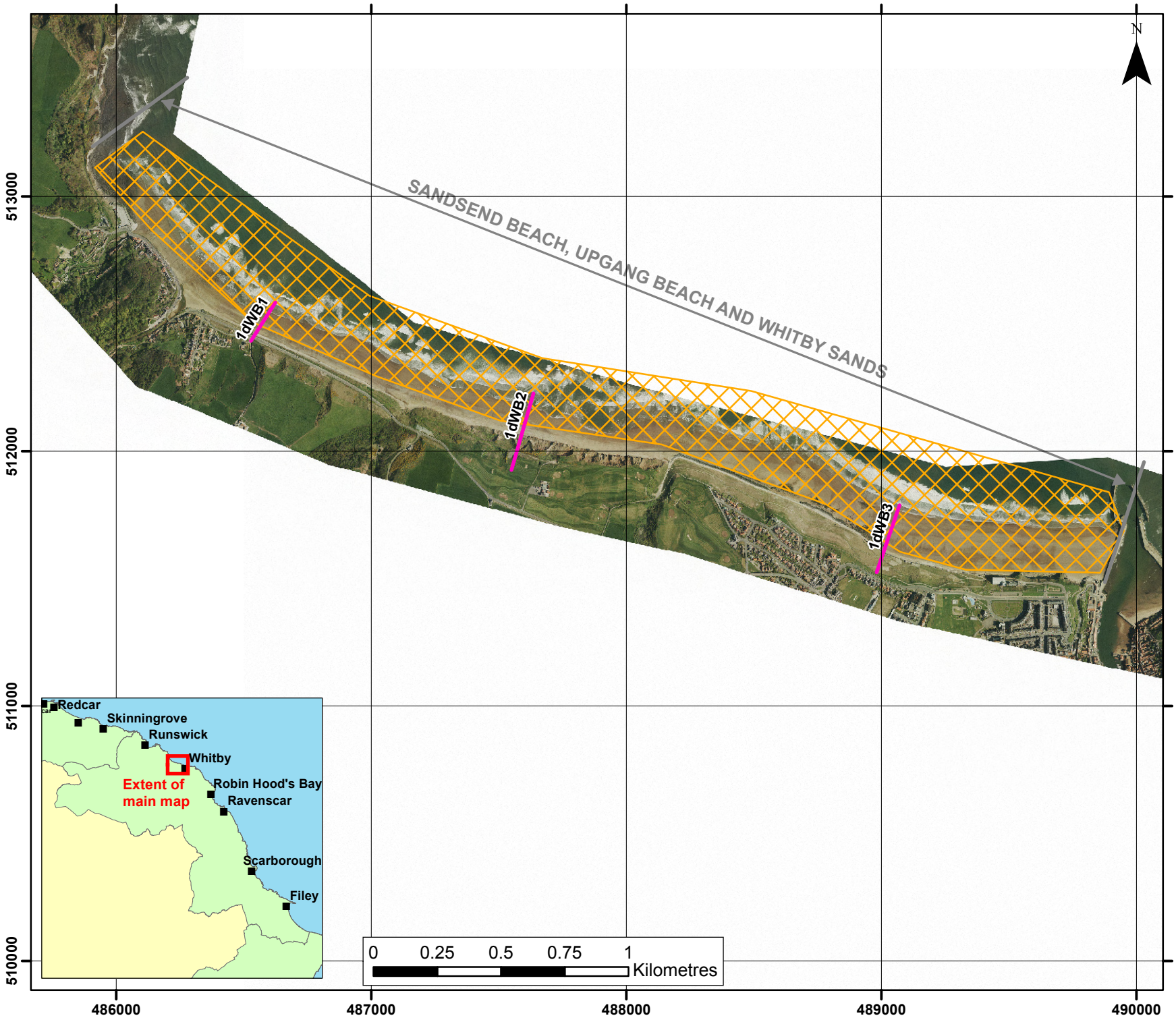


## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 3
# Survey Locations
# Sandsend to Whitby
# Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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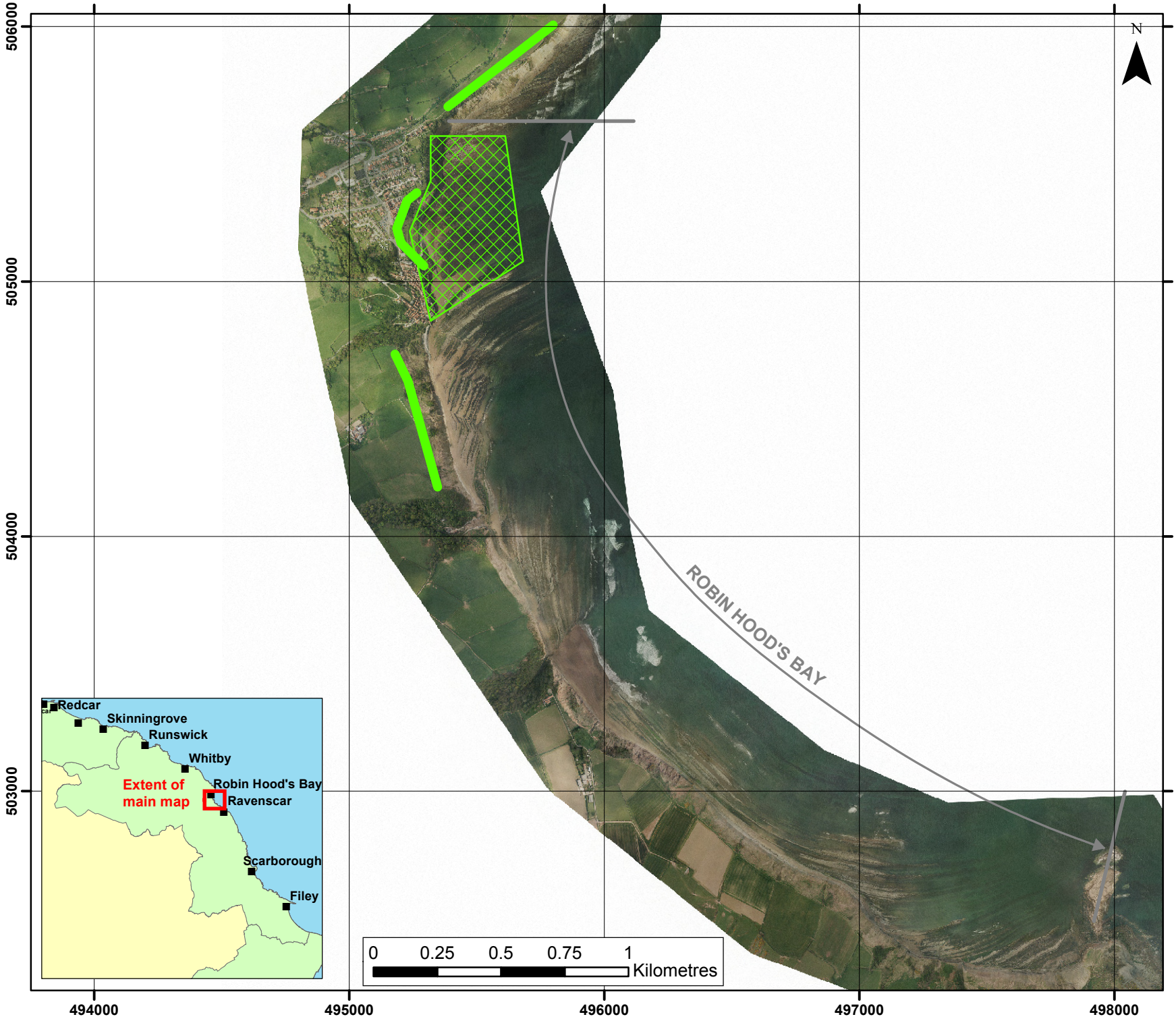


## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 4
# Survey Locations
# Robin Hood's Bay
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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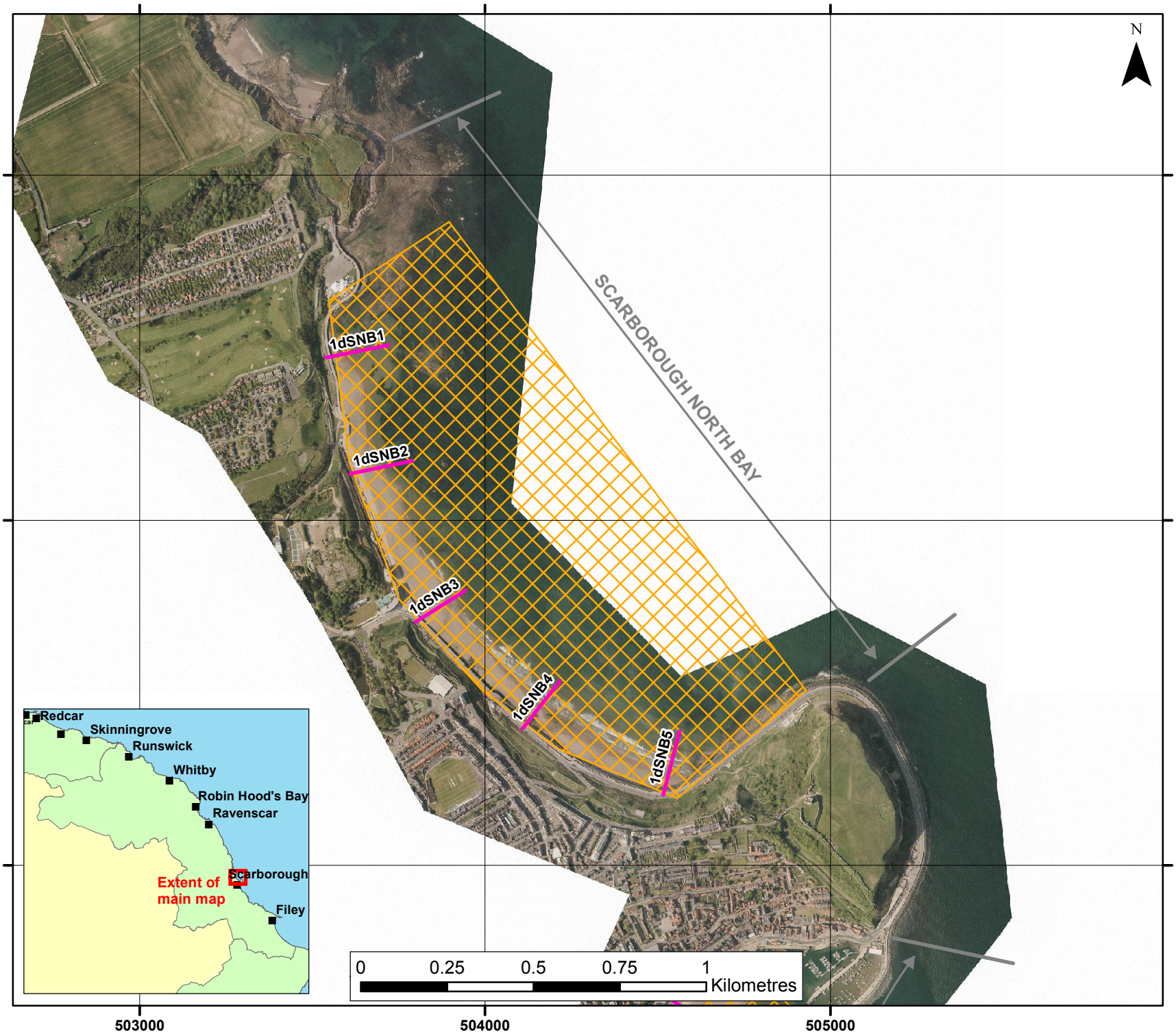


## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 5
# Survey Locations
# Scarborough North
# Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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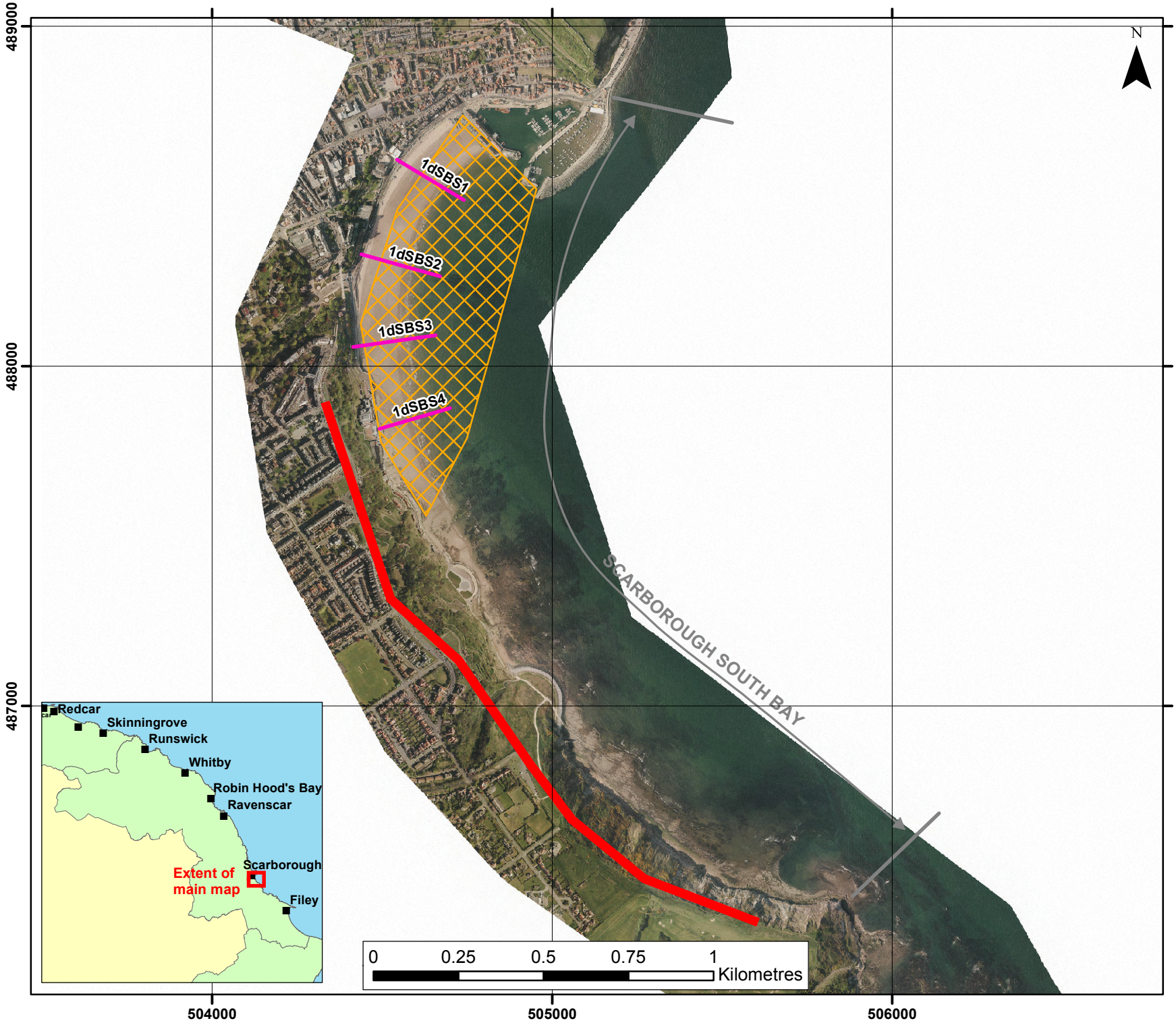


## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 6
# Survey Locations
# Scarborough South
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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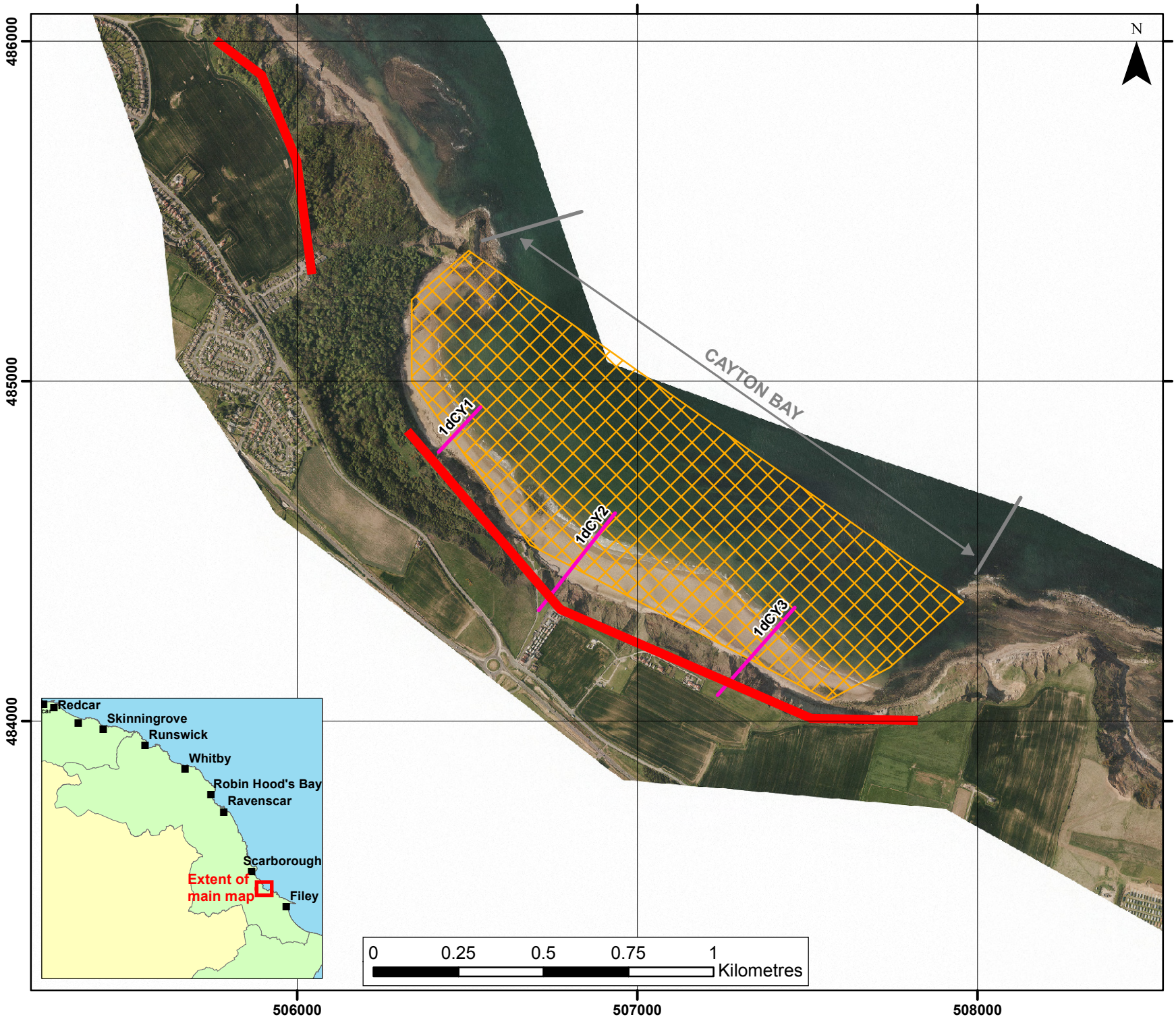


## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 7
# Survey Locations
# Cayton Bay
# Scarborough Borough Council

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Winter 2011

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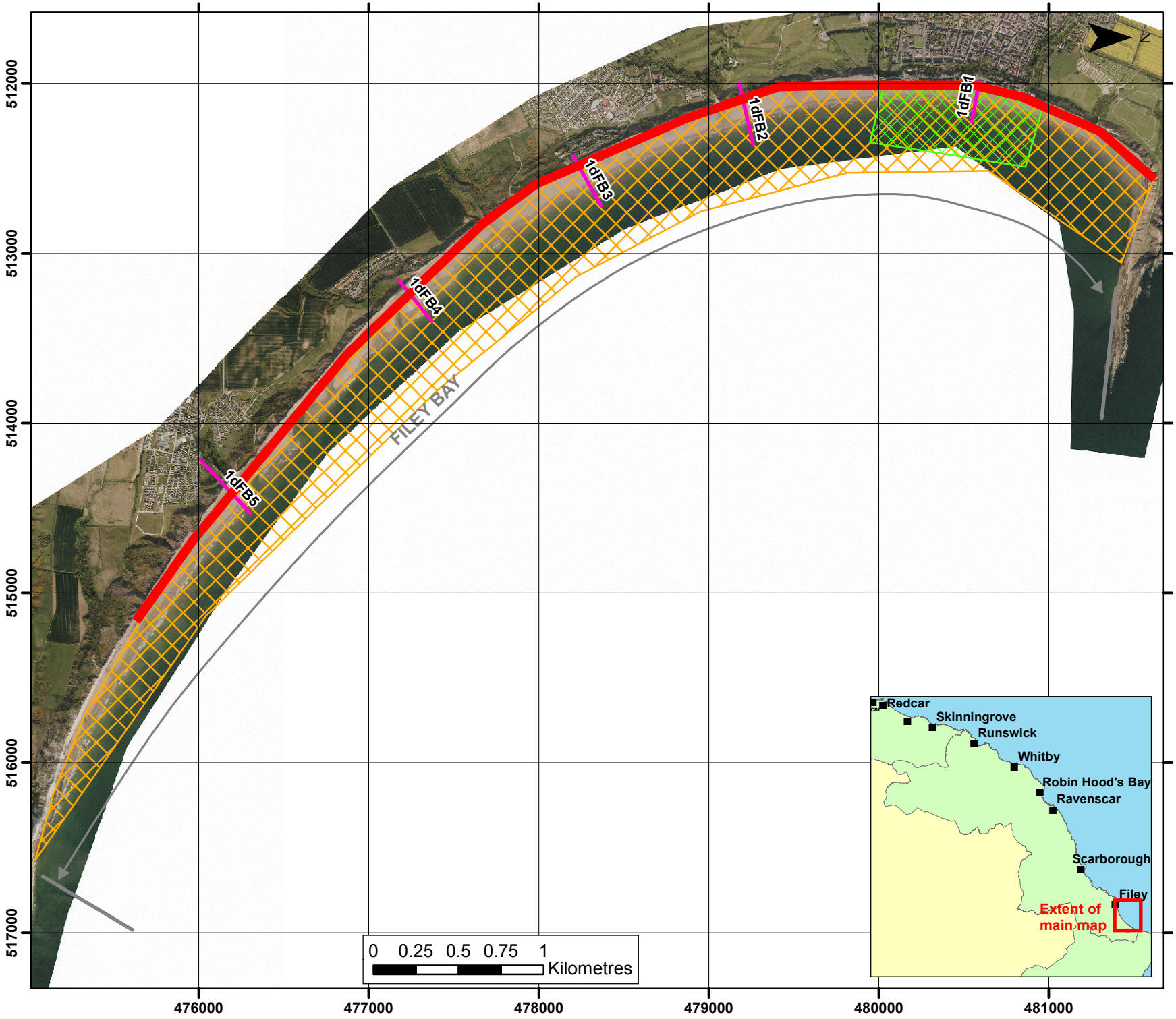


## KEY

**Topographic Profiles**

- Annual
- 6 monthly

**Topographic Surveys**

- 6 monthly
- yearly
- 5 yearly

**Cliff Top Monitoring Pegs**

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

*(Indicative Survey Extents shown)*

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Figure 2 - Map 8
# Survey Locations
# Filey
# Scarborough
# Borough Council

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Winter 2011

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## 2. Analysis of Survey Data

## 2.1 Staithes

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| **3rd October 2011** | **Cliff-top Survey:**<br><br>Twenty ground control points have been established at Staithes for the purposes of cliff top erosion monitoring.<br><br>The separation between any two points is typically around 100 m (although occasionally less). The cliff top surveys at Staithes are undertaken bi-annually. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing.<br><br>In the 2010 report ten of the twenty points have shown no change since the November 2008 survey, indicating local stability of the cliff face. Three locations showed erosion (locations 1, 4 and 13) ranging 0.2 to 2.1 m (±0.1 m due to survey accuracy). It was also noted that points 3, 10, 12 (all in the west) have consistently registered an advancing cliff line.<br><br>In 2011 the cliffs were measured again and a similar pattern of overall stability. When the measurements to the cliff are compared between the April 2011 and October 2011 readings there has been erosion (above the 0.1m error of the survey) at 15 out of the 20 stations, with only one area which recorded some 'growth' of the cliff. When survey errors are taken into consideration, only three of the 20 locations (points 14, 17, 18) have shown no change since the November 2008 baseline survey.<br><br>Appendix C provides results from the September 2011 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. | 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 October 2011, resulting in a long term average recession rate of 0.75m/yr. Two locations (points 1, 4) have shown cliff line recession ranging 0.1 to 0.2 m (±0.1 m due to survey accuracy).<br><br>Points 4 and 13 have consistently registered cliff erosion between November 2008 and October 2011. Less consistent recession measurements are also determined for points 2 and 5 where recession has typically been less than 0.1m/yr. These survey locations are principally located adjacent to Cow Bar Lane.<br><br>Compared to the 2008 baseline, eight locations (points 3, 5 8, 9, 10, 12, 15, 16) have shown an increase in distance to the cliff edge indicating errors in the survey technique. |

## 2.2 Runswick Bay

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| **26th Sept 2011** | **Topographic Survey:**<br><br>Runswick Bay is covered by a 6-monthly topographic survey. A consistently applied routine of GIS processing have been used to create a digital ground model (DGM) (Appendix B - Map 1a) and to calculate the differences between the current topographic survey (Spring 2011) and the previous survey (Winter 2011). In all cases, a 5m raster grid has been used to identify areas of erosion and accretion. (Appendix B – Map 1b).<br><br>Appendix B - Map 1b shows the majority of the beach at Runswick Bay eroded by up to 0.25m between March 2011 and September 2011. The erosion is more concentrated in some areas (such as the shingle bar), which have losses of up to 1m. Areas with severe erosion of over 1m are concentrated in isolated patches close to the shoreline. There were parts of the centre of the bay near the shoreline which showed no change, there were only isolated spots of accretion. | During the 2010 summer period there had been a migration of beach material landwards, and some shore parallel erosion at the toe of the beach. Overall the beach had accreted. In previous years there had been a pattern of accretion in the summer and erosion in the winter.<br><br>During 2011 Runswick Bay showed signs of widespread erosion, which is not expected during the summer months. It may be that there is a lag between material being deposited on the beach from the eroding cliffs and the fines being washed offshore. In the centre of the bay there is a large bar, which persisted but experienced loss of sediment over the summer of 2011. There are also areas of erosion close to the shore along the defended sections of the bay |

## 2.3 Sandsend Beach, Upgang Beach and Whitby Sands

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| 28 and 29 Sept 2011 | **Beach Profiles:**<br><br>The frontage spanning Sandsend Beach, Upgang Beach, and Whitby Sands is covered by three beach profile lines, spaced between Sandsend and Whitby West Cliff (Appendix A).<br><br>At profile **1dWB1** the beach level has dropped by around 0.5m during the summer from the level during the last survey. Below the HAT level the beach has accreted by 0.5m and is flattening out to gain a shallower gradient. There is erosion at the base of the sea wall and accretion below the 1mOD level.<br><br>In the March 2011 survey at **1dWB2** changes to the cliff face could not be assessed. The profile was interpolated between cliff top and cliff toe locations, due to soft slumped till that reduced accessibility. This year the middle of this section could be reached over the dry mud. An overview of the cliff face behaviour can be delineated if the surveys where the cliff profile was interpolated and is a straight line are ignored. The profiles show that the cliff face has been stable since 2008. Below the HAT level the beach has shown some variability. Since last year the upper beach has eroded by up to 1m and the lower beach has accreted by around 1m. As a result it is likely that the beach volumes were similar in March and September 2011<br><br>At profile **1dWB 3** the stabilised face of Whitby West Cliff demonstrates negligible change. The March 2011 survey was discounted from the analysis because it was not clear what had produced the stepped profile. When compared to the other profiles the beach surface is similar to that previously existing, The beach below HAT has been variable over the years but shows no real trend in behaviour. The September 2011 profile is around 0.5m higher than the November 2010 profile | In the 2010 report the three beach profiles had eroded over the summer months. However, during the summer of 2011 WB 1 and 2 profiles the beaches have taken a shallower gradient. The upper beach has eroded and the lower beach has accreted although there are no obvious changes in overall beach volume<br><br>Profile WB 3 the beach has not changed greatly since previous profiles showing that it is the most stable profile of the three.<br><br>There is no straightforward pattern to the distribution of erosion and accretion in the topographic difference plots. However, the losses and gains in the centre of the Bay are much more pronounced than at the distal ends of the Bay where the changes tend to be smaller. This distinction between the middle and end of the bay was also noted in 2010.<br><br>The central area of this frontage near Upgang runs from the Eat Row Beck to the eastern end of Whitby Golf Course. This section of the coast is undefended and as a result is more likely to have variations in erosion and accretion as material is redistributed across the beach from the eroding cliffs.<br><br>At the exact beach profile locations, there are contrary beach change patterns to that indicated by the topographic surveys. This probably represents the |
| | **Topographic Survey:**<br><br>The Sandsend to Whitby frontage is covered by an annual topographic survey, providing continuous survey of Sandsend Beach, Upgang Beach, and Whitby Sands. Data have been used to create a DGM (Appendix B – Map 2a) using a GIS computer software package.<br><br>The GIS has also been used to calculate the differences between the current topographic survey DGM (Winter 2011) and the earlier topographic survey DGM (Spring 2011), with 5m raster grids (as shown in | |

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| | Appendix B – Map 2b), to identify areas of erosion and accretion.<br><br>Appendix B – Map 2b shows a reasonably even distribution of erosion and accretionary areas. The changes in 2011 can be divided into three main areas. At Sandsend from the western edge of the topographic survey to East Row beck there is slight (±0.5m) erosion and accretion in adjacent areas. This pattern of the most intense changes in topography being in the centre of the bay was also observed in the 2010 Full Measures Report. There is no obvious pattern of where the erosion or accretion occurs in front of Sandsend, although there has been up to 1m of material lost along the whole of the defended frontage in a thin strip.<br><br>The central area of this frontage near Upgang runs from the East Row Beck to the eastern end of Whitby Golf Course. This area has been subject to significant erosion and accretion during the summer of 2011. There is severe erosion of around 2m in the middle of this frontage on the foreshore. The erosion is concentrated in a shore-parallel tract, which has accretion occurring on either side of it. There is also 2m loss of material at the toe of the cliff in front of the Golf Course.<br><br>The final part of the shoreline is Whitby, between the golf course and harbour walls. The Whitby frontage has not been subject to large scale erosion or accretion, the changes have been more subdued (±0.25m). There is an area of 0.5m of accretion which runs parallel to the shore on the foreshore. There are adjacent areas of erosion also running parallel to the shore. There has been moderate accretion of up to 0.75m on the part of the Whitby Beach in front of West Cliff.<br><br>Beach profiles and the topographic survey data were collected at the same time. However, interpretations of beach change are different for each data series; this reflects the use of different baseline data, i.e. beach profiles (March 2010, partial measures data), and topographic survey (October 2009, full measures data) in the respective comparisons. | complex spatial pattern of erosion and accretion of sediment; the overall pattern of upper beach material loss is recorded by both data series. |

## 2.4 Robin Hood's Bay

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| **28th Sept 2011** | **Topographic Survey:**<br><br>Robin Hood's Bay is covered by a six-monthly topographic survey. Data have been used to create a DGM (Appendix B - Map 3a) using a GIS computer software package. The GIS has also been used to calculate the differences between the current topographic survey DGM (Winter 2011) and the earlier topographic survey DGM (Spring 2011), with 5m raster grids (as shown in Appendix B – Map 3b), to identify areas of erosion and accretion.<br><br>Appendix B - Map 3b shows a very patchy distribution of areas of accretion and erosion. There are broad areas of small change (+/- 0.1 m) across this Bay through the summer of 2011. Areas showing the greatest deposition were concentrated in the north of the Bay and in the south, close to the shoreline. There was modest erosion close to the shore in the centre of the Bay. | The Bay as a whole appears to have been subject to erosion. Although the changes on the difference plot are generally small, the pattern was observed in the 2010 Full Measures Report. The limited change in Robin Hoods Bay is likely to be due to the relative erosional resistance of the rock platforms and the limited sediment supply to the bay. In contrast, the erosional hotspots are likely to correspond to local pockets of more mobile sand adjacent to the shore.<br><br>Overall the cliffs at Robin Hoods Bay have been stable with minimal change since cliff-top monitoring began in 2010, see Table C2. Marker 1 has shown consistent recession and currently has a high rate. Because this is the second year of this type of monitoring it is difficult to tell the long term trends from the natural variability and any errors in the measurements. |
| | **Cliff-top Survey:**<br><br>Thirteen ground control points have been established at Robin Hood's Bay (since March 2010) to monitor the cliff top The separation between any two points is around 200m Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing. The results are unlikely to be representative of the long-term trends because the data has only been collected over a short amount of time.<br><br>Table C2 shows that, taking into account the survey accuracy of +/-0.1m, four of the 13 markers show no change in cliff top position since the baseline March 2010 survey. Of the other remaining markers four show advance of the cliff, which suggests survey error. Four of the markers show recession of 0.1m to 0.5m between March 2010 and September 2011. The remaining profile (Marker 1) has shown a significant recession of 3.3m since the baseline was established in 2010.<br><br>In 2010 the cliff survey showed a similar pattern to that one observed over the summer of 2011. The vast majority of the profiles showed stability, with eight of the 13 markers showing no change. Four locations (points 1, 5, 7, & 11) have shown cliff recession of 0.2 m (±0.1 m due to survey accuracy). | |

## 2.5 Scarborough North Bay

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| **27th Sept 2011** | **Beach Profiles:**<br><br>Scarborough North Bay is covered by five beach profile lines, spaced between the Sealife Centre at Scalby Mills to Clarence Gardens (Appendix A).<br><br>Profile **1dSBN1** the profile below MHWS has shown variability over the years. In the February 2011 survey the beach had accreted higher than previously recorded. The September 2011 survey indicates the level of the beach had reduced from February 2011 but was comparable with previous profiles.<br><br>At **1dSBN2** the upper beach adjoining the seawall (5m to 55m chainage) has experienced significant accretion (up to 1.2m). Below 1m OD the beach has eroded by 0.5m since February 2011. The beach has a much steeper profile now than in previous years.<br><br>The beach at profile **1dSBN3** is well within the limits of variability observed at this location. The beach profiles show stability overall, although 0.2m accretion since the March 2011 survey.<br><br>The beach at profile **1dSBN4** has experienced a slight gain of material. Between chainage c. 30-60 m the uneven topography includes rock platform and boulder deposits where the survey profile shows zones of erosion and deposition typically of 0.5 m. These apparent changes may well reflect survey positioning over the seaweed covered bedrock rather than real change. Between chainage c. 60-125 m there has been accretion of up to 0.1m of material.<br><br>On profile **1dSBN5** There has been very little change to the upper beach. Between 40m and 80m chainage there has been up to 0.6m of accretion of the foreshore since the last survey in February 2011. | Overall the Scarborough North Bay profiles have remained stable. Most of the profiles have shown some accretion, which is to be expected over the summer months and was the pattern observed in the 2010 Full Measures Report.<br><br>The plot of change between topographic surveys also points to accretion on the majority of the frontage over the summer of 2011. There is a zone of erosion running oblique to the shore. The eroded sediment is likely to have been redistributed within the bay. There was a band of accretion in the 2010 topographic change plots in the same location, which suggests seasonal migration of large sand bar/bank features. |

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| | **Topographic Survey:**<br><br>Scarborough North Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Map 4a) using a GIS computer software package. The GIS has also been used to calculate the differences between the current topographic survey DGM (Winter 2011) and the earlier topographic survey DGM (Spring 2011), with 5 m raster grids (as shown in Appendix B – Map 4b), to identify areas of erosion and accretion.<br><br>Appendix B - Map 4b shows that the centre of the Bay has been dominated by accretion in the summer of 2011. The nearshore has accreted by around 0.5m along much of the frontage. In the southern third of the bay there has been around 0.25m erosion.<br><br>In the northern third of the Bay there is a zone of erosion running oblique to the shore for c. 700m. The erosion has been severe in some places with up to 2m of material lost since the winter of 2010. A zone of accretion was observed in the same part of the bay as the erosion band in the 2010 Full Measures Report. | |

## 2.6 Scarborough South Bay

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| **16th Sept 2011** | **Beach Profiles:**<br><br>Scarborough South Bay is covered by four beach profile lines, spaced between the Harbour in the north and The Spa Complex in the south (Appendix A).<br><br>At profile **1dSBS1** the upper beach fronting the seawall between c. 15 and 50 m chainage, has experienced a gain of over 1m of material through the years since April 2009. The profile is similar to the profile recorded in September 2010 because there is a 0.5m high feature between 90 and 120m chainage. This is believed to be a persistent sand berm, which was noted in the survey.<br><br>The beach at profile **1dSBS2** has shown variability in its profile location since 2008. During this survey the beach levels were close to the average for this frontage. The beach has accreted by 0.5m since the levels were low in February 2011.<br><br>At profile **1dSBS3** there is some variation in the height of the beach over the surveys years but the gradient remains similar. Since February 2011 there has been accretion of the upper beach by 0.4m the centre of the beach has remained stable overall while the lower beach has accreted by 0.2m.<br><br>At profile **1dSBS4** the gradient is very similar to previous years although the beach level is comparatively high. The beach has accreted by a maximum of 0.3m since February 2011. | During the summer of 2010 the beach at Scarborough South had accreted along each of its profiles.<br><br>The Scarborough South beach levels in September 2011 were similar to the profiles dating back to 2008. All of the September 2011 profiles had shown some accretion since March 2011, which is expected over the summer months. The profile SBS 1 had accreted a sand berm.<br><br>The topographic survey change plots show bands of shore parallel changes in accretion and erosion. The plots in the 2010 Full Measures Report showed a very similar pattern, but with erosion at the upper beach close to the shore. The pattern of shore parallel bands in the bay is likely to be due to the refraction of the incoming waves within the bay points to the stability of the bay form.<br><br>The beach itself is showing signs of accretion on the upper beach, which broadly agrees with the profile data. The beach management activities carried out by Scarborough Council are the likely cause of some of the changes seen in South Bay. As a result, the accretion of material seen in these profiles may be due to human action rather than coastal processes.<br><br>Table C3 shows that since March 2010 the majority of the profiles have shown minimal recession rates. Of |
| | **Topographic Survey:**<br><br>Scarborough South Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Map 5a) using a GIS computer software package. The GIS has also been used to calculate the differences between the current topographic survey DGM (Winter 2011) and the earlier topographic survey DGM (Spring 2011), with 5m raster grids (as shown in Appendix B – Map 5b), to identify areas of erosion and accretion.<br><br>Appendix B - Map 5b shows that the northern part of the survey is characterised by a sequence of shore parallel changes including slight deposition (up to 1m) at the rear of the beach with around 0.5m of erosion further seaward, and then deposition at the beach toe and erosion on the foreshore. This is the | |

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| | second consecutive year where this pattern has been observed.<br><br>The shore-parallel trend weakens as you move south so that at the southerly end of the beach the pattern becomes patchy and the erosion and accretion becomes weaker (±0.25m of change).<br><br>The current beach profiles and the topographic survey were collected on the same day. However, interpretations of beach change are in large part different between these data series; this reflects the use of different baseline data, i.e. beach profiles (March 2010, partial measures data), and topographic survey (October 2009, full measures data) in the respective comparisons. | the significant rates the highest is 1.1m/year at location number 13. The data collection will need to continue for a number of years before an accurate picture of the behaviour of these cliffs is established. |
| | **Cliff-top Survey:**<br><br>Thirteen ground control points have been established at Scarborough South Bay, extending from South Bay to Cayton Bay for the purposes of cliff top monitoring. The separation between any two points is around 300 m. The cliff top surveys at Scarborough South Bay are undertaken bi-annually. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing.<br><br>In the 2010 round of measurements eleven of the thirteen points showed no change since the baseline March 2010 survey, indicating local stability of the cliff face. For the September 2011 survey six of the cliff survey profiles still show no change. Of the profile locations showing erosion five have shown recession of between 0.1 and 0.5m since March 2010. The two largest losses were of 0.6m and 1.1m which result in annual recession rates of 0.4m and 0.7m respectively.<br><br>Appendix C provides results from the September 2011 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 March 2010 baseline survey. | |

## 2.7 Cayton Bay

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| **15th Sept 2011** | **Beach Profiles:**<br><br>Cayton Bay is covered by three beach profile lines, spaced between Tenants' Cliff and the south of Cayton Sands (Appendix A).<br><br>The cliff face at profile **1dCY1** is largely vegetated and was difficult for the surveyors to access. So there is low confidence in that part of the profile. There is also a large spike in the profile at 0m chainage which will be ignored as an error in the data. The remainder of the survey shows little change from the previous year. There was 0.5m of accretion recorded between 30m and 70m chainage and around 0.4m of erosion between 70m and 100m chainage. The profile has flattened since February 2011.<br><br>The centre of cliff profile **1dCY2** could not be accessed for the survey, which is why 45 to 115m chainage is such a straight profile. The beach has remained stable since 2008 and there are very small differences (±0.1m) in the February 2011 and September 2011 recorded beach levels.<br><br>At profile **1dCY 3** The centre of this cliff profile could not be accessed for the survey, which is why the line between 55m to 125m chainage is very flat in the profile. The upper beach has accreted by around 1m while the lower beach has eroded by 1m. The centre of the beach has not changed significantly and as a result there is a similar volume shown on both 2011 beach profiles. | In Cayton Bay the beach profiles show that the coast has remained stable since the last survey. Only profile CY 3 is showing obvious change and that is accretion. In the 2010 Full Measures Report the beach was showing signs of accretion across the whole beach, which is a pattern repeated this summer.<br><br>The change plot of the differences between the March 2011 and September 2011 surveys shows variability in the erosion and accretion in the bay. The majority of the change in Cayton Bay was not significant, although there are two areas of erosion which are significant and were centred on the sandbank and rock outcrops in the foreshore. The difference plots from the 2010 Full measures report shows a similar pattern of shore parallel bands of accretion and erosion. However the positioning of these bands of coastal change means that when this year and the previous year are compared the areas of accretion have become erosion and *vice versa*. This reversal of trends could be a part of the annual variability on this part of the coast.<br><br>The cliff top survey results show little change or positive growth. There are two profile locations which show recession. Profile 1 has a recession rate of 0.2m/yr and Profile 2 has a recession rate of 1.6m/yr. The data has only been collected over a few years so a better understanding of the average trends will be |
| | **Topographic Survey:**<br><br>Cayton Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Map 6a) using a GIS computer software package. The GIS has also been used to calculate the differences between the current topographic survey DGM (Winter 2011) and the earlier topographic survey DGM (Winter 2010), with 5m raster grids (as shown in Appendix B – Map 6b), to identify areas of erosion and accretion.<br><br>Appendix B - Map 6b shows that there has been up to 2m of erosion at the base of the cliff for the majority of the Cayton Bay frontage. Further seaward there is a shore parallel bank of accretion of around 0.5m across most of the beach although the magnitude of the change is small. The foreshore is dominated by two areas of significant erosion of around 1.5m, one in the middle of the northern half of | |

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| | the bay and the second in the centre of the southern half of the bay. Both areas of erosion appear to be centred on sandbanks or rock out crops. These two areas of erosion are separated by an accreting section<br><br>The current beach profiles and the topographic survey were collected on the same day. However; interpretations of beach change are in large part different between these data series, this reflects the use of different baseline data, i.e. beach profiles (March 2010, partial measures data), and topographic survey (October 2009, full measures data) in the respective comparisons. | gained through further years of monitoring. |
| | **Cliff-top Survey:**<br><br>Eight ground control points have been established within Cayton Bay for the purposes of cliff top monitoring. The separation between any two points is typically around 200 m. The cliff top surveys at Cayton Bay are undertaken bi-annually. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing.<br><br>The results of the cliff top survey are varied, as shown in Table C4. Three of the eight profiles show very little change (within the 0.1m accuracy of the survey). Three have shown growth – which points to larger errors in the data set. The remaining two profile locations which show significant recession.<br><br>Appendix C provides results from the September 2011 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. | |

## 2.8 Filey Bay

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| **12th Sept 2011** | **Beach Profiles:**<br><br>Filey Bay is covered by five beach profile lines, spaced between Filey Sands and Speeton Sands (Appendix A).<br><br>At profile **1dFB1**, which is at Filey seawall, the overall the beach profile has fluctuated but shows no long term trend of accretion or erosion. The part of the profile which has changes the most since March 2010 is at the base of the seawall between 20m and 60m chainage, which has accreted by 0.4m.<br><br>The cliff top and cliff face at profile **1dFB2** have been static since the last survey, with the exception of the cliff toe (c. 3.5 to 5 m AOD) where tills are exposed by periodic marine erosion. The upper beach between 100m and 160m chainage has accreted by up to 0.5m. Seaward of 160m chainage the beach profile has remained stable.<br><br>At profile **1dFB3**, near Flat Cliff, the cliff face remains unchanged. The beach profile shows greatest change on the upper beach where a large sand berm has formed and the beach has accreted by 0.5m. The sand berm is evident in the profile and was noted in the survey description. Beyond 150m chainage the beach is similar to the March 2011 survey but with some slight accretion showing through the summer months.<br><br>The survey of the cliff face remains interpolated at **1dFB4**, Hunmanby Gap, and at this coarse level shows negligible change. At the cliff toe, around MHWS, tills materials have eroded by 0.3m. However the rest of the beach has accreted overall with an increase in level of around 0.4m since the March 2011 survey.<br><br>The September 2011 profile for **1dFB5** is close to the middle of the range of profiles recorded since 2009. The upper profile, between 65m and 200m the profile was interpolated due to the thick vegetation. As a result the profile up to 200m remains unchanged. The rest of the beach looks very similar to the March 2011 profile although it has accreted by 1m.<br><br>**Topographic Survey (Filey Bay):**<br><br>Filey Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix | The beach profile data shows that the Filey Bay profiles have remained stable overall. All of the profiles have accreted to some extent although FB4 has been prone to localised erosion at the toe of the sea wall.<br><br>The topographic change assessment shows that the whole of Filey Bay is dominated by shore parallel successive bands of accretion and erosion. The beach sediment appears to be being redistributed within the bay. This is a continuation of the trend observed in the 2010 Full Measures Report, where shore parallel bands were also observed.<br><br>The topographic change plot of Filey town shows that the losses and gains which have occurred tend to be in shore-parallel bands, which agrees with the picture provided over the longer period in Appendix B- Map 14a (which included the preceding winter season). Overall there has been accretion in front of Filey and especially on the upper beach.<br><br>The cliff top survey data provided in Table C5 shows that of the 27 profiles recorded 23 had no data or a measurement too small to be significant. Four profiles recorded significant change, one of those showed growth. As a result only three profiles showed recession. The maximum total erosion seen since the baseline survey is at location 5, just south of Filey |

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| | B - Maps 7a and 8a) using a GIS computer software package. The GIS has also been used to calculate the differences between the current topographic survey DGM (Winter 2011) and the earlier topographic survey DGM (Winter 2010), with 5m raster grids (as shown in Appendix B – Maps 7b, 8b and 9) to identify areas of erosion and accretion.<br><br>Appendix B - Map 7b shows shore parallel change between Filey Brigg and Hunmanby Gap, with alternating bands of erosion and accretion, which are more prominent in the south. The upper beach in front of the town of Filey eroded by around 0.25m over 2011. Further down the beach there is a large swath of accretion, especially in front of the Primrose Valley Holiday Village where the beach has accreted by around 0.75. Overall there is a fairly even mix of accretion and erosion in the bay, so it is likely that the sediment has been re-distributed within the Bay.<br><br>Appendix B – Map 8b (Hunmanby Sands) shows a continuation of the shore parallel sequence of depositional and erosional bands, with the erosion of around 0.75m tending to dominate at the top of the beach. Mid way down the topographic profile there is a large area of accretion of up to 1m. There are areas of severe erosion between Hunmanby Gap and Reighton Gap, in front of Reighton Gap and at the edge of the topographic survey, it is considered likely that the sediment is being redistributed within the Bay.<br><br>**Topographic Survey (Filey Town):**<br><br>Further to the more extensive annual survey of Filey Bay, a smaller (selected) area within this extent (i.e. fronting Filey Town) is also surveyed in the partial measures programme, enabling further analysis of change, but specifically for the shorter spring to early autumn period fronting this asset.<br><br>The GIS has been used to calculate the differences between the current (full measures) topographic survey DGM (Winter 2011) and the earlier (partial measures) topographic survey DGM (Spring 2011), with 5m raster grids (as shown in Appendix B – Map 9), to identify areas of erosion and accretion during the defined time period. Appendix B - Map 9 shows very little change has occurred over the summer with minimal losses and gains (±0.25m). There is a zone of accretion very close to the coast where around 0.5m of material was gained. | seawall where there has been 5.7m of erosion, equivalent to an annual rate of 2m/yr, . Location 7 was 0.6m/yr and Location 14 was 0.3m/yr. |
| | **Cliff-top Survey:**<br><br>Twenty-six ground control points have been established within Filey Bay for the purposes of cliff top | |

| Survey Date | Description of Changes Since Last Survey | Interpretation |
|---|---|---|
| | monitoring. This includes the installation of three new locations in September 2010, these being points 12A (as a replacement for point 13 which can no longer be accessed due to vegetation growth), 24 & 25 (to the north of Filey Bay at Filey Brigg). The maximum separation between any two points is nominally 300 m. The cliff top surveys at Filey Bay are undertaken bi-annually. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing.<br><br>Appendix C provides results from the September 2011 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 (where applicable). | |

## 3. Problems Encountered and Uncertainty in Analysis

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

**Cliff top erosion errors & data capture techniques**
The cliff top surveys are in general assumed to have a limit of accuracy of ± 0.1m due to the techniques used. At a number of locations apparent cliff advance is calculated, which is highly unlikely excepting if a toppling mechanism of failure is being recorded, so the accuracy may actually be worse than this. It is more likely that this is due to a different point being identified as the edge of the cliff, especially with different seasonal vegetation cover. This problem remains marked at all locations. Over a longer monitoring period, it is anticipated that any underlying patterns of cliff recession will become clear. However, in the short term, analysis of high quality aerial photography will allow detailed assessment of short term cliff recession rates.

Repeat terrestrial laser scan surveys of cliff faces and tops could be undertaken at key locations within the cliff survey areas if a very detailed understanding of changing conditions was required for risk management.

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

The following recommendations are suggested:

- Consider and implement measures to improve the accuracy of cliff top and cliff face survey data capture. This may include a site visit by a geomorphologist with knowledge of cliffs, and a programme of targeted laser scanning.
- More consideration needs to be given to the analysis and reporting of longer-term beach behaviours demonstrated by the topographic survey data. This may include the calculation of volumetric sediment budgets (as best possible) for each successive time period.

## 5. Conclusions and Areas of Concern

The following points have been observed:

- The Staithes cliff face shows stability overall. However, the monitoring has only been being carried out for three years so a trend is unlikely to be clear from such a limited data set. There is one point which has eroded by 2.2m since November 2008 and October 2011, which is the maximum erosion observed for this frontage.
- Runswick Bay showed erosion on the topographic survey comparison. Erosion is not usual during the summer months so the erosive trend of summer 2011 is noteworthy.
- At Sandsend Beach, Upgang Beach and Whitby Sands the volumes of the beaches appear to have remained stable. The changes in level on the topographic differences plot are greater at the distal ends of the bay that at the centre. The beach profiles show some accretion at their centre and erosion at the top of the beach, but stability overall.
- Robin Hoods Bay saw the majority of change due to the erosion and accretion of the veneer of mobile sand on top of the rock platform. The cliff top survey shows minimal change since cliff top monitoring began in 2010. The maximum observed change was at

a rate of 2m/yr, although monitoring will need to be carried out over a longer period to assess the long term behavioural trends.

- Scarborough North Bay has shown stability overall but accretion in some places. The topographic change plot shows accretion overall but with a large line of erosion running at an angle through the bay.
- Scarborough South Bay is similar to the North Bay because it shows some accretion although overall the beach profiles were similar to previous years. The topographic change plots show successive shore-parallel bands of accretion and erosion, which probably means that sediment, is being redistributed within the Bay. The cliff top survey points have shown recession rates of between 0.2 and 0.7m/yr. Further monitoring and inclusion of records of significant beach management are needed to give a better appreciation of the erosional trends on this frontage.
- The Cayton Bay beach profiles show stability overall with accretion detected on CCY 3, the southernmost profile. The topographic change plots show minimal accretion and erosion through most of the bay. The cliff top profiles show stability of the cliff overall, with the largest calculated rate in a single profile being 1.6m/yr. More data is needed to gain confidence in these calculated rates.
- Filey Bay has remained stable overall although there has been limited accretion on the beach. One of the profiles in the middle of the bay has shown erosion, but this is localised. The topographic change plot of bay as a whole is dominated by shore parallel bands of accretion and erosion where the beach material is being redistributed within the Bay. The smaller Filey town area shows a similar pattern to the Bay as a whole, although the erosion and accretion recorded is relatively small scale. The cliff profiles show stability overall with localised erosion in places of up to 2m/year.

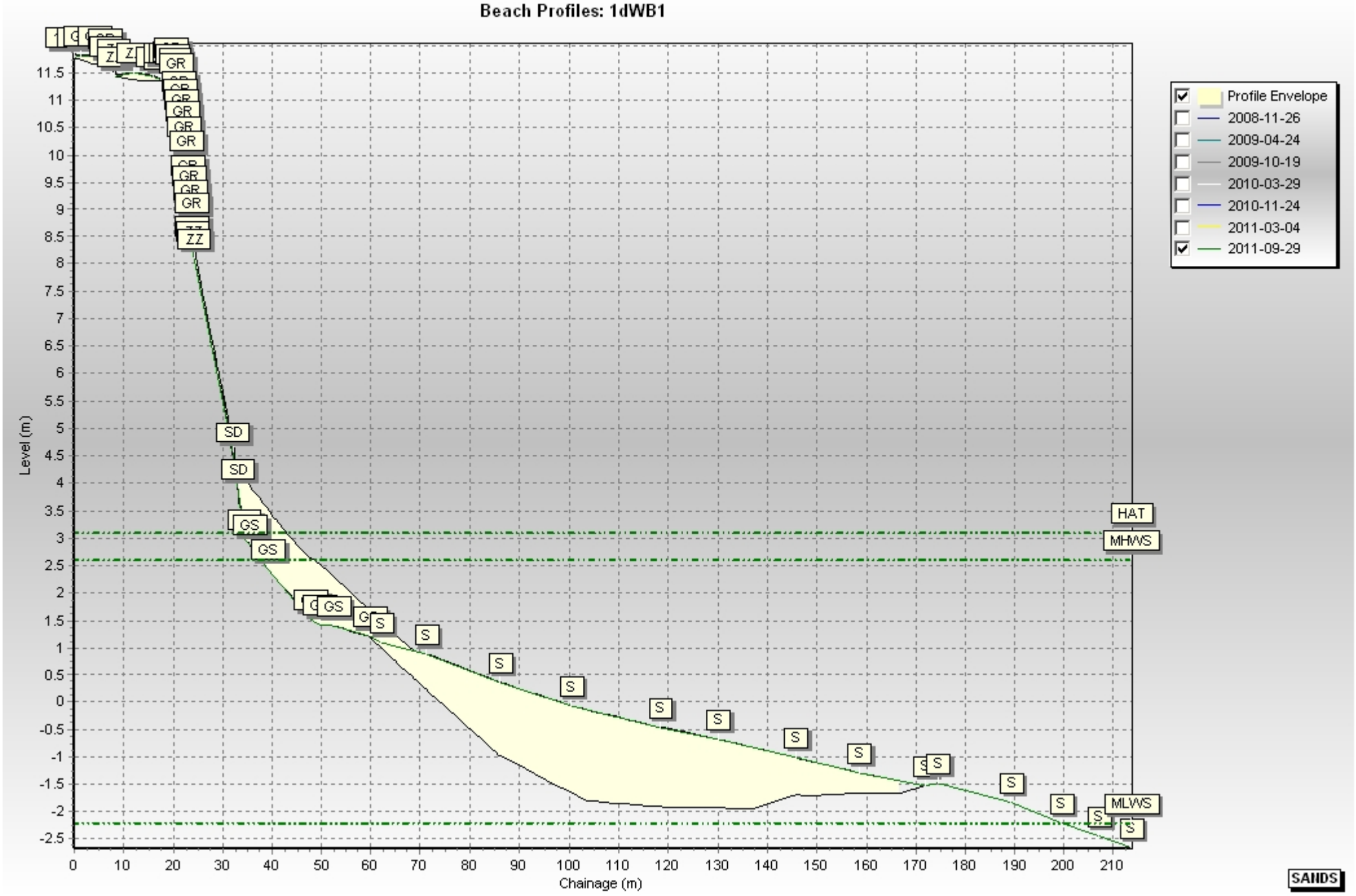
# Appendices

# Appendix A

# Beach Profiles

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

| Code | Description |
|---|---|
| S | Sand |
| M | Mud |
| G | Gravel |
| GS | Gravel & Sand |
| MS | Mud & Sand |
| B | Boulders |
| R | Rock |
| SD | Sea Defence |
| SM | Saltmarsh |
| W | Water Body |
| GM | Gravel & Mud |
| GR | Grass |
| D | Dune (non-vegetated) |
| DV | Dune (vegetated) |
| F | Forested |
| X | Mixture |
| FB | Obstruction |
| CT | Cliff Top |
| CE | Cliff Edge |
| CF | Cliff Face |
| SH | Shell |
| ZZ | Unknown |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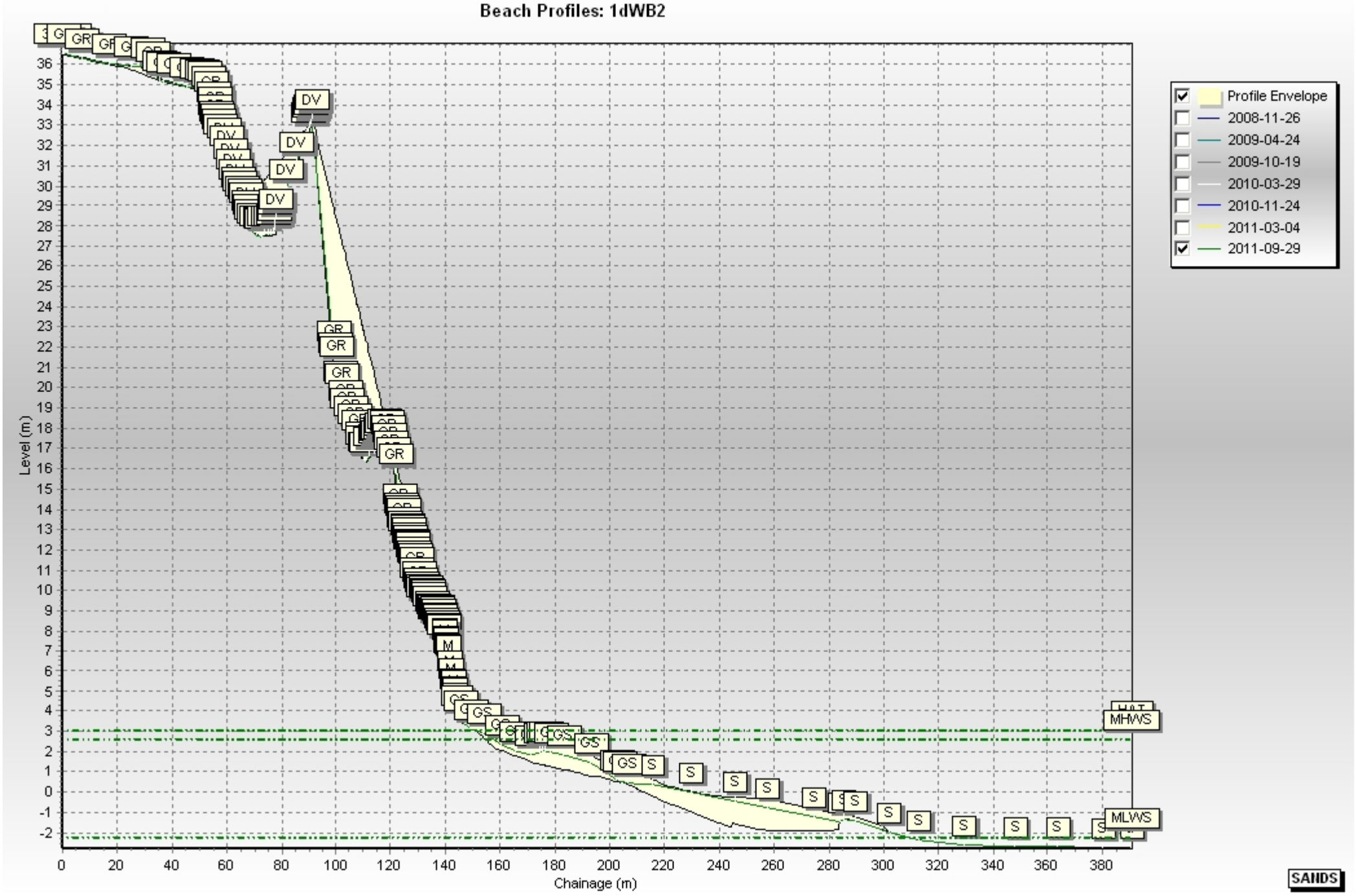
2011-09-29
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
GS
S
GR
ZZ
SANDS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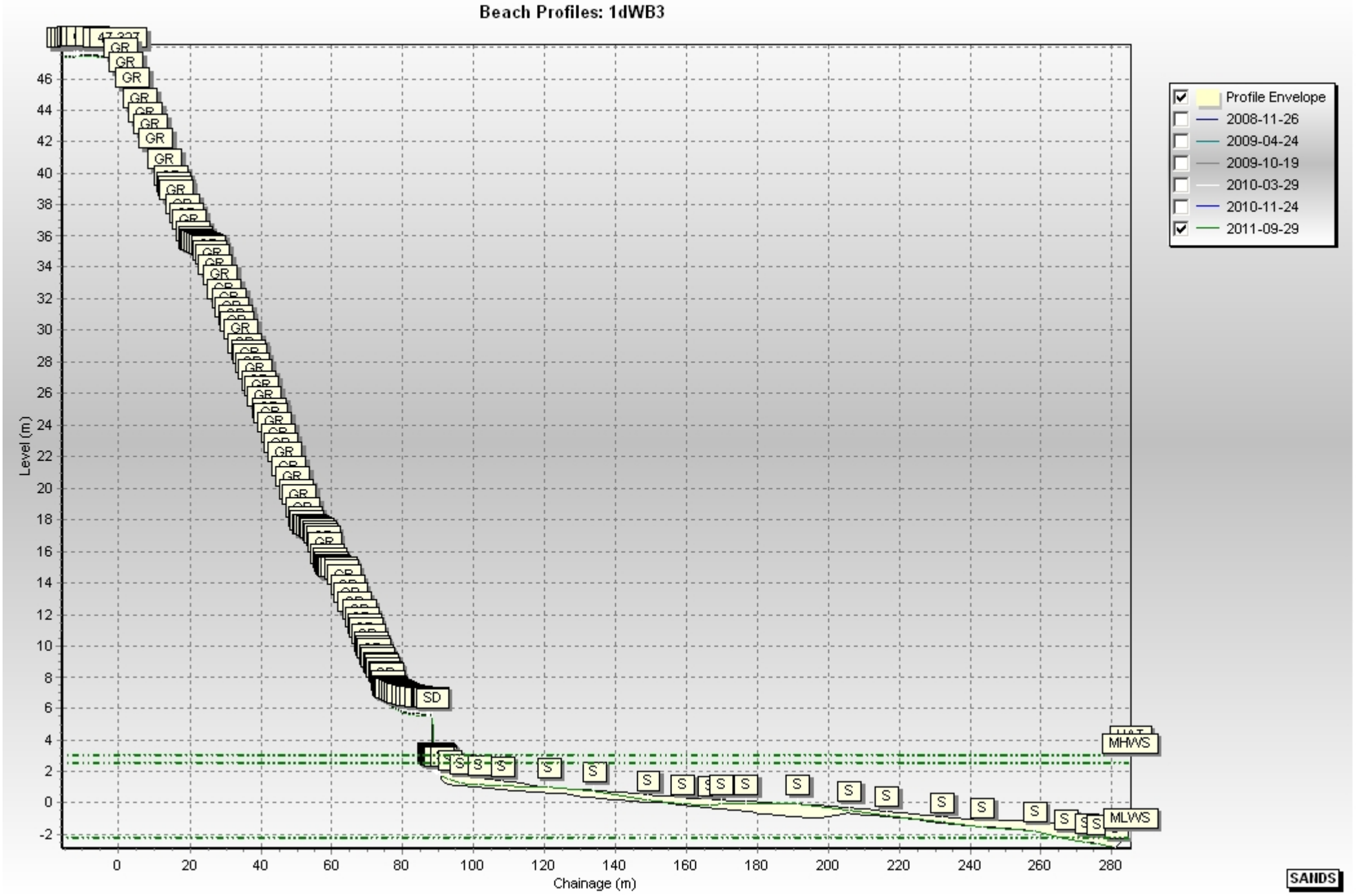
MLWS
SANDS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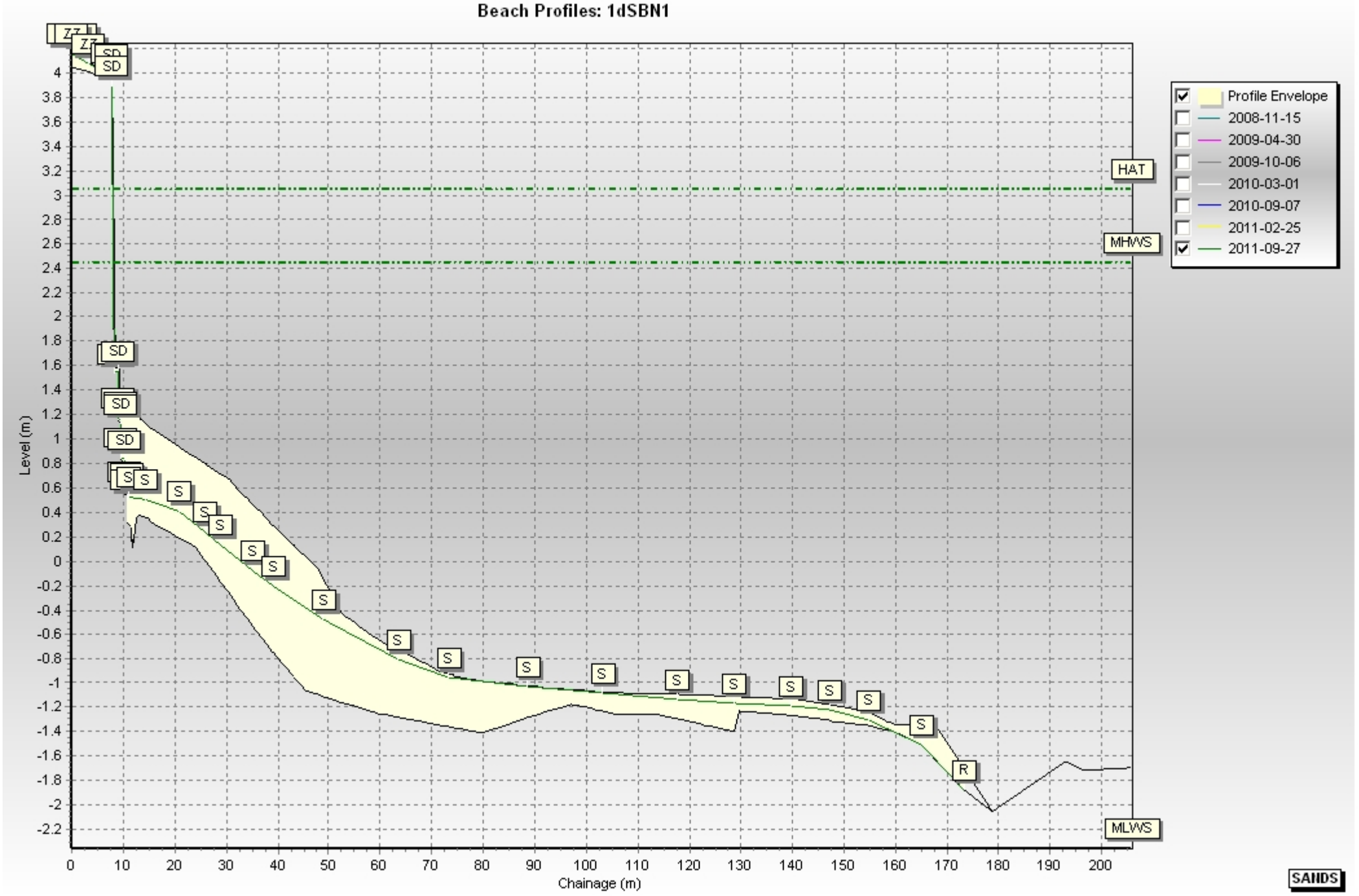
MLWS
SD
GR
S
SANDS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2010-03-01
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2011-09-27
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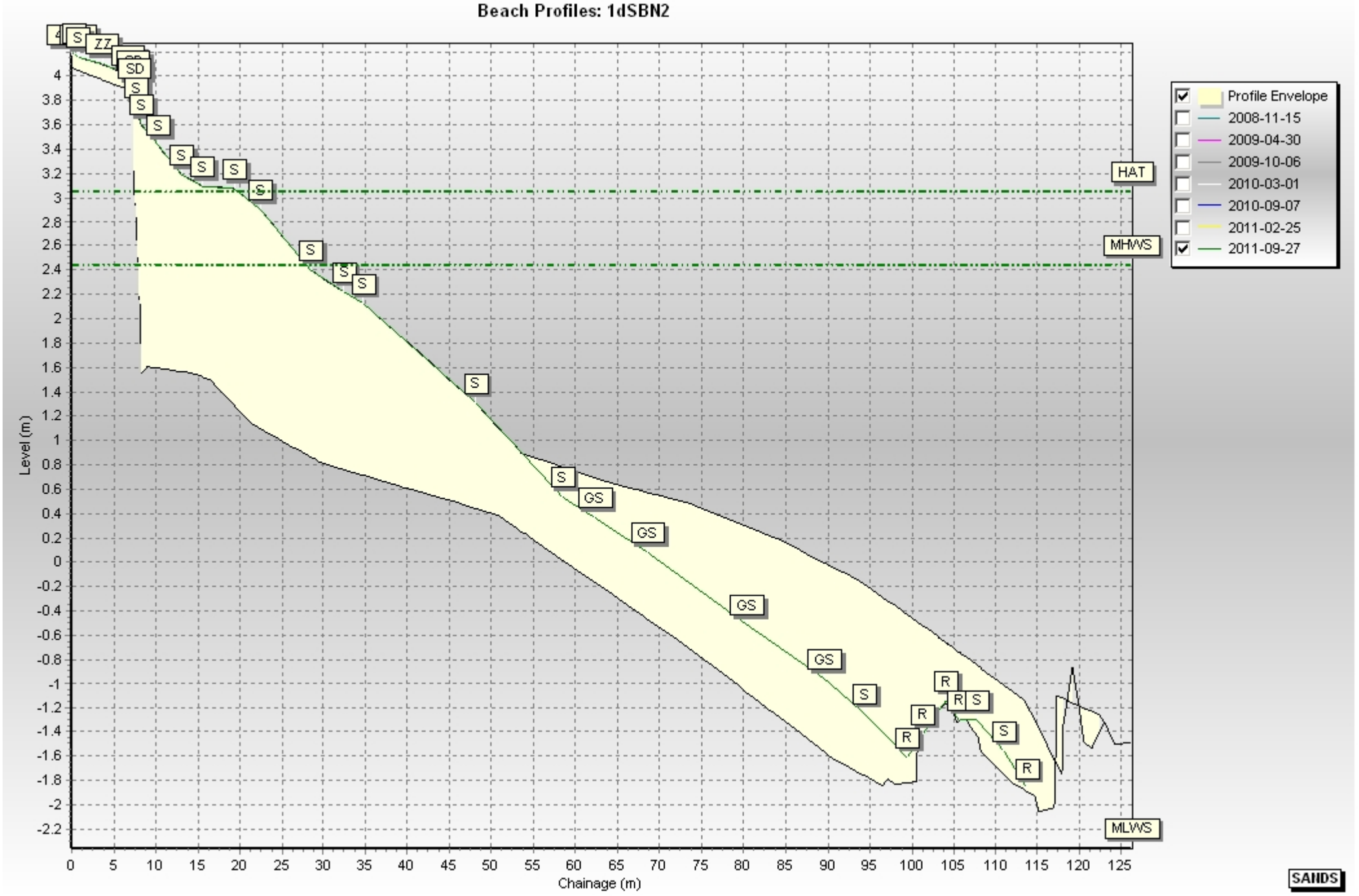
MLWS
Level (m)
Chainage (m)
SD
S
R
SANDS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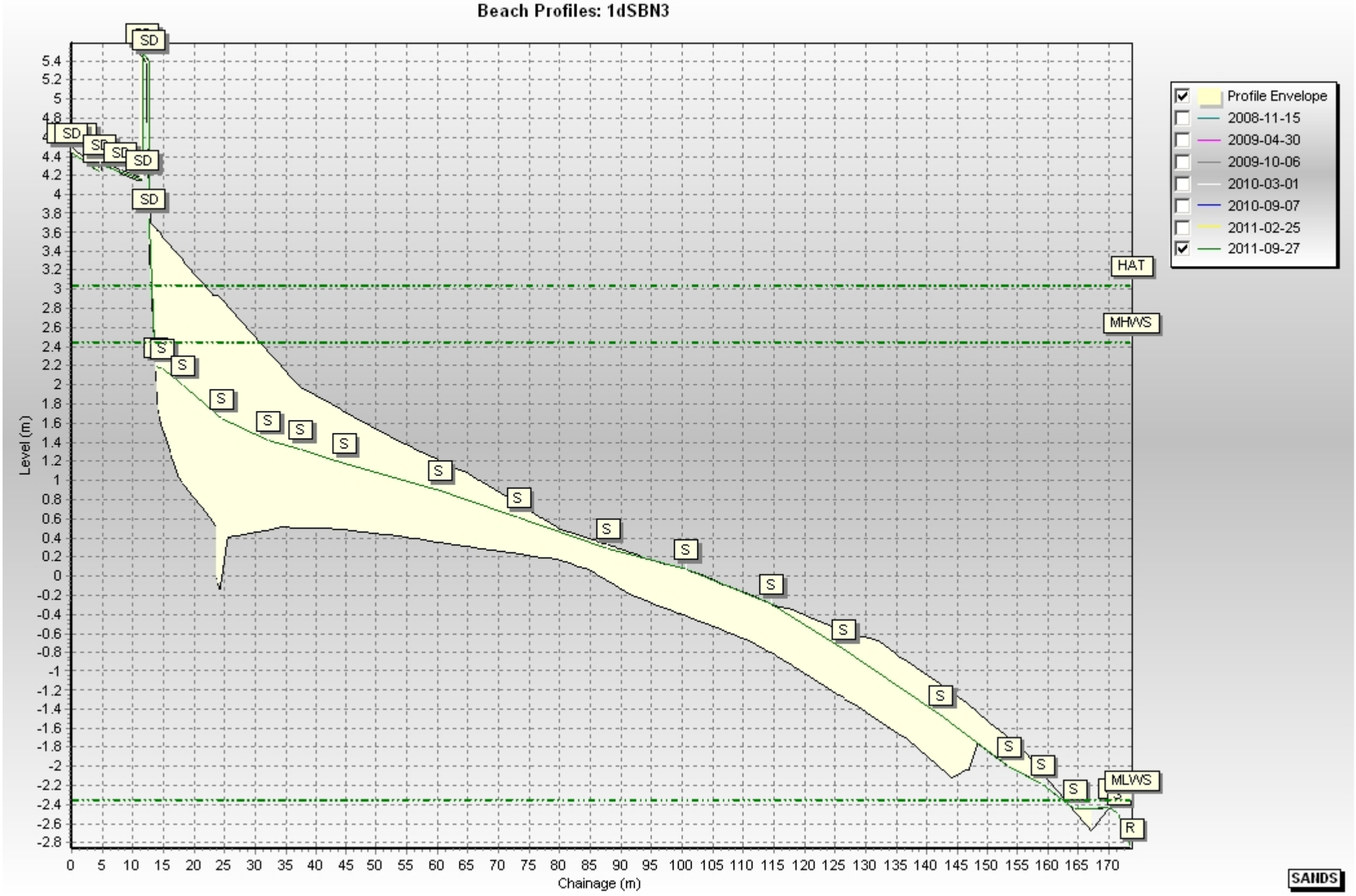
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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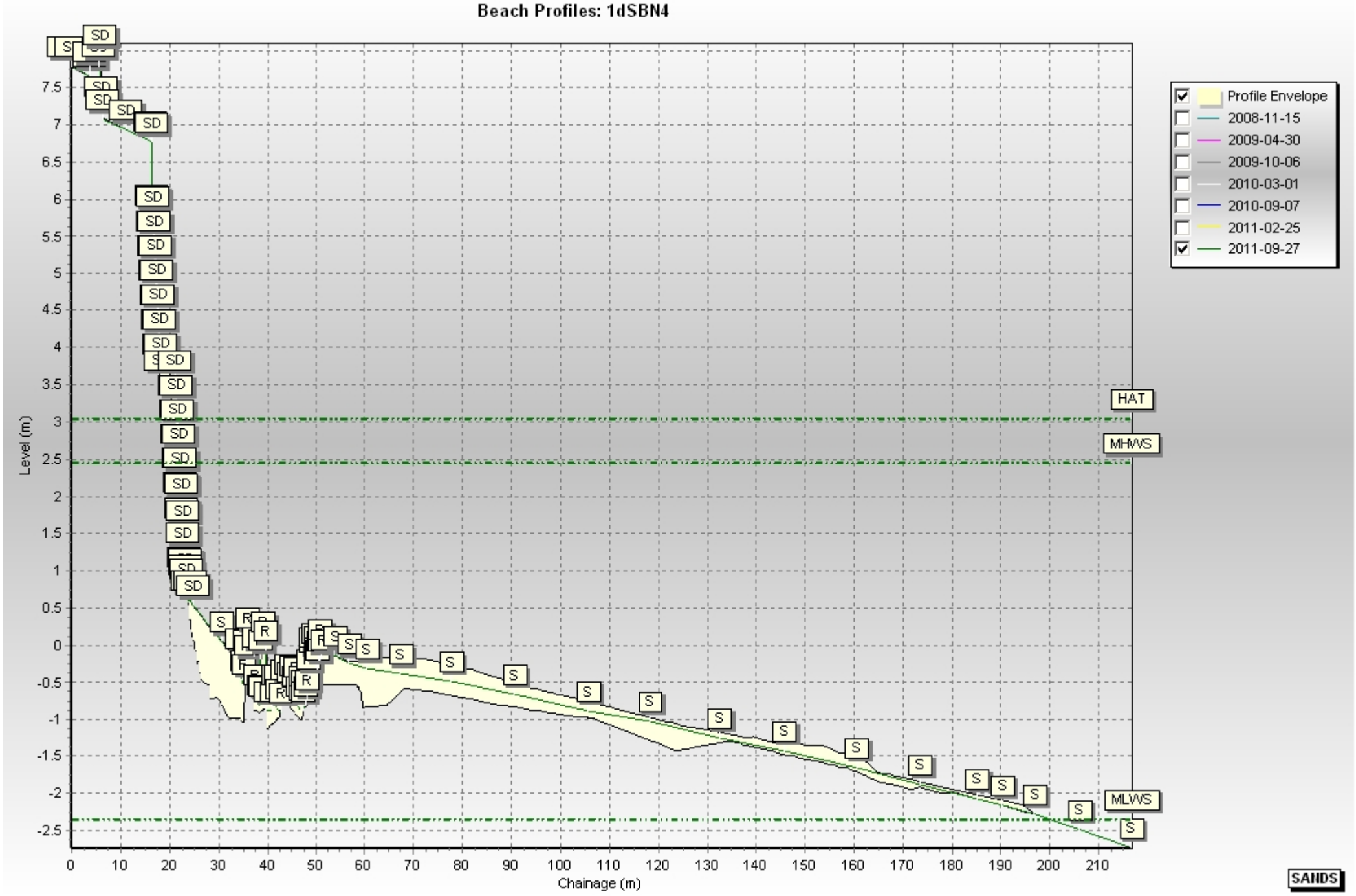
MLWS
Level (m)
Chainage (m)
SD
S
R
SANDS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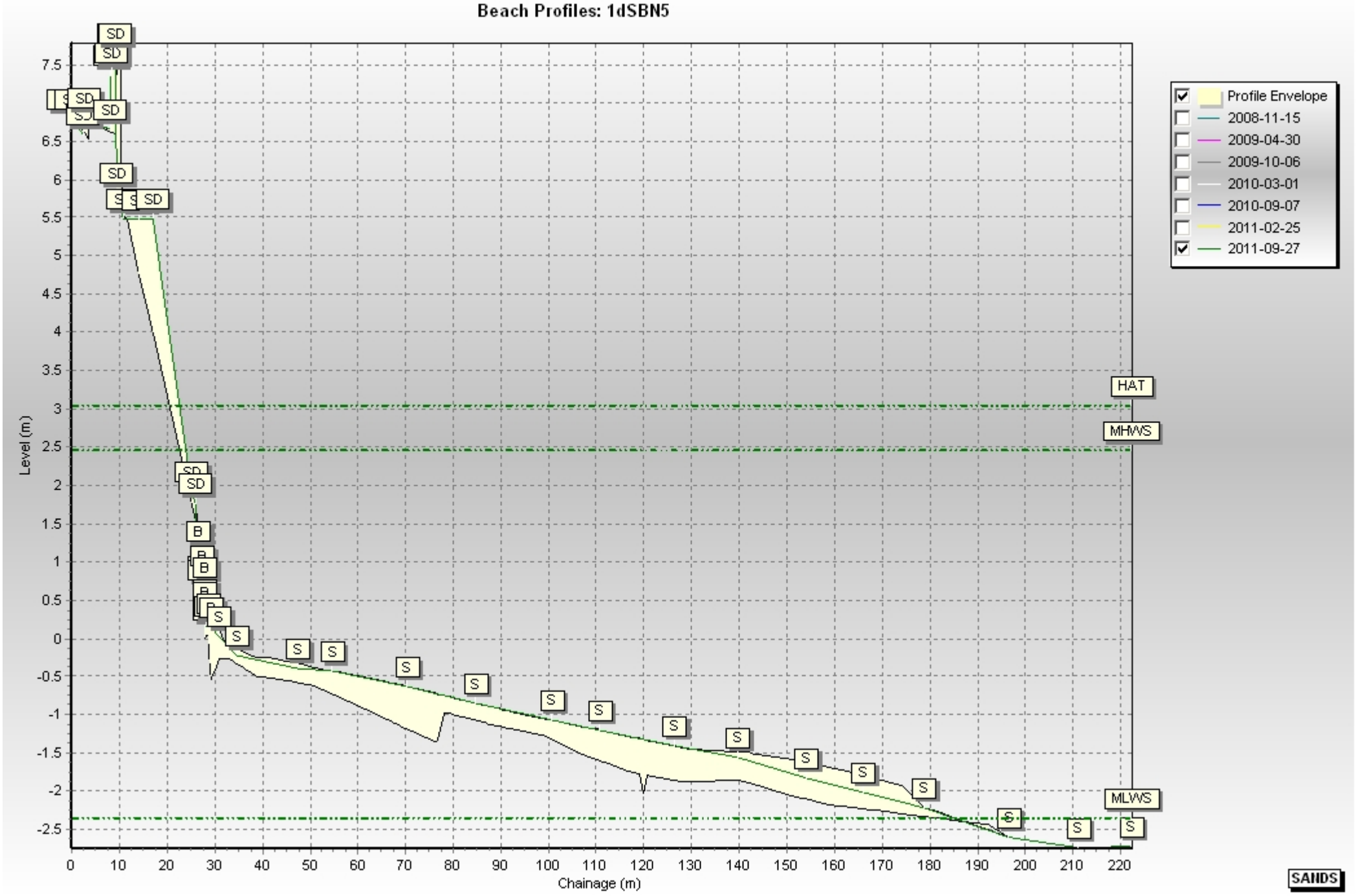
2011-02-25
2011-09-27
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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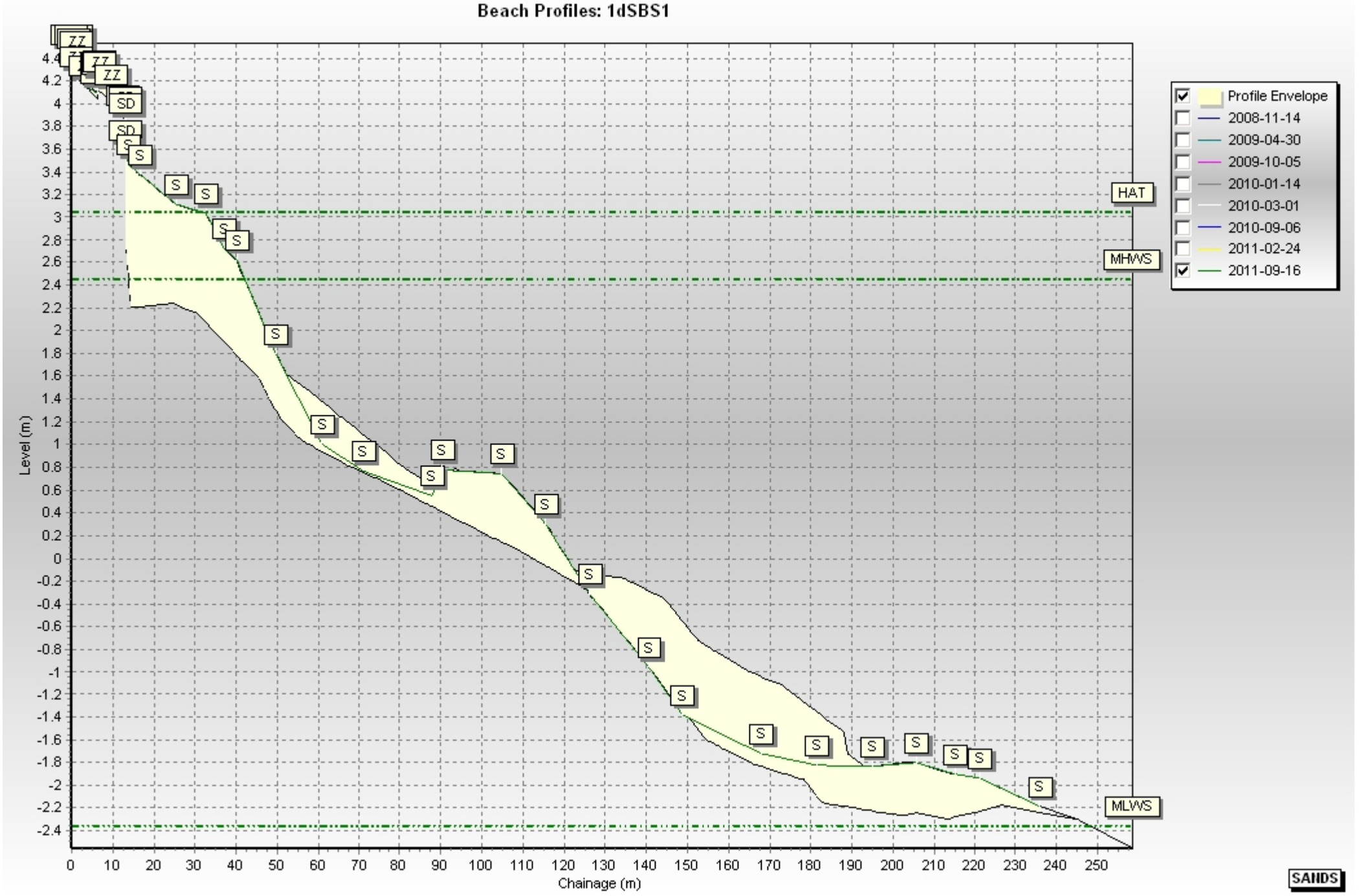
2011-09-27
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SD
B
S
SANDS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MLWS
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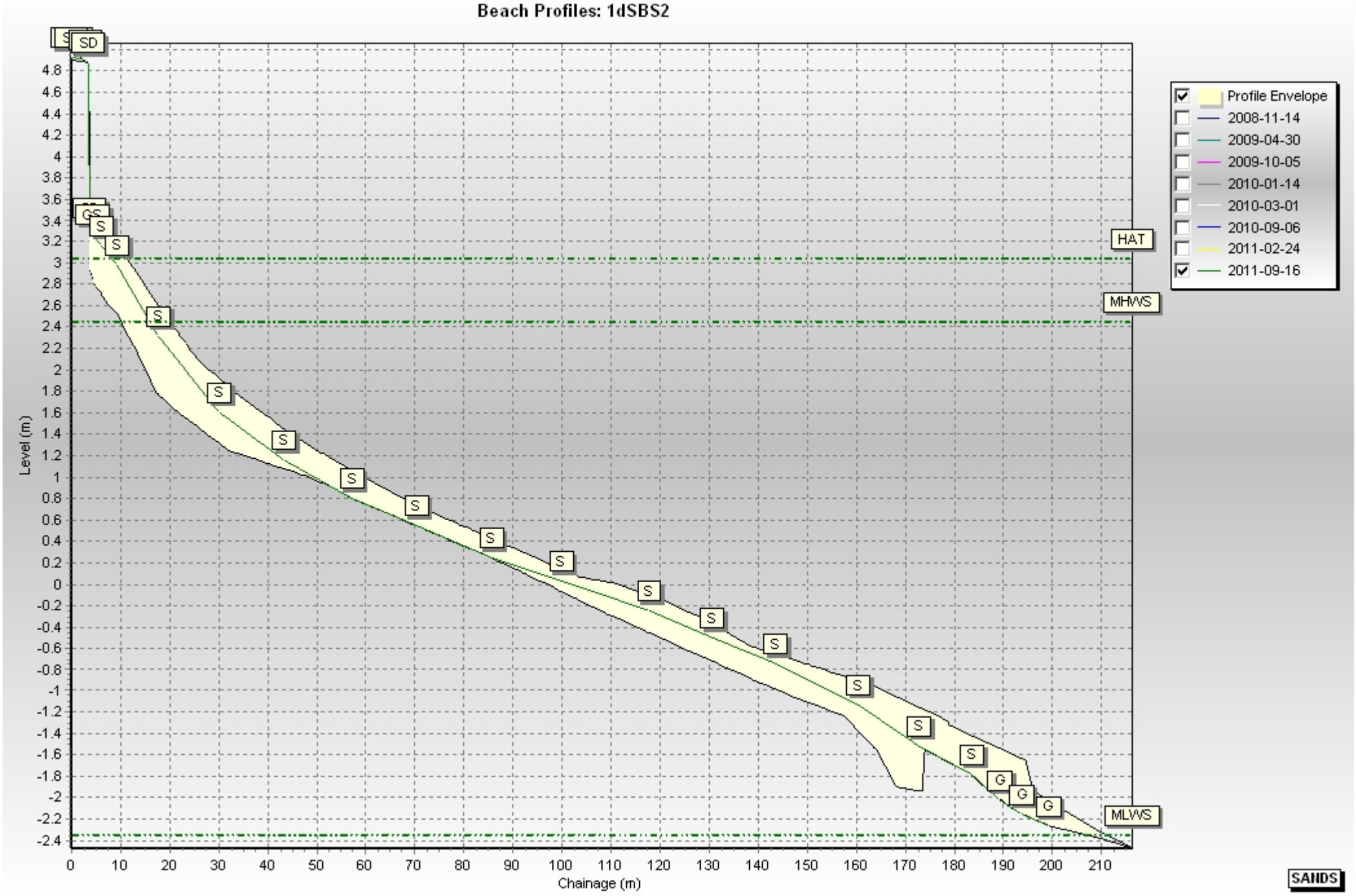
2010-09-06
2011-02-24
2011-09-16
SANDS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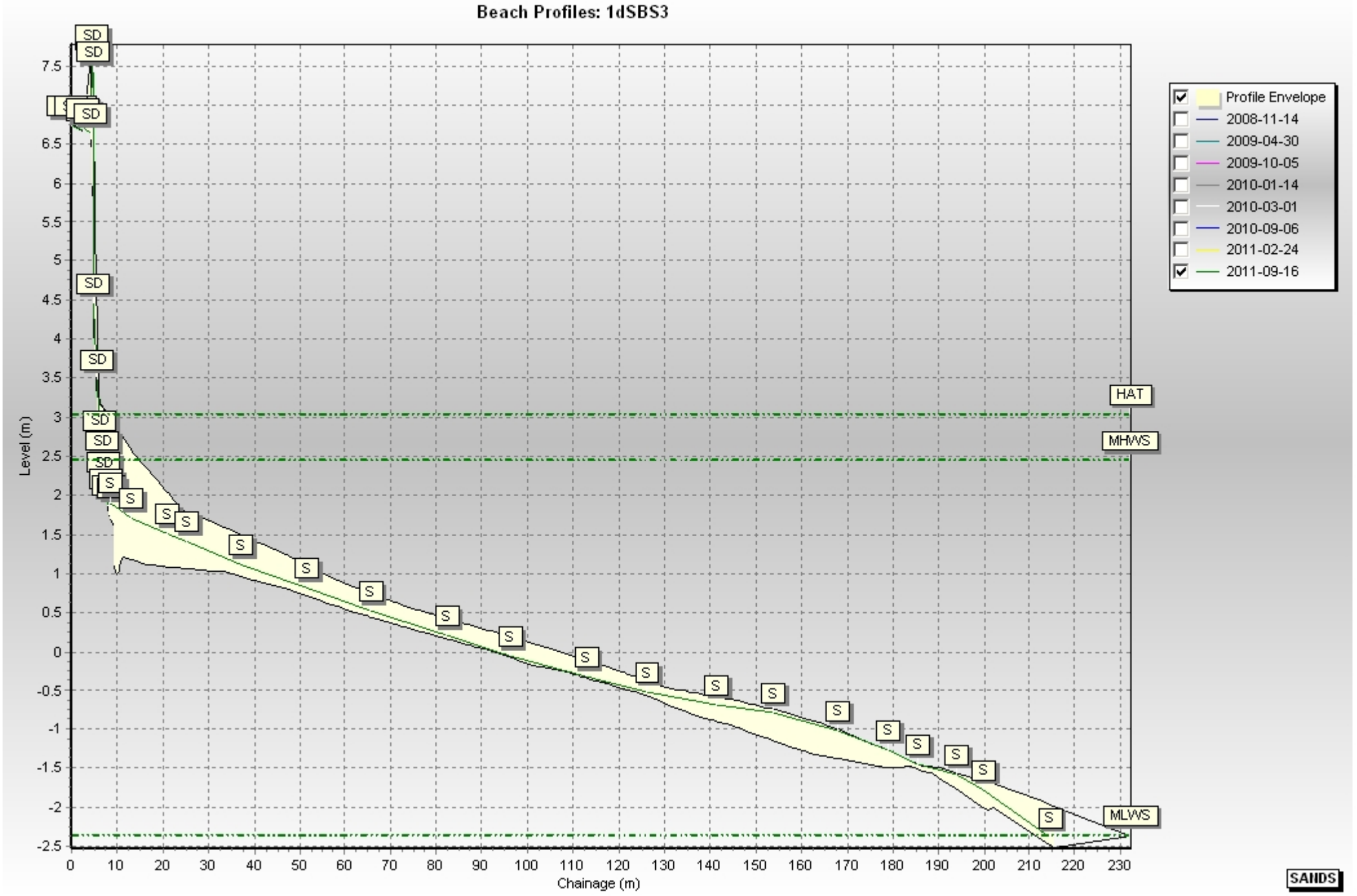
2009-04-30
2009-10-05
2010-01-14
2010-03-01
2010-09-06
2011-02-24
2011-09-16
HAT
MHWS
MLWS
SD
S
G
Level (m)
Chainage (m)
SANDS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2010-03-01
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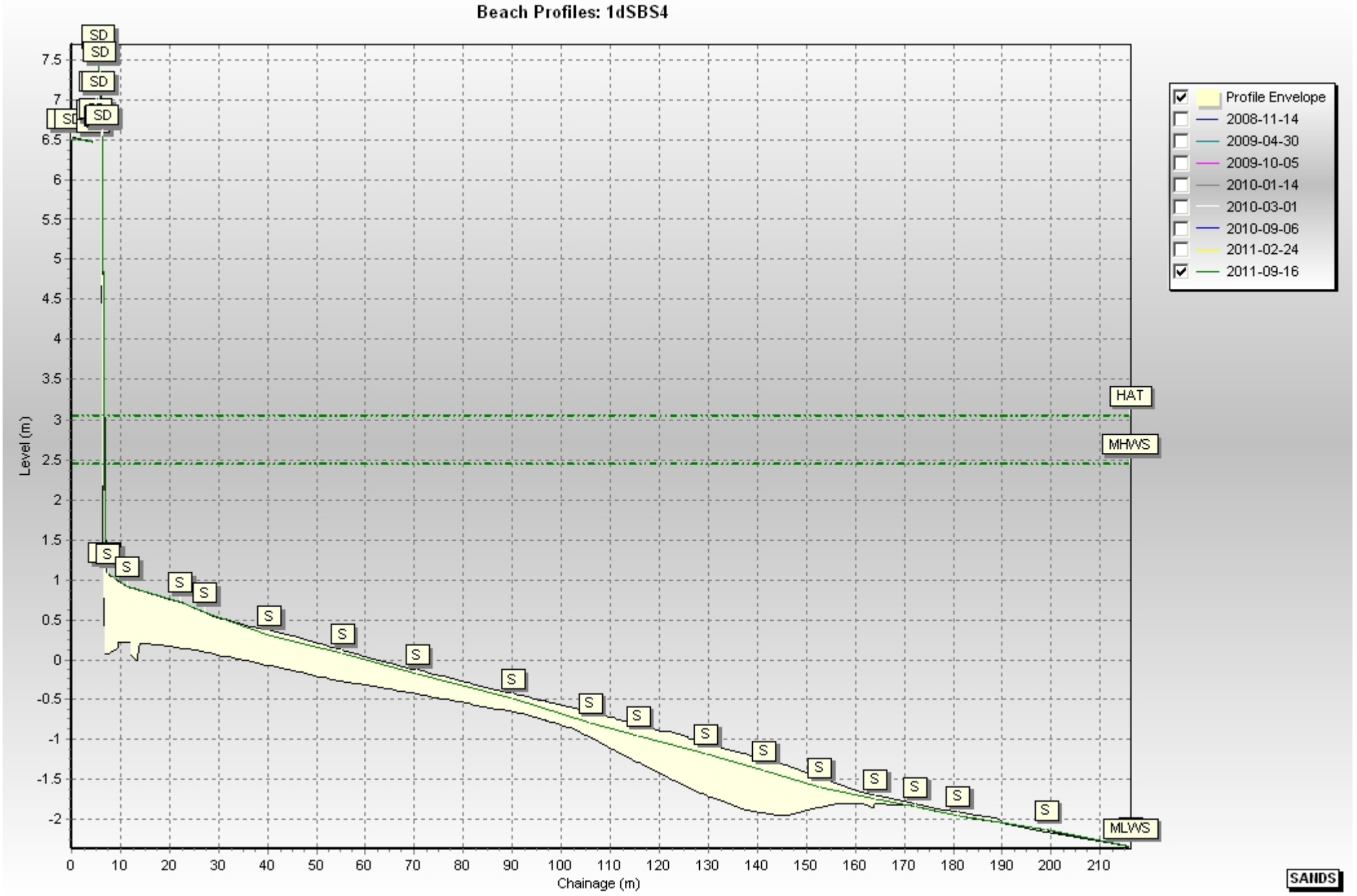
2011-09-16
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SD
S
SANDS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2008-11-14
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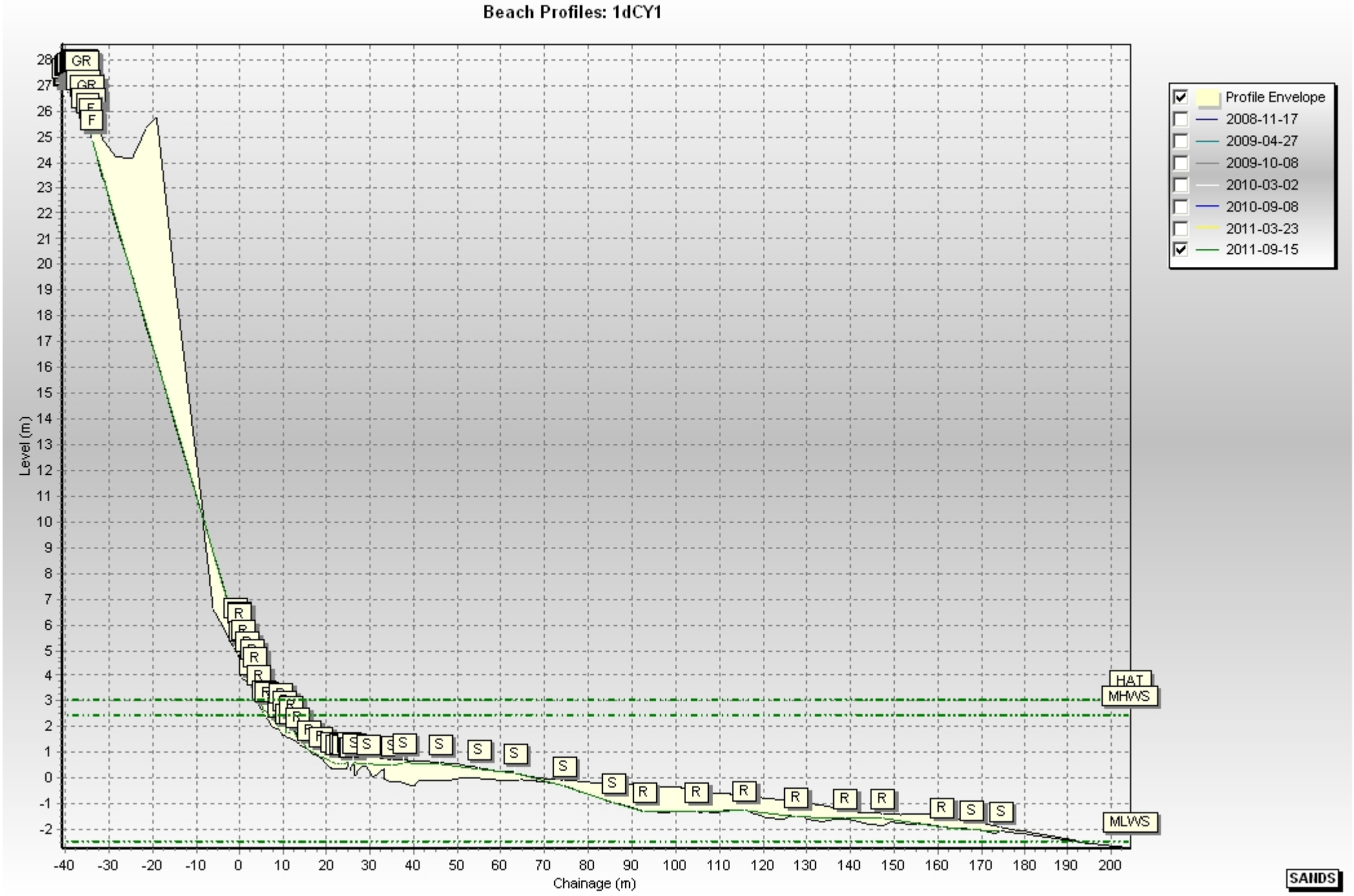
2011-09-16
HAT
MHWS
MLWS
SD
S
Level (m)
Chainage (m)
SANDS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2008-11-17
2009-04-27
2009-10-08
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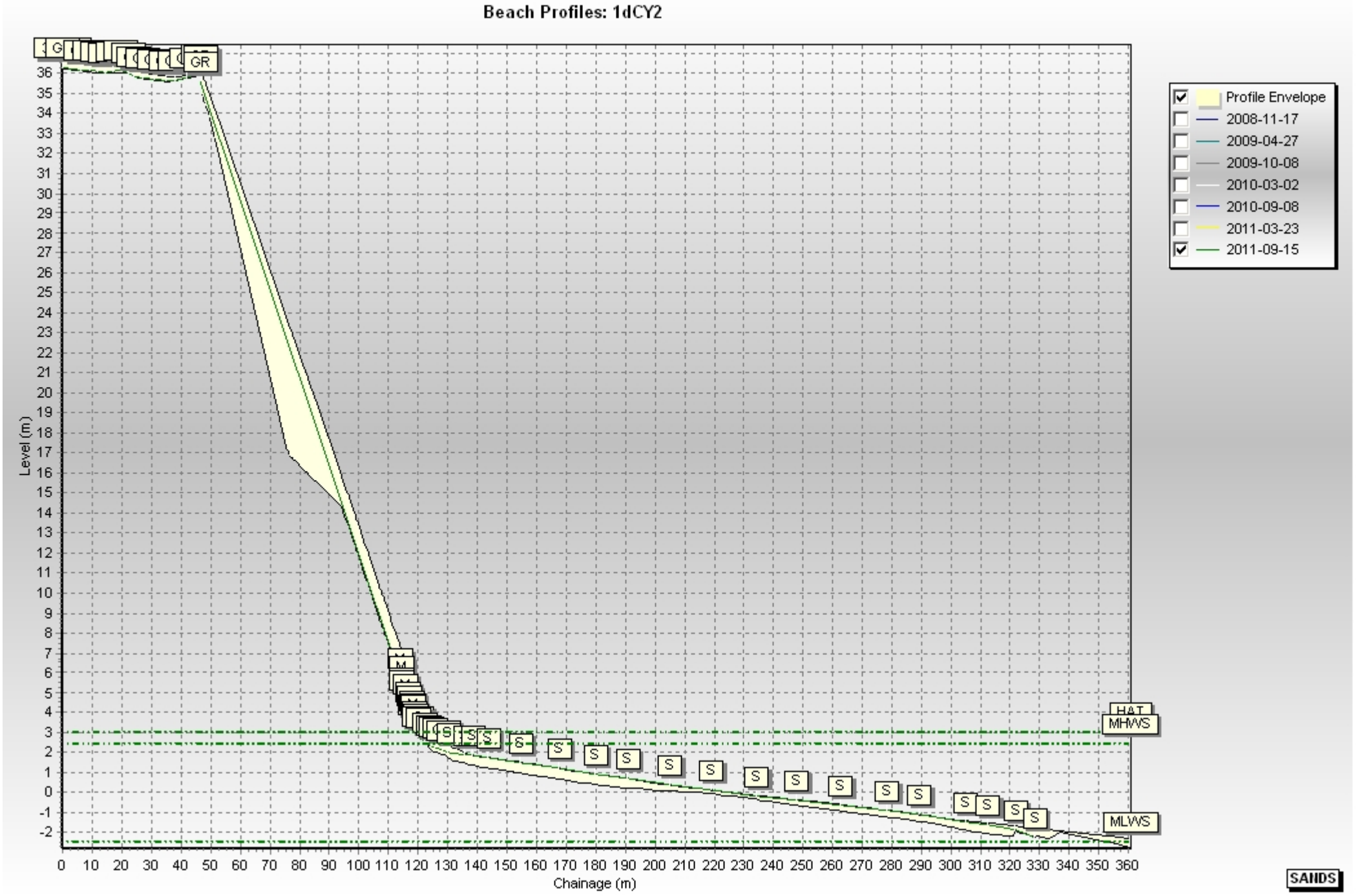
2011-03-23
2011-09-15
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SANDS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2009-04-27
2009-10-08
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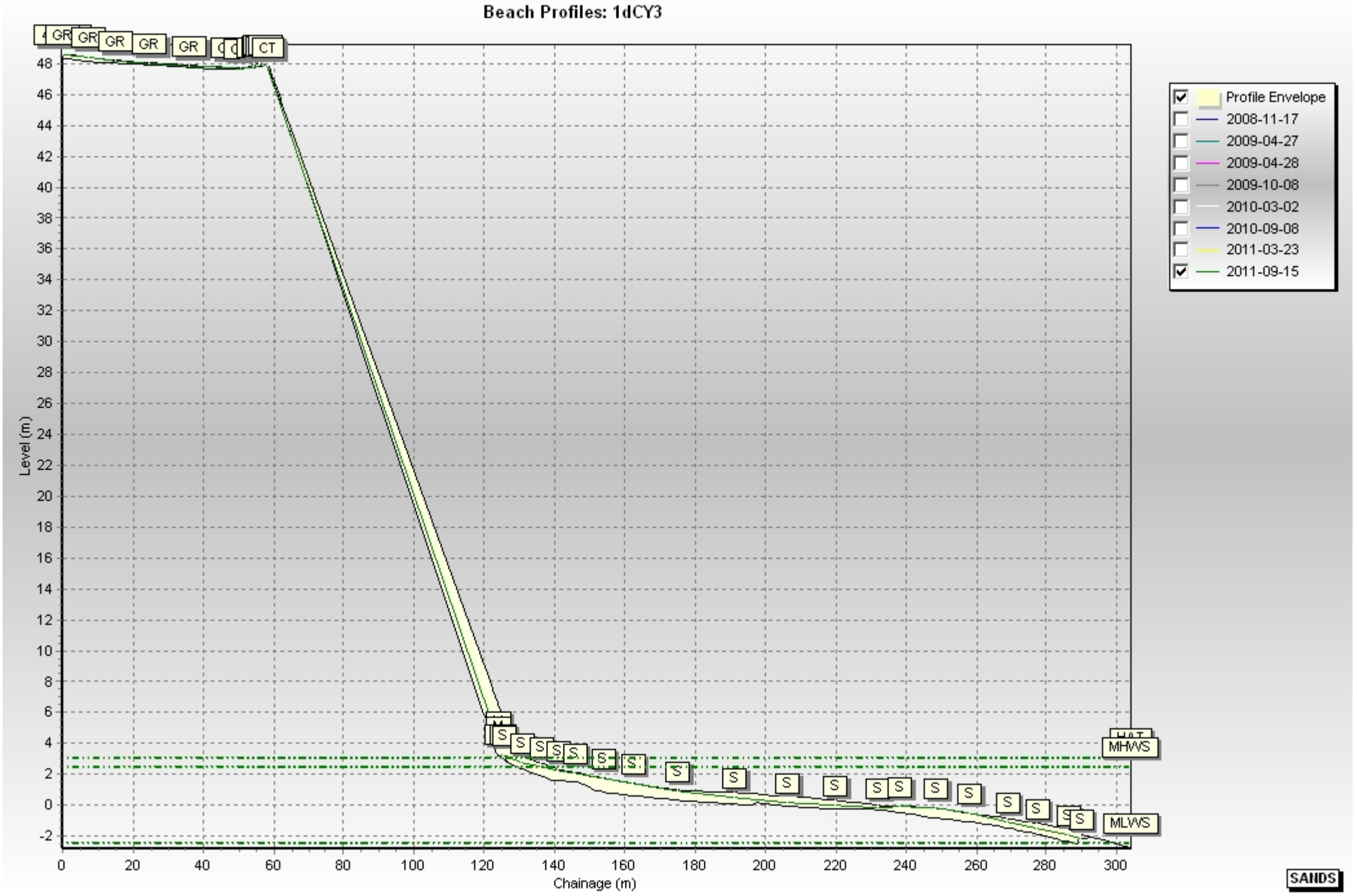
GR
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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CT
Profile Envelope
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2009-04-27
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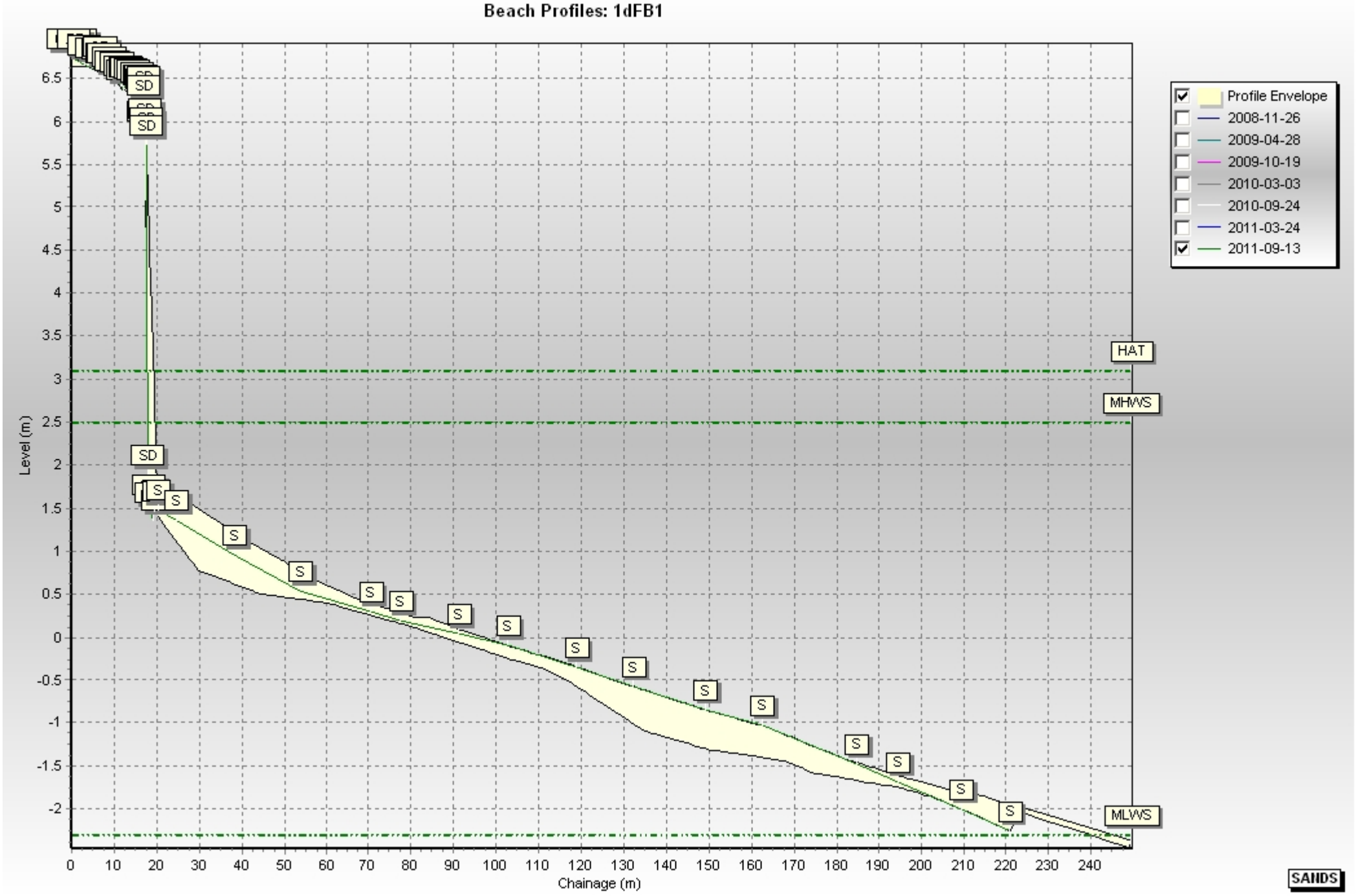
MHWS
MLWS
Level (m)
Chainage (m)
SANDS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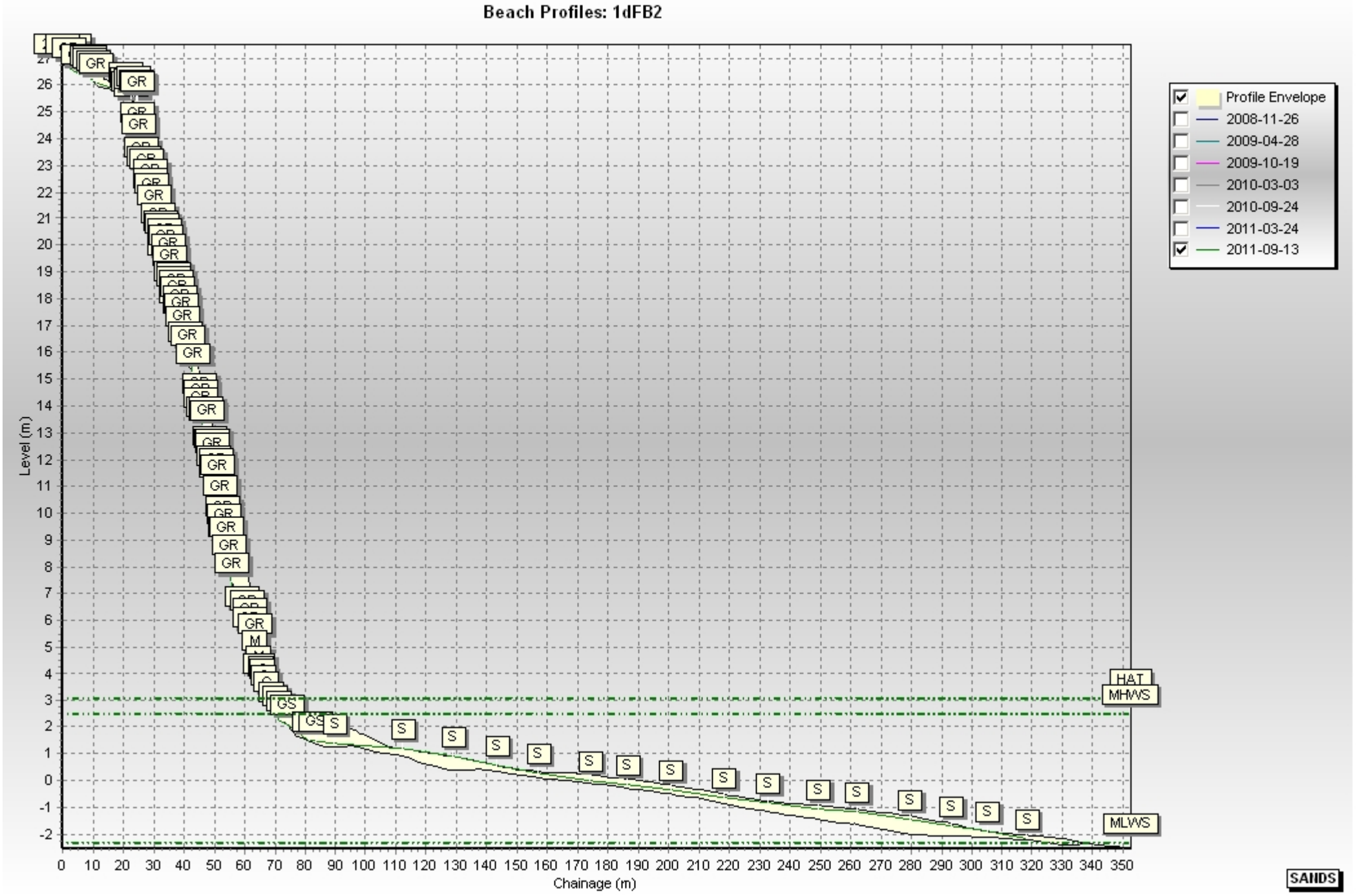
HAT
MHWS
MLWS
SD
S
Level (m)
Chainage (m)
SANDS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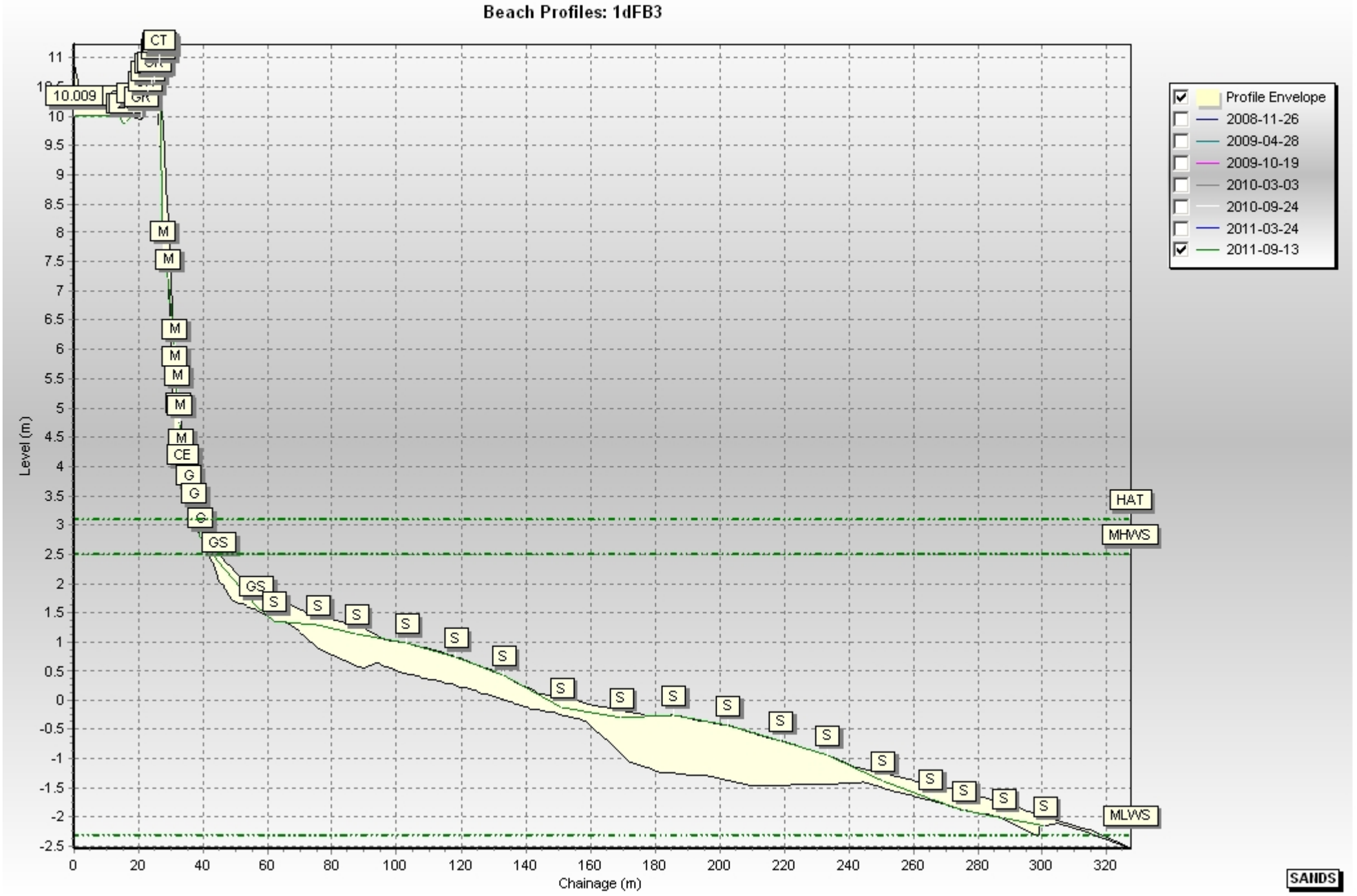
2010-03-03
2010-09-24
2011-03-24
2011-09-13
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SANDS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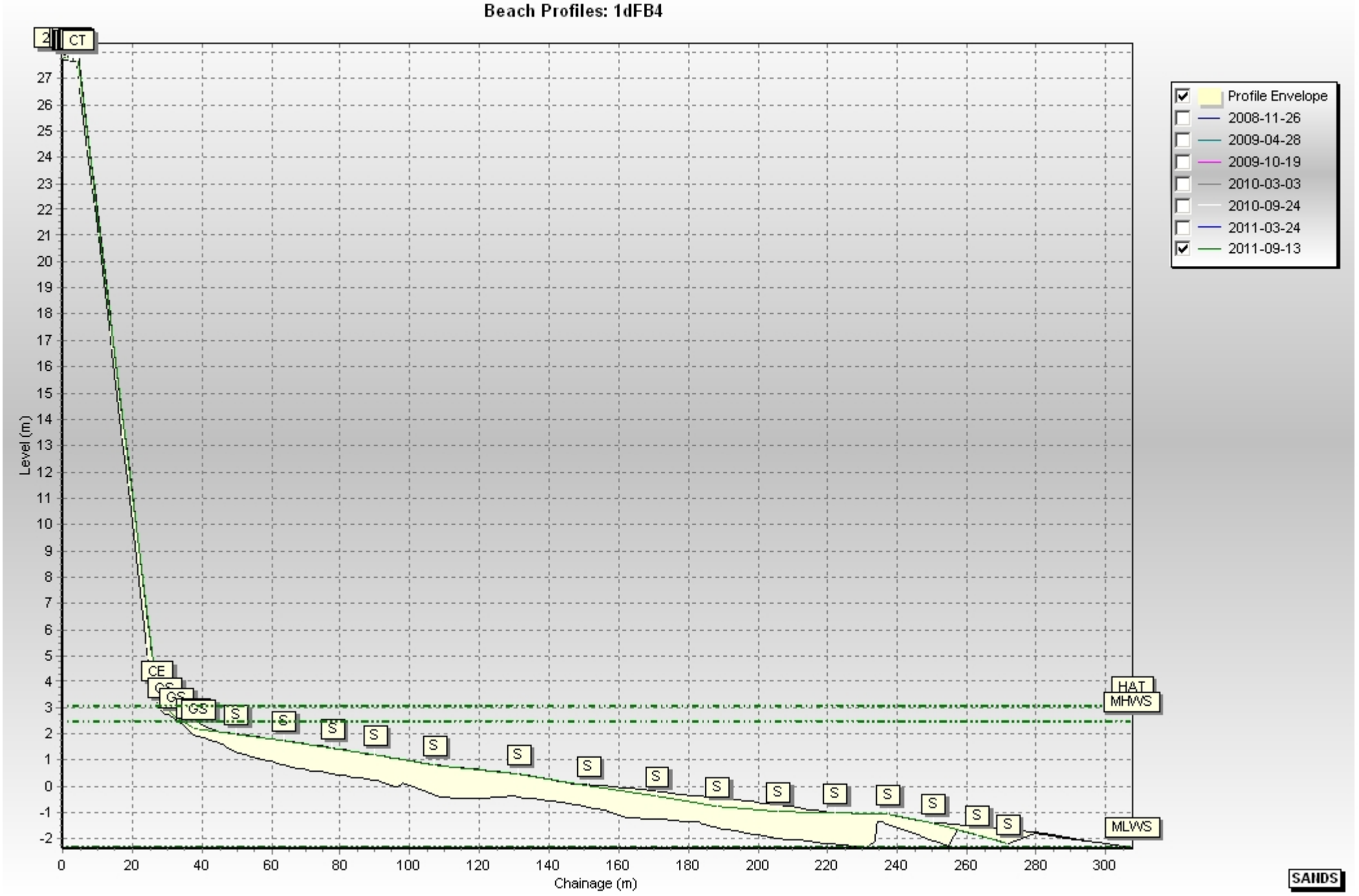
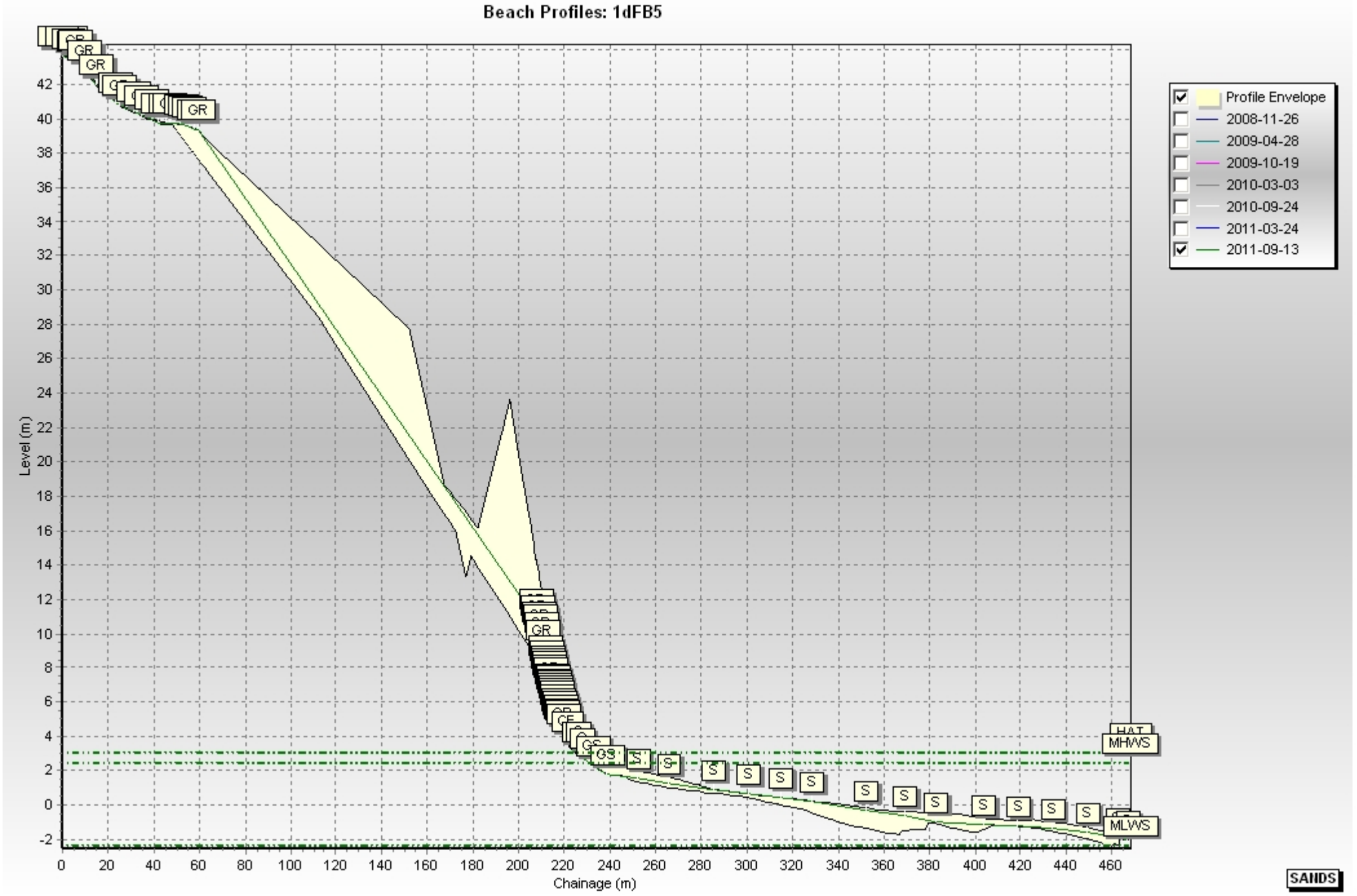
2010-03-03
2010-09-24
2011-03-24
2011-09-13
Level (m)
Chainage (m)
HAT
MHWS
MLWS
10.009
CT
M
CE
G
GS
S
SANDS


Beach Profiles: 1dFB4
CT
CE
GS
S
HAT
MHWS
MLWS
Profile Envelope
2008-11-26
2009-04-28
2009-10-19
2010-03-03
2010-09-24
2011-03-24
2011-09-13
Level (m)
Chainage (m)
SANDS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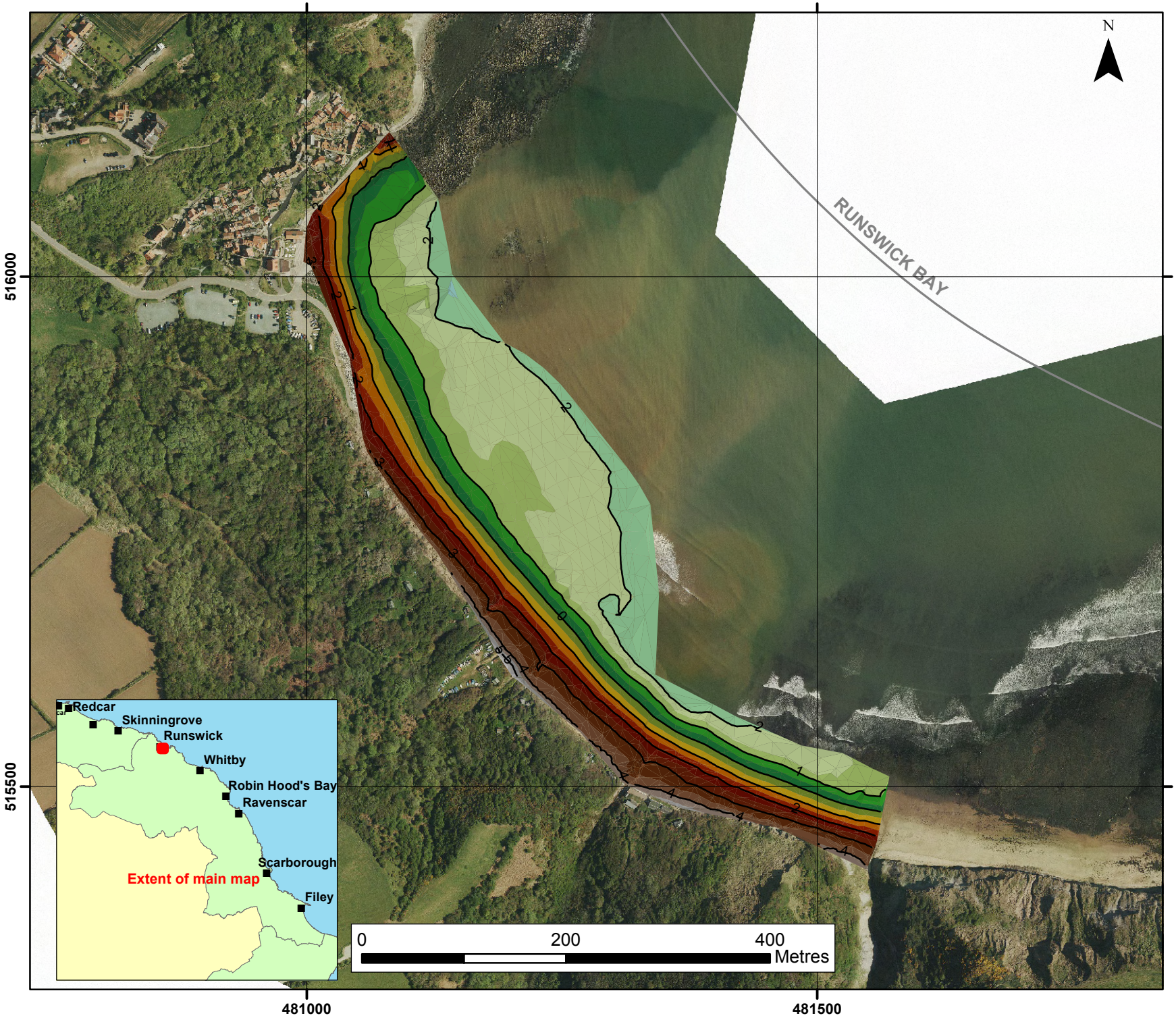
2009-10-19
2010-03-03
2010-09-24
2011-03-24
2011-09-13
Level (m)
Chainage (m)
GR
S
HAT
MHWS
MLWS
SANDS

# Appendix B

# Topographic Survey




## 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 (m)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

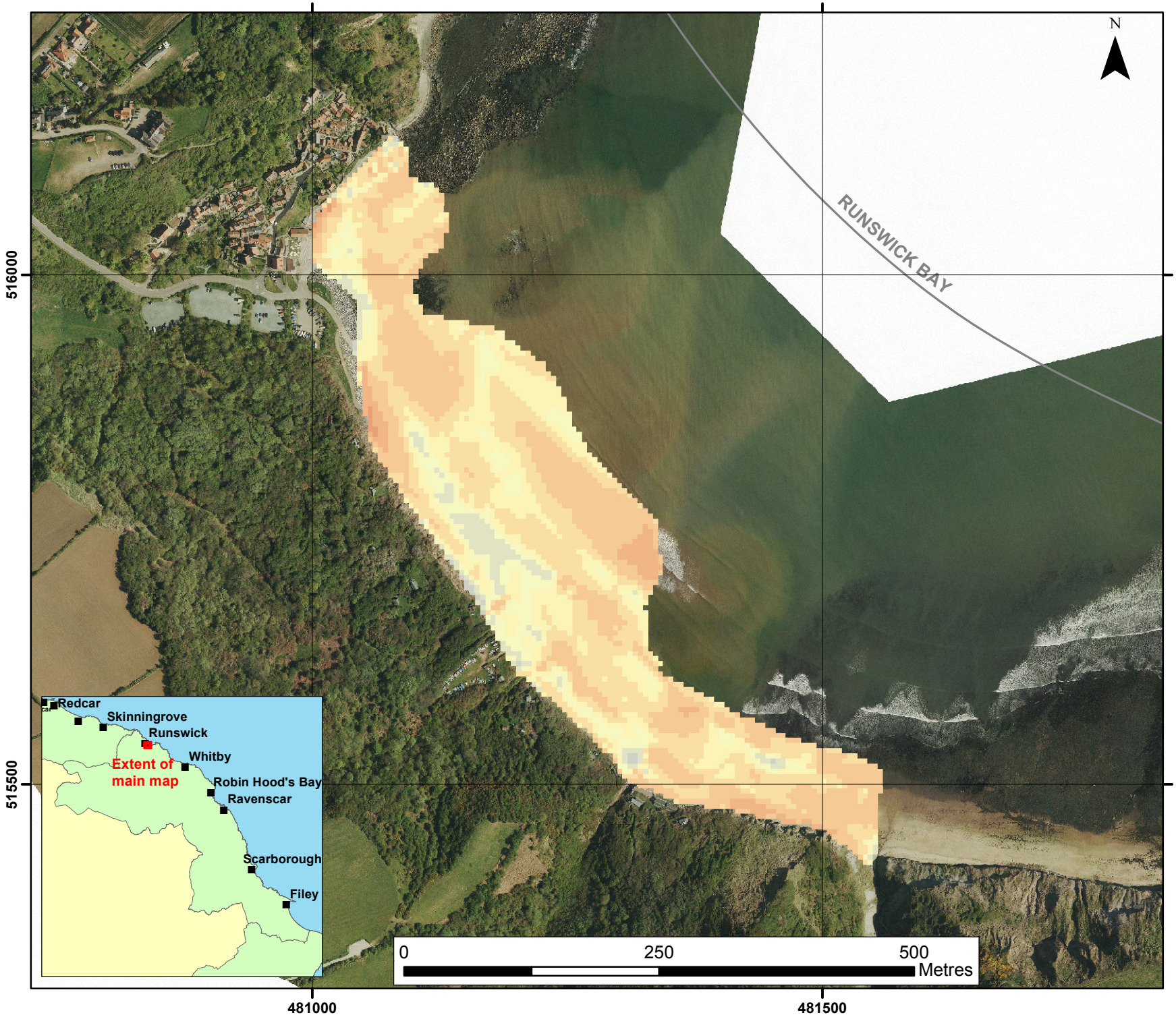
# Appendix B - Map 1a
# Topographic Survey
# Runswick
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

Halcrow
A CH2M HILL COMPANY

Halcrow Group Ltd, Lyndon House, 62 Hagley Road, Edgbaston, Birmingham, B16 8PE

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.halcrow.com




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

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B - Map 1b
# Topographic Difference
# Runswick
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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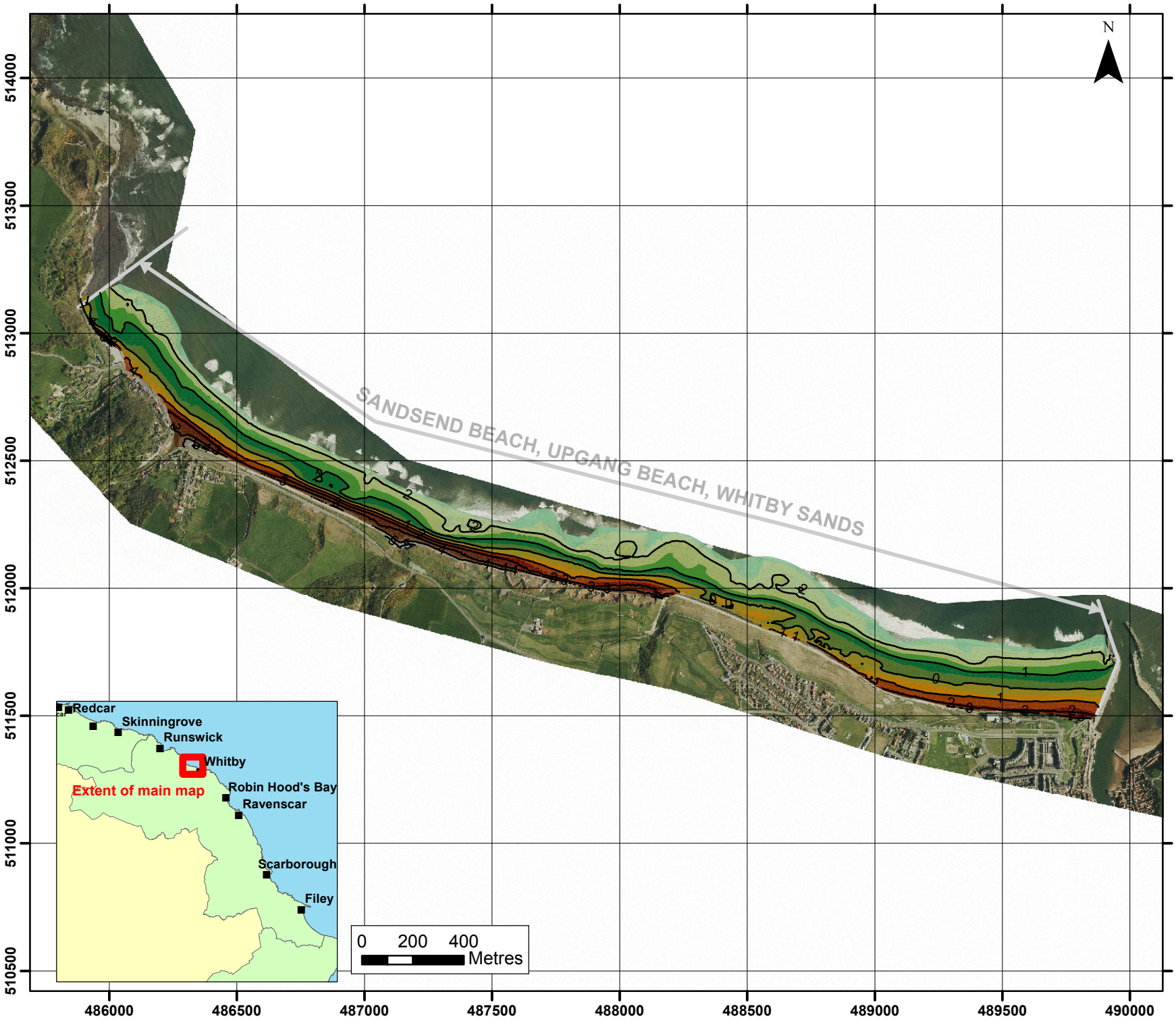


## KEY

**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
- -3 - -2.5
- -3.5 - -3
- Contour (m)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 2a
# Topographic Survey
# Whitby
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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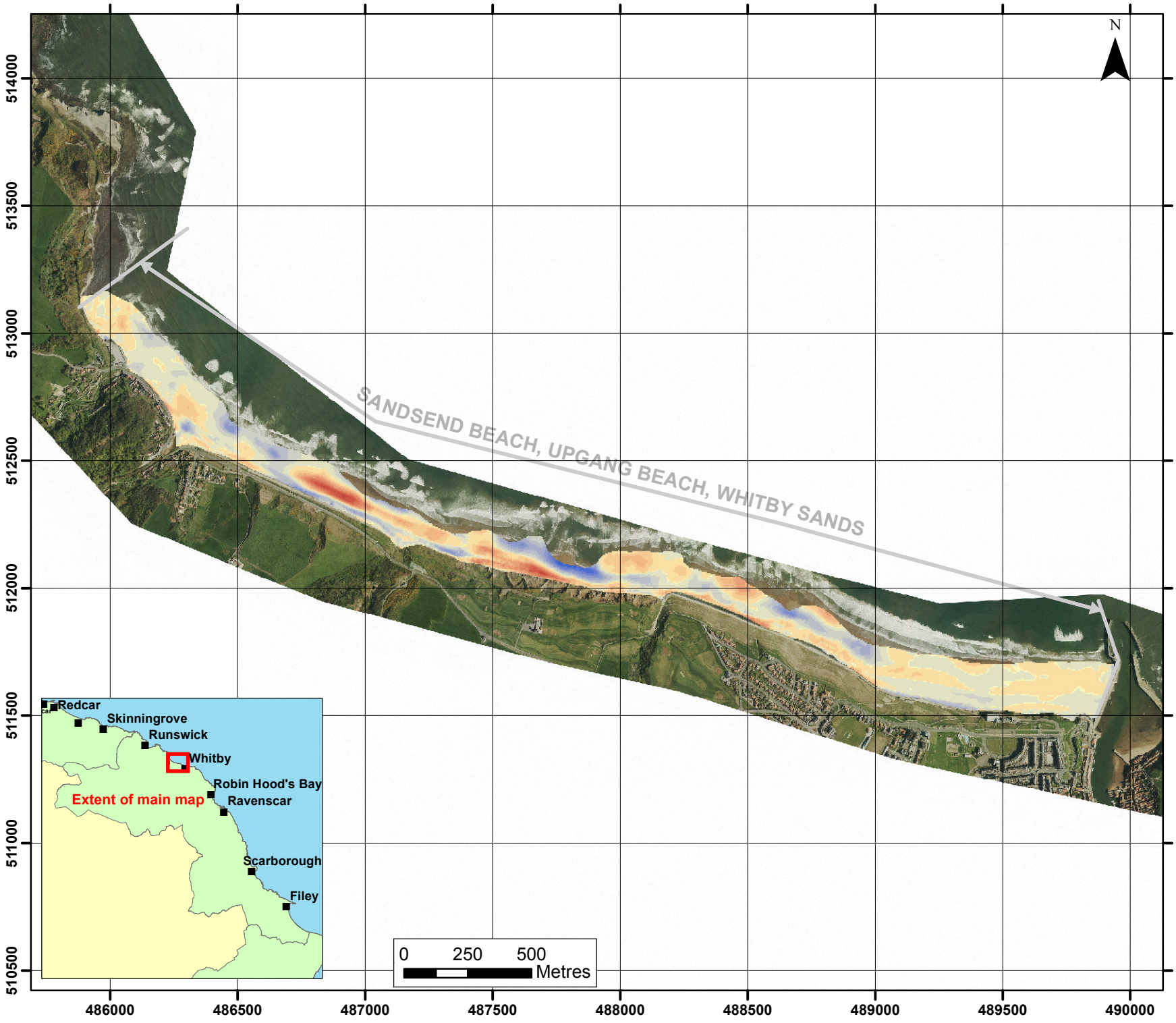


**KEY** Winter 2011 and Spring 2011 Change in elevation (m OD)

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B - Map 2b
# Topographic Difference
# Whitby
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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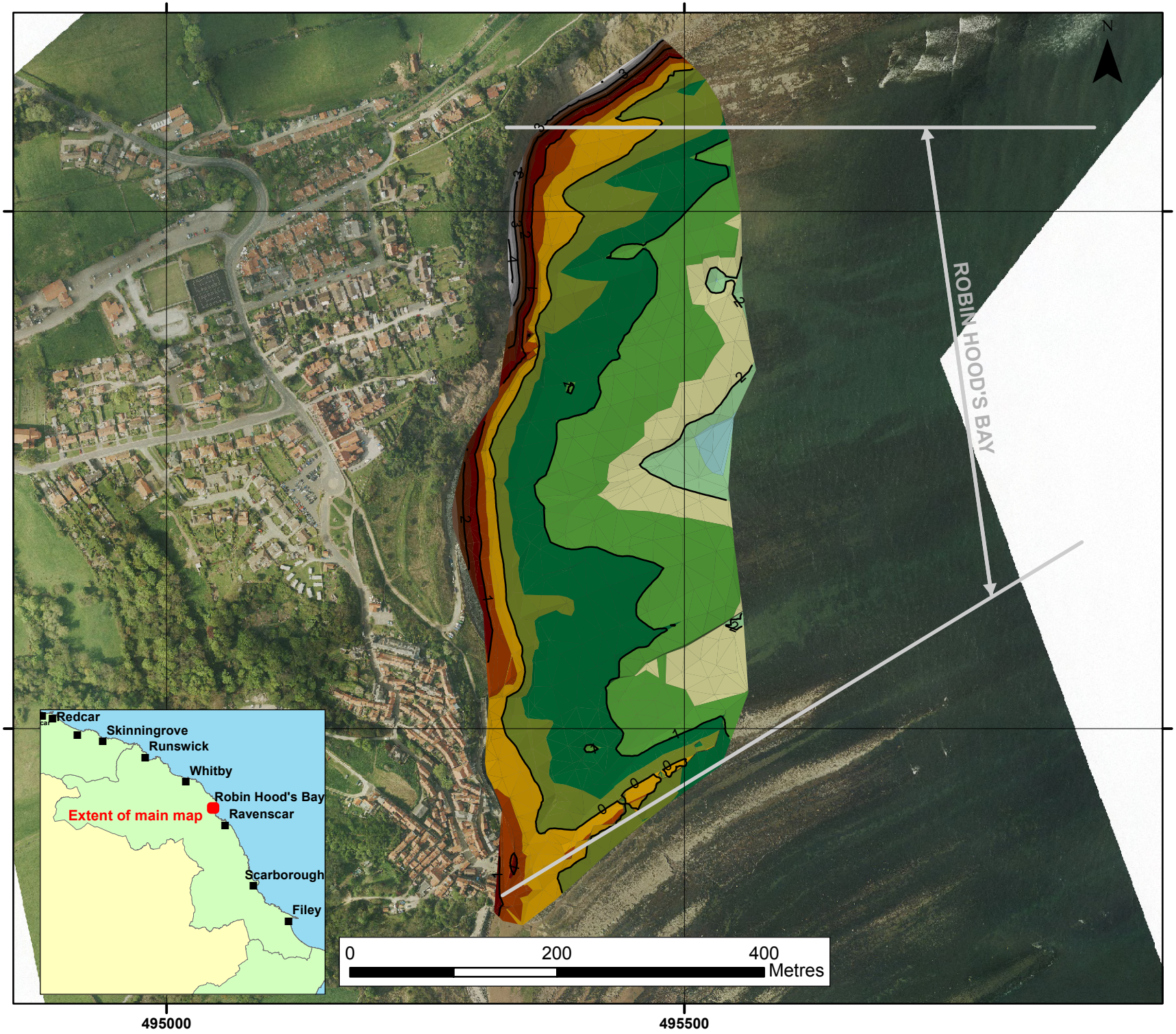


## KEY

**Elevation (m OD)**

- 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
# Robin Hood's Bay
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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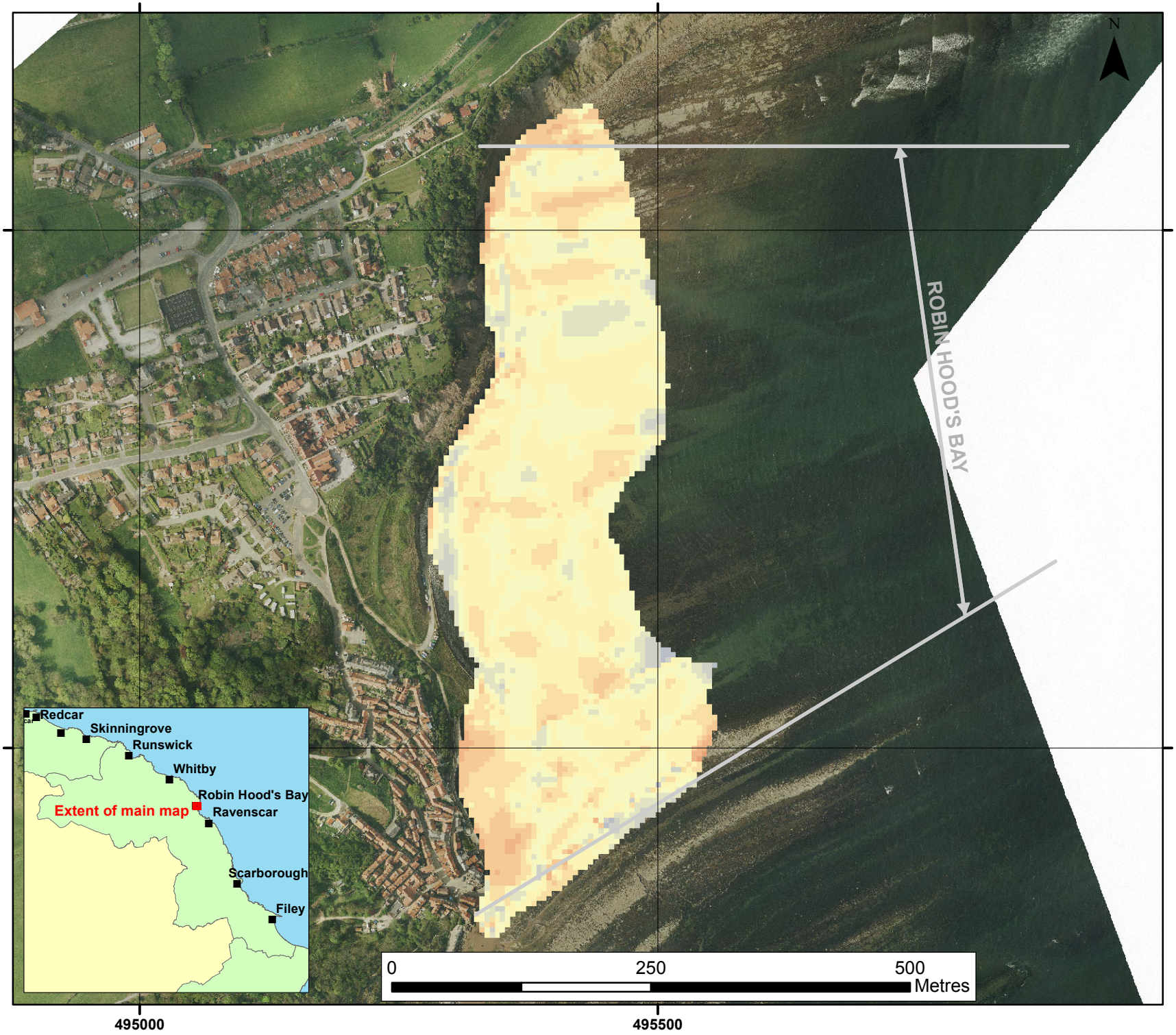
www.halcrow.com




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

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 3b
# Topographic Difference
# Robin Hood's Bay
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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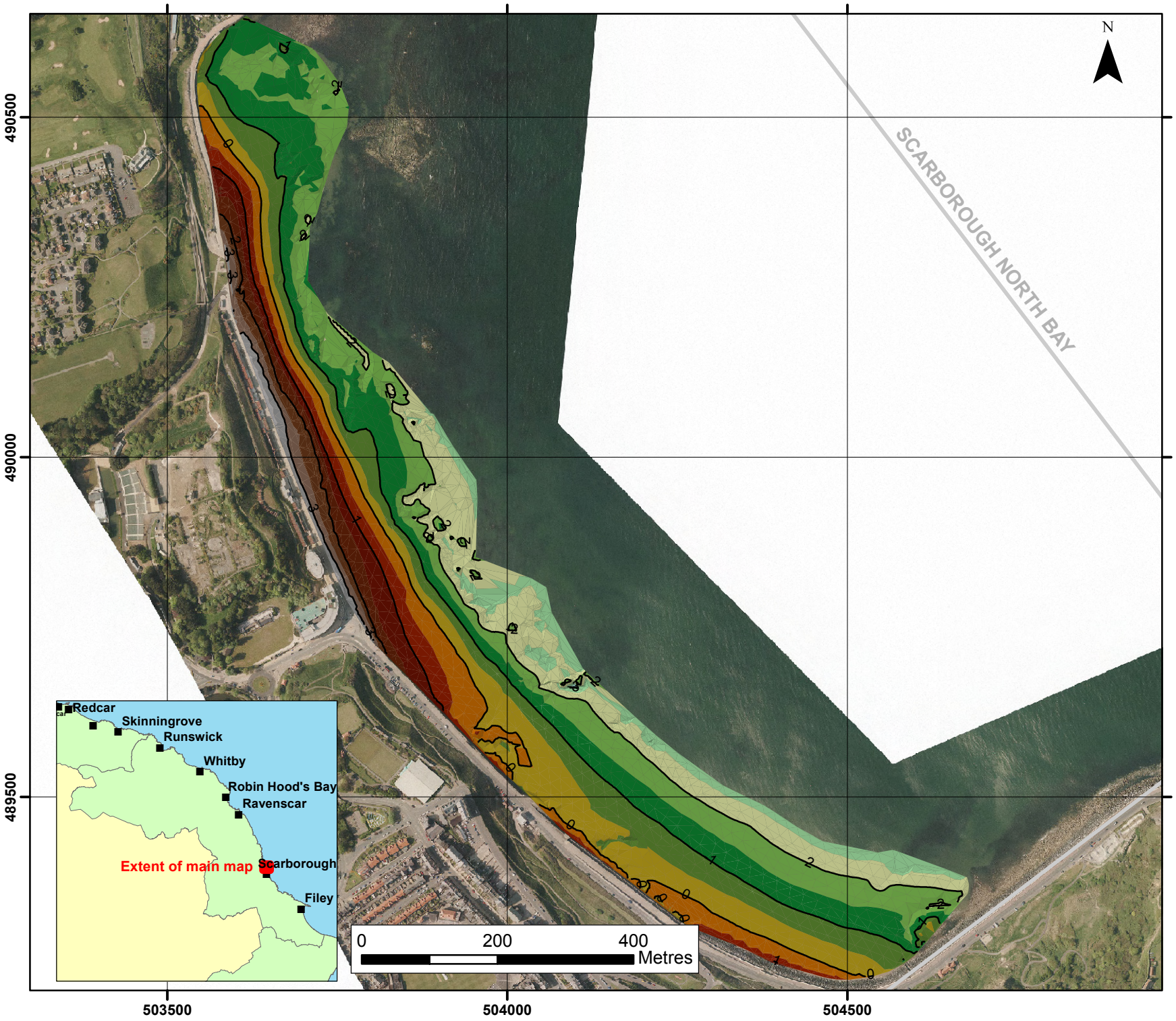


## KEY

**Elevation (m OD)**

- 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
- -3.5 - -3
- Contour (m)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 4a Topographic Survey Scarborough North Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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Fax: +44(0)121 456 1569
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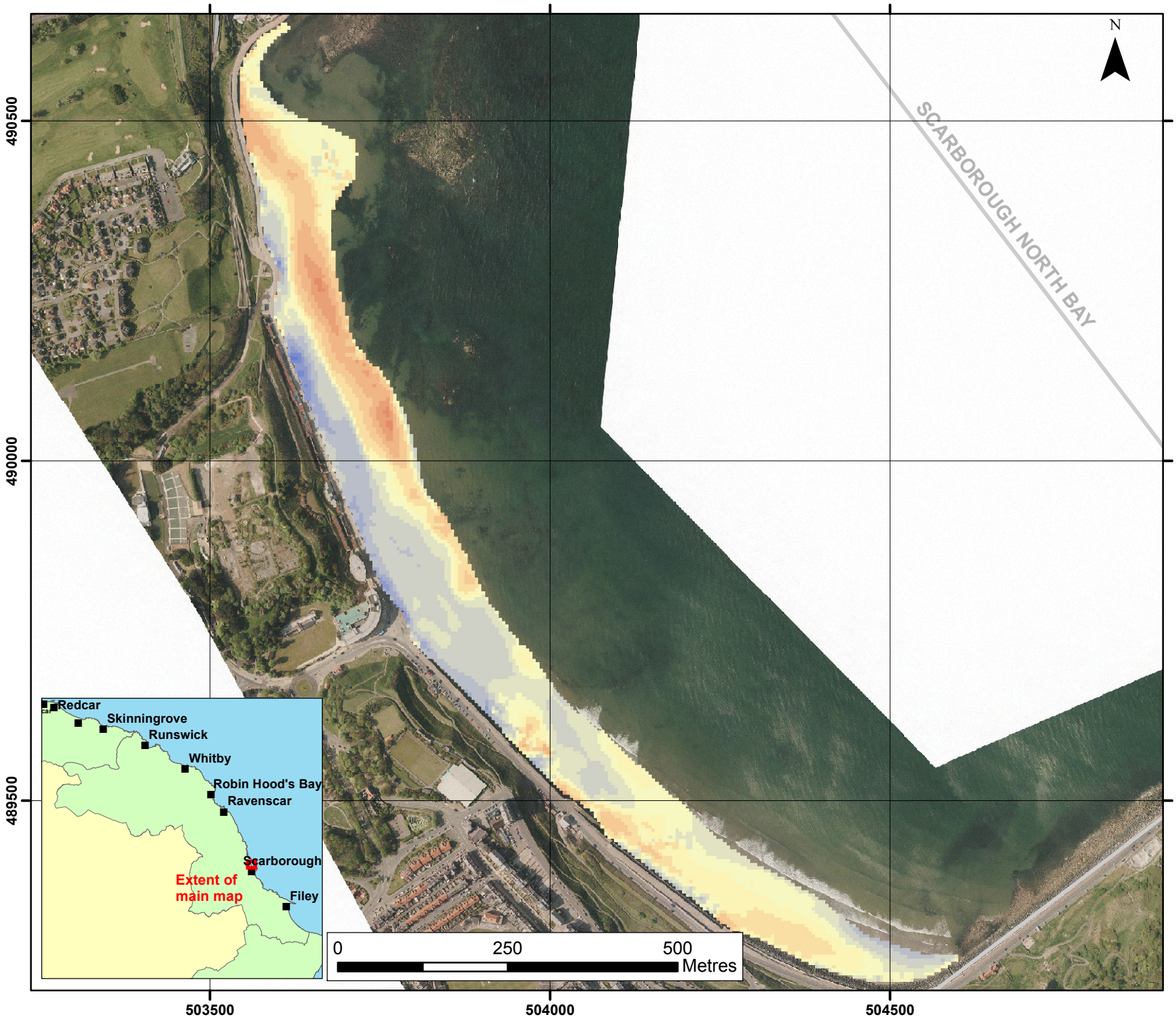


**KEY** Winter 2010 and Winter 2011 Change in elevation (m OD)

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 4b Topographic Difference Scarborough North Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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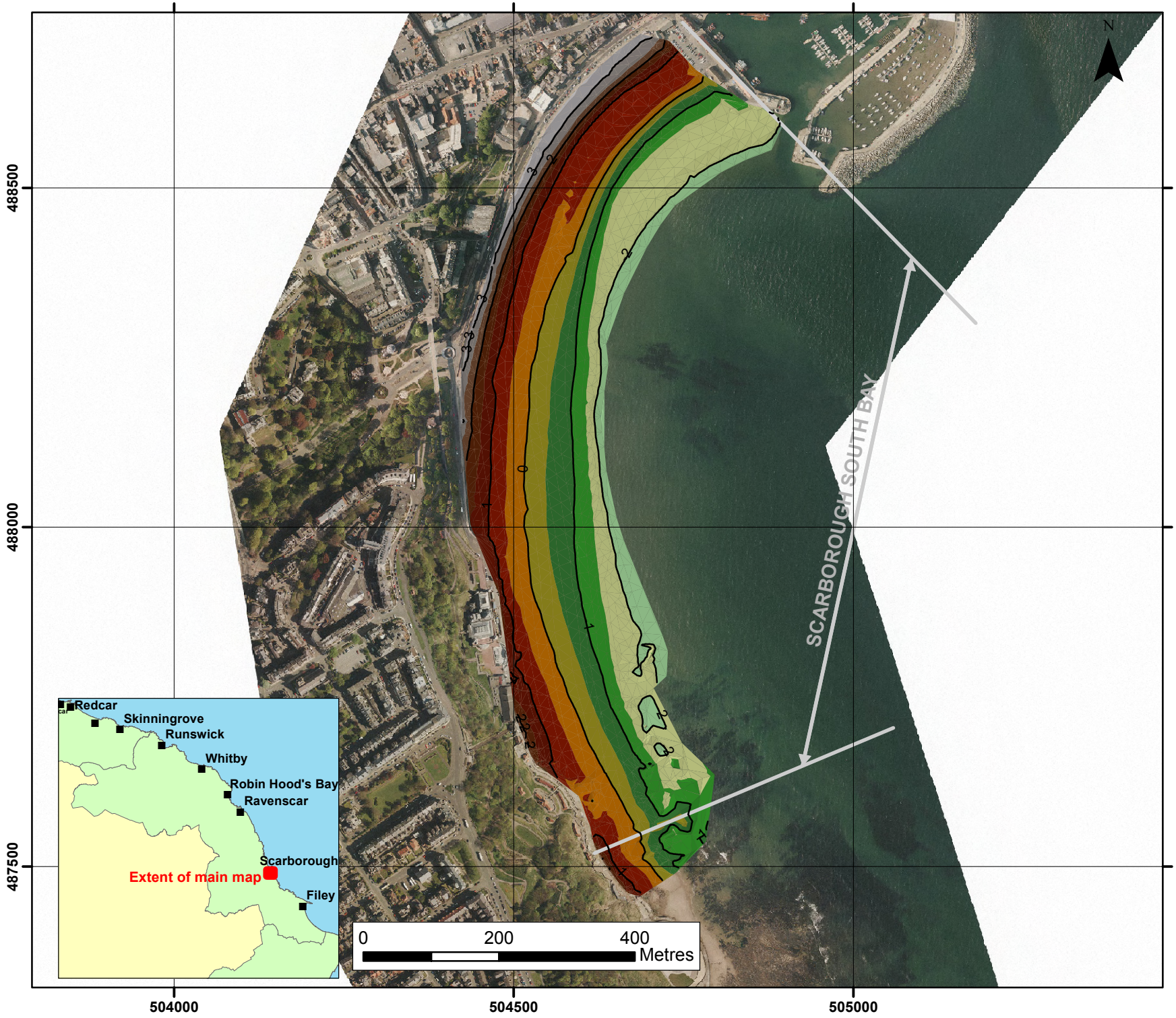


## KEY

**Elevation (m OD)**

- 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 (m)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 5a Topographic Survey Scarborough South Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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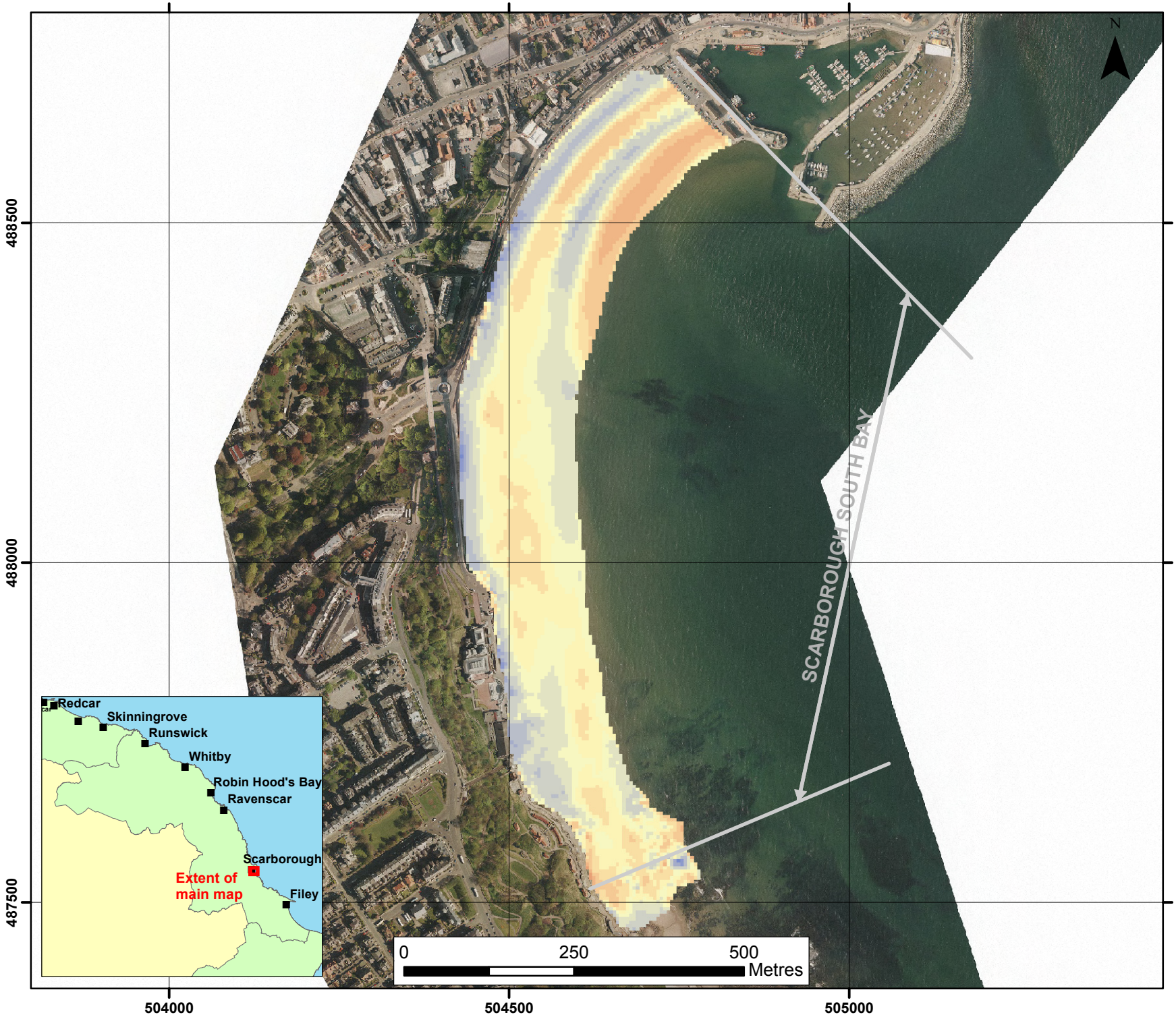


**KEY** Winter 2010 and Winter 2011 Change in elevation (m OD)

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 5b Topographic Difference Scarborough South Scarborough Borough Council

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Full Measures Survey
Winter 2011

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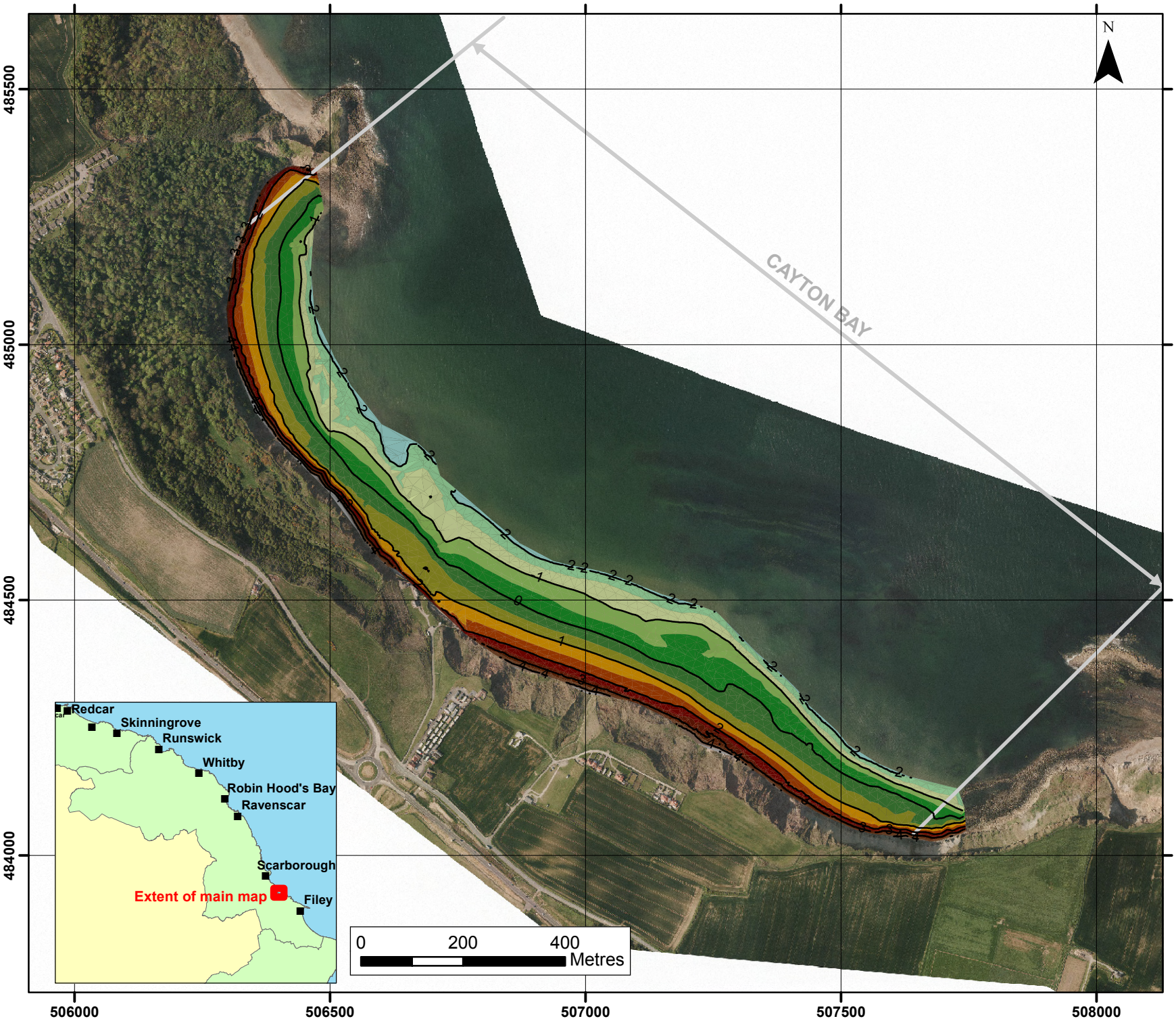


## KEY

**Elevation (mOD)**

- 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
- Contours (1m)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B - Map 6a
# Topographic Survey
# Cayton Bay
# Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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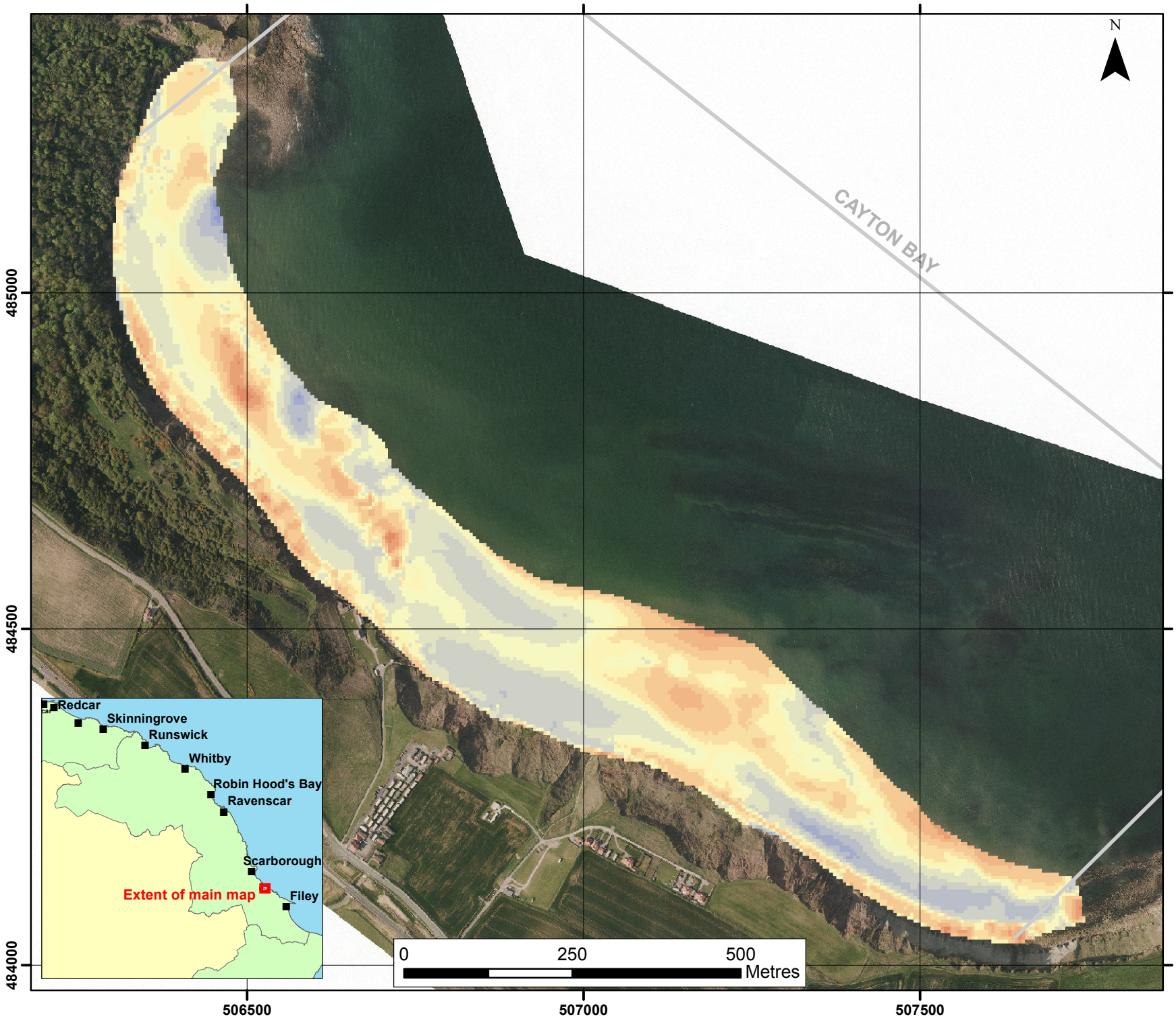


**KEY** Winter 2010 and Winter 2011 Change in elevation (m OD)

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B - Map 6b
# Topographic Difference
# Cayton
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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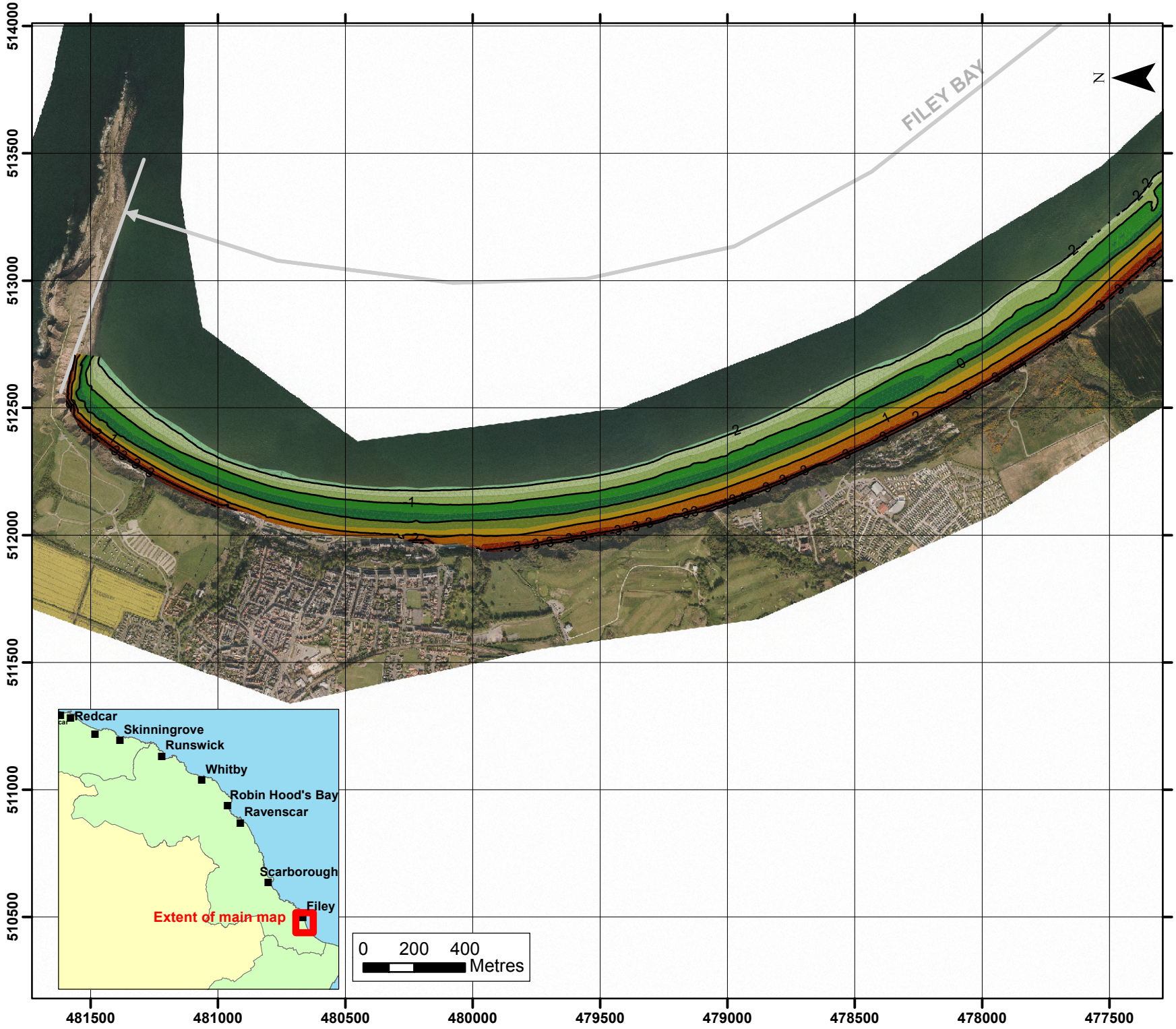


## KEY

**Elevation (mOD)**

- 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 7a Topographic Survey Filey Bay a Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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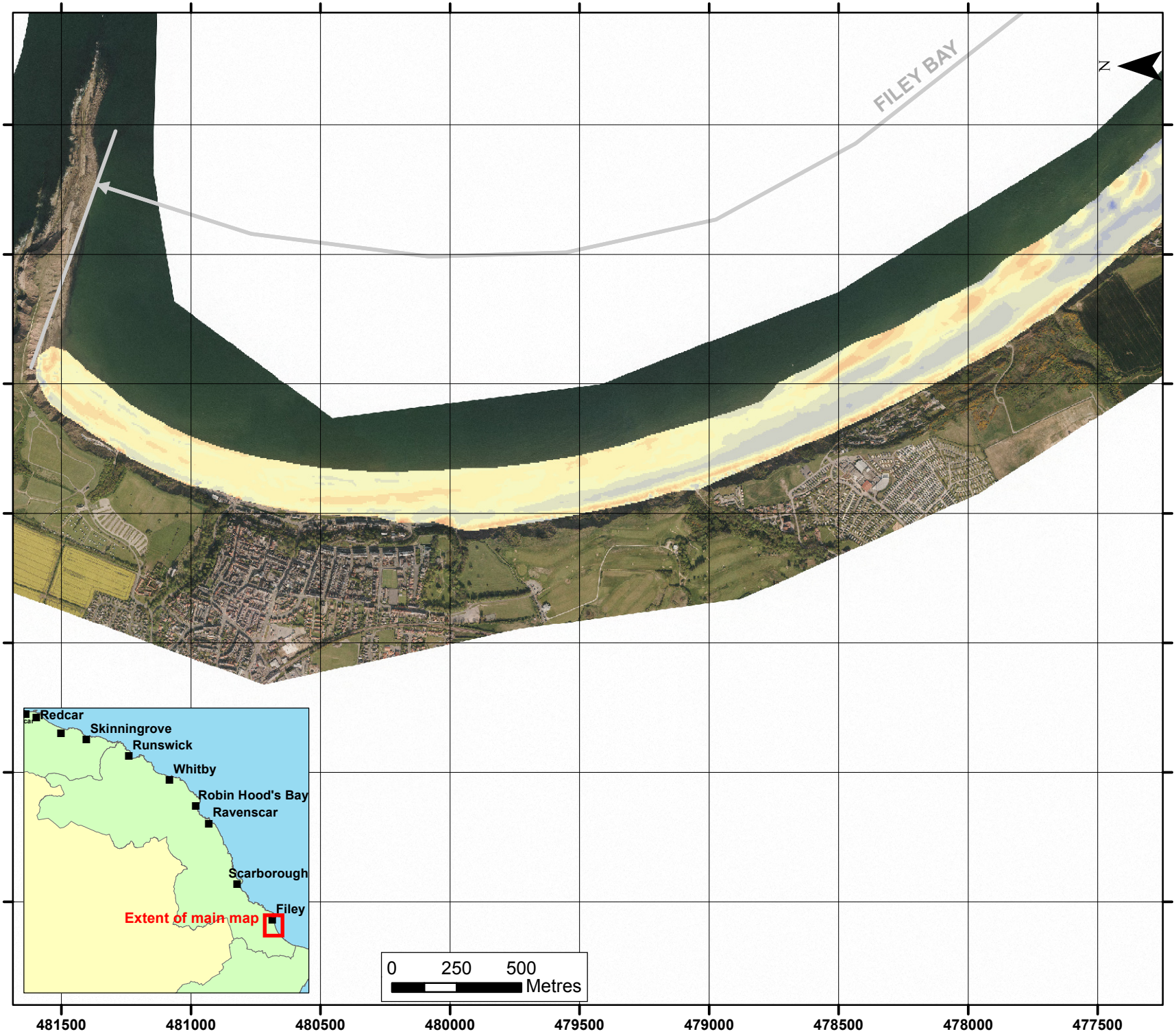


**KEY** Winter 2010 and Winter 2011 Change in elevation (m OD)

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 7b Topographic Difference Filey a Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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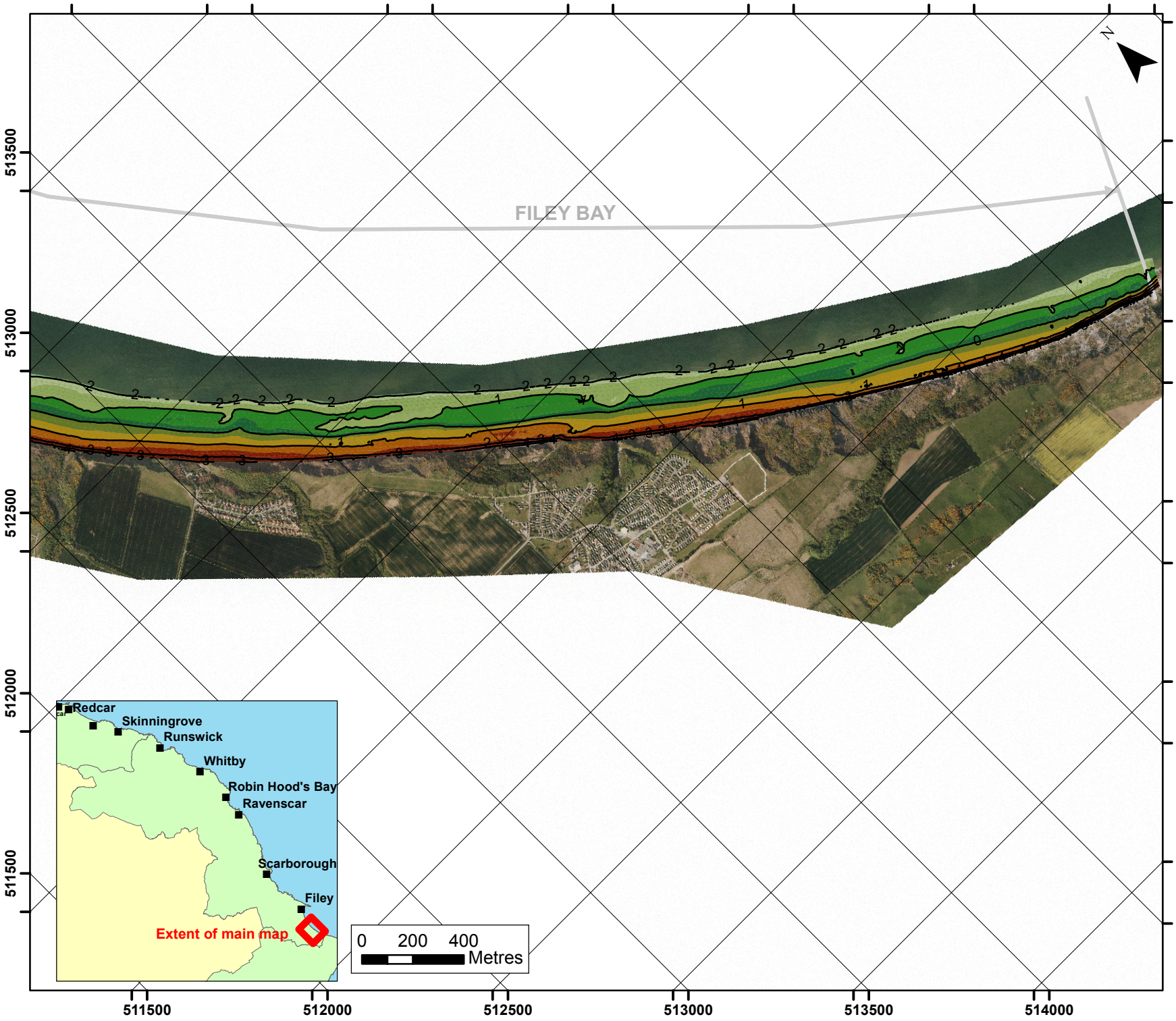


## KEY

**Elevation (mOD)**

- 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 8a
# Topographic Survey
# Filey Bay b
# Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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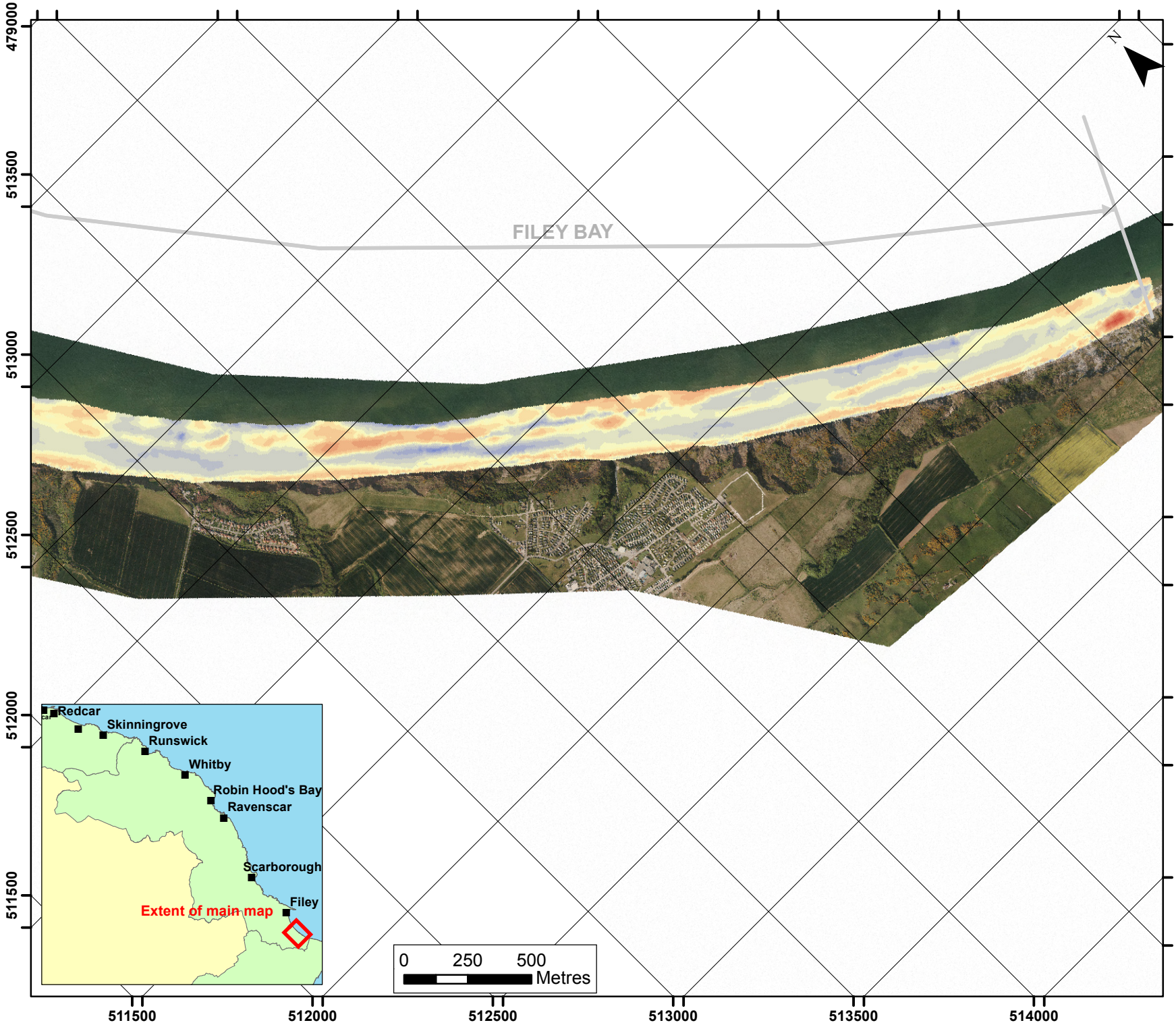


**KEY** Winter 2010 and Winter 2011
Change in elevation (m OD)

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 8b
# Topographic Difference
# Filey b
# Scarborough Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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

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

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

# Appendix B- Map 9
# Topographic Difference
# Filey
# Scarborough
# Borough Council

Analytical Report 4
Full Measures Survey
Winter 2011

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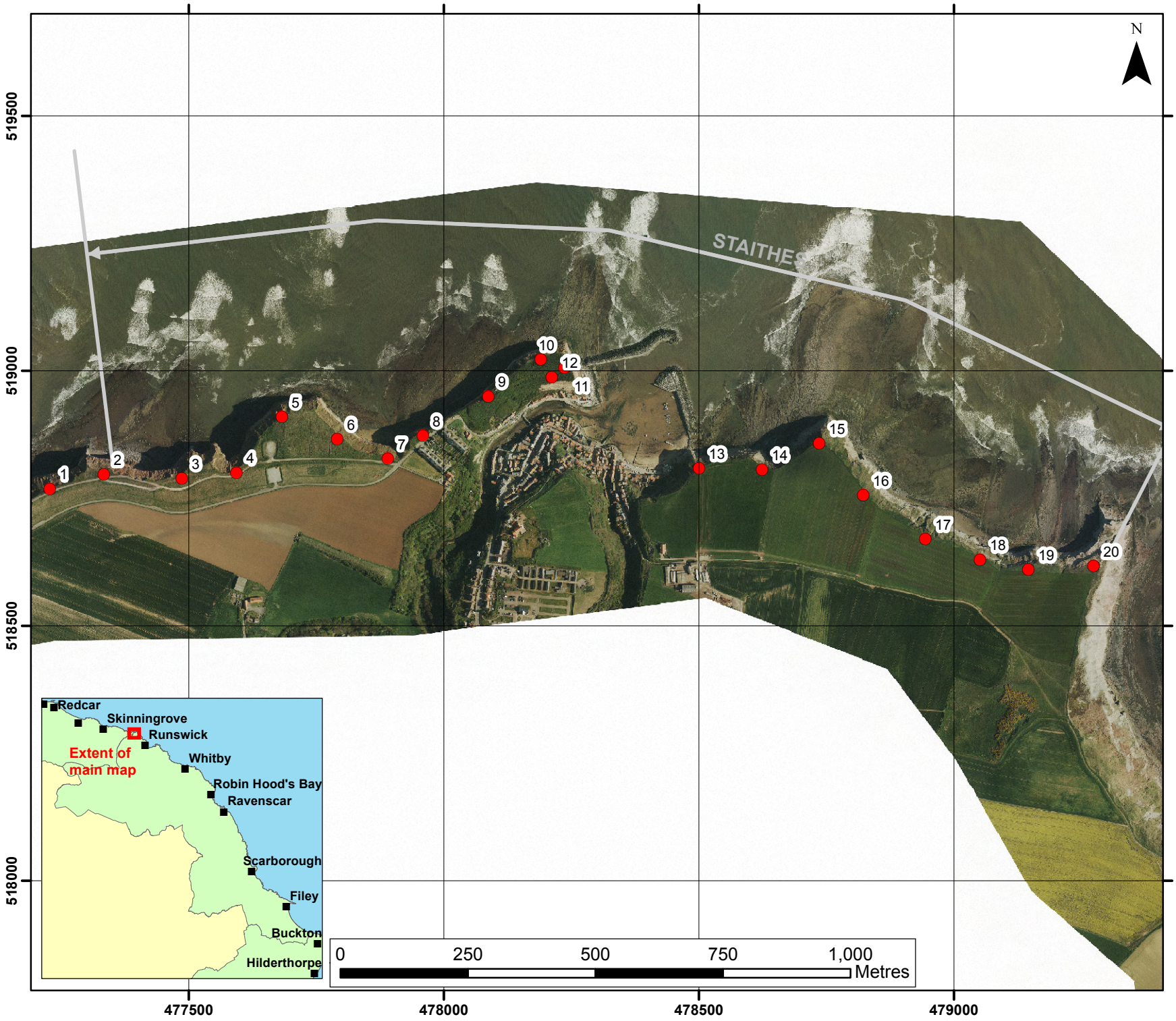
# Appendix C

# Cliff Top Survey




**KEY**

- Ground Control Points

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

**Appendix C - Map 1**
**Ground Control Points**
**Staiths**
**Scarborough**
**Borough Council**

Analytical Report 4
Full Measures Survey
Winter 2011

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## Cliff Top Survey

### Staithes

Twenty ground control points have been established within Staithes (Figure C1). The maximum separation between any two points is nominally 100m. The cliff top surveys at Staithes are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

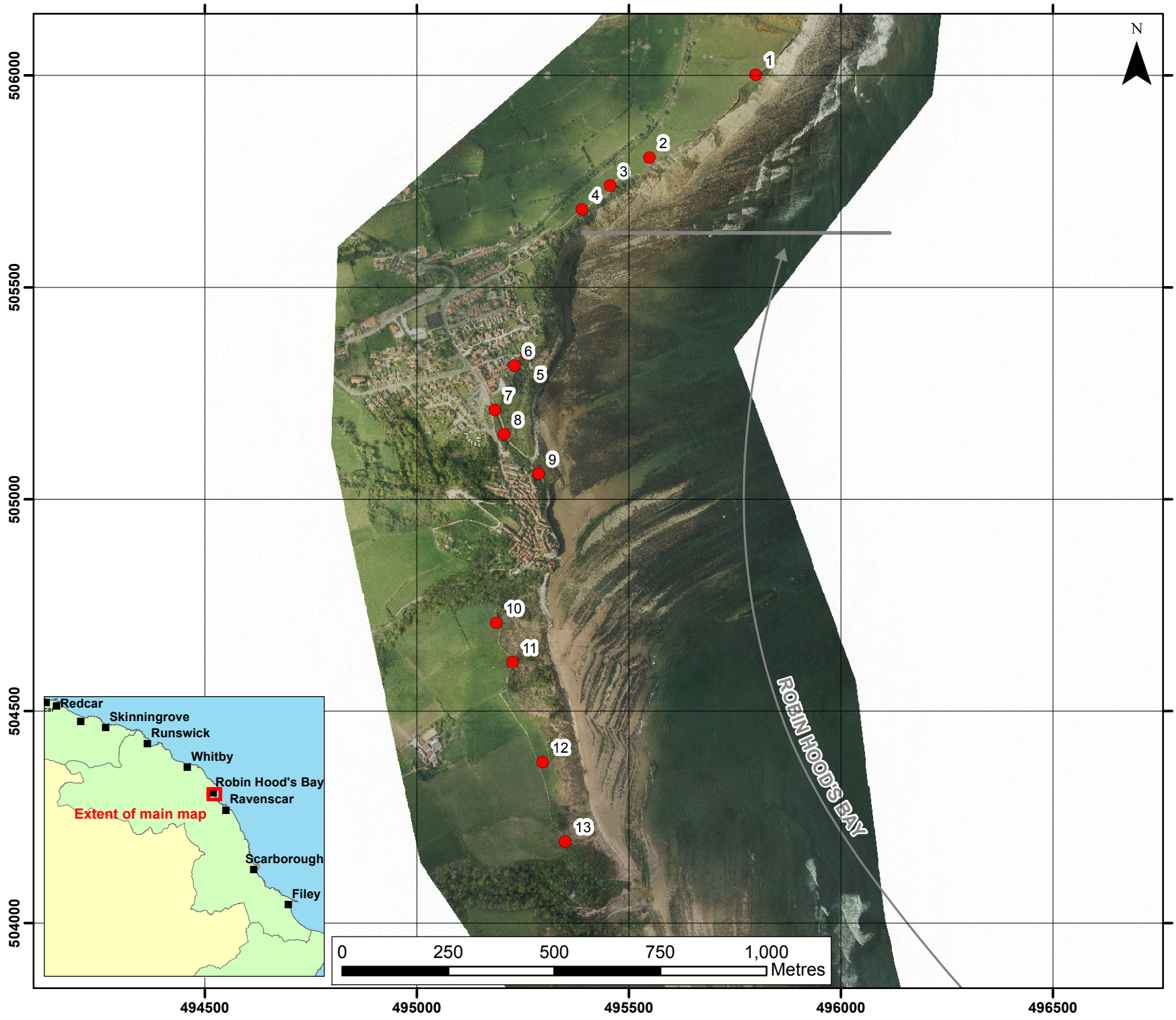
Table C1 provides baseline information about these ground control points and results from the 2008 (baseline) survey showing the position from the ground control point to the edge of the cliff top along the defined bearing. Future reports will show results from subsequent surveys and provide a means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

**Table C1 – Cliff Top Surveys at Staithes**

| Ground Control Point Details | | | | Distance to Cliff Top (m)* | | | Total Erosion (m)* | | Erosion Rate (m/year)* |
|---|---|---|---|---|---|---|---|---|---|
| Ref | Easting | Northing | Bearing (º) | Baseline Survey (Nov 2008) | Previous Survey (April 2011) | Present Survey (Oct 2011) | Baseline (Nov 2008) to Present (Oct 2011) | Previous (April 2011) to Present (Oct 2011) | Baseline (Nov 2008) to Present (Oct 2011) |
| 1 | 477228 | 518769 | 320 | 1.9 | 1.7 | 1.6 | -0.3 | -0.1 | -0.1 |
| 2 | 477334 | 518798 | 0 | 10.9 | 10.8 | 10.6 | -0.3 | -0.2 | -0.1 |
| 3 | 477487 | 518789 | 350 | 7.1 | 8.5 | 8.2 | 1.1 | -0.3 | 0.4 |
| 4 | 477594 | 518801 | 340 | 5.9 | 5.4 | 5.2 | -0.7 | -0.2 | -0.2 |
| 5 | 477683 | 518911 | 350 | 8.4 | 9.7 | 9.4 | 1.0 | -0.3 | 0.3 |
| 6 | 477792 | 518867 | 30 | 8.6 | 8.5 | 8.5 | -0.1 | 0.0 | 0.0 |
| 7 | 477891 | 518828 | 60 | 7.7 | 7.7 | 7.5 | -0.2 | -0.2 | -0.1 |
| 8 | 477959 | 518873 | 350 | 8.7 | 9.8 | 9.6 | 0.9 | -0.2 | 0.3 |
| 9 | 478088 | 518950 | 350 | 7.6 | 8.4 | 8.0 | 0.4 | -0.4 | 0.1 |
| 10 | 478191 | 519023 | 340 | 8.4 | 8.9 | 8.7 | 0.3 | -0.2 | 0.1 |
| 11 | 478237 | 519007 | 60 | 6.9 | 6.8 | 6.7 | -0.2 | -0.1 | -0.1 |
| 12 | 478213 | 518988 | 150 | 6.1 | 6.5 | 6.5 | 0.4 | 0.0 | 0.1 |
| 13 | 478501 | 518809 | 15 | 11.4 | 9.4 | 9.2 | -2.2 | -0.2 | -0.8 |
| 14 | 478624 | 518807 | 20 | 7.5 | 7.5 | 7.5 | 0.0 | 0.0 | 0.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 478737 | 518858 | 60 | 6.1 | 6.2 | 6.4 | 0.3 | 0.2 | 0.1 |
| 16 | 478823 | 518757 | 60 | 8 | 8.4 | 8.4 | 0.4 | 0.0 | 0.1 |
| 17 | 478944 | 518671 | 30 | 9.3 | 9.9 | 9.4 | 0.1 | -0.5 | 0.0 |
| 18 | 479052 | 518630 | 20 | 9.2 | 9.4 | 9.3 | 0.1 | -0.1 | 0.0 |
| 19 | 479147 | 518610 | 0 | 14.2 | 14.5 | 14.3 | 0.1 | -0.2 | 0.0 |
| 20 | 479274 | 518618 | 20 | 11.4 | 11.5 | 11.2 | -0.2 | -0.3 | -0.1 |

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




**KEY**

- Ground Control Points

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

**Appendix C- Map 2**
**Ground Control Points**
**Robin Hood's Bay**
**Scarborough**
**Borough Council**

Analytical Report 4
Full Measures Survey
Winter 2011

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**Robin Hoods Bay**

Thirteen ground control points have been established within Robin Hoods Bay (Figure C1). The maximum separation between any two points is nominally 200m.

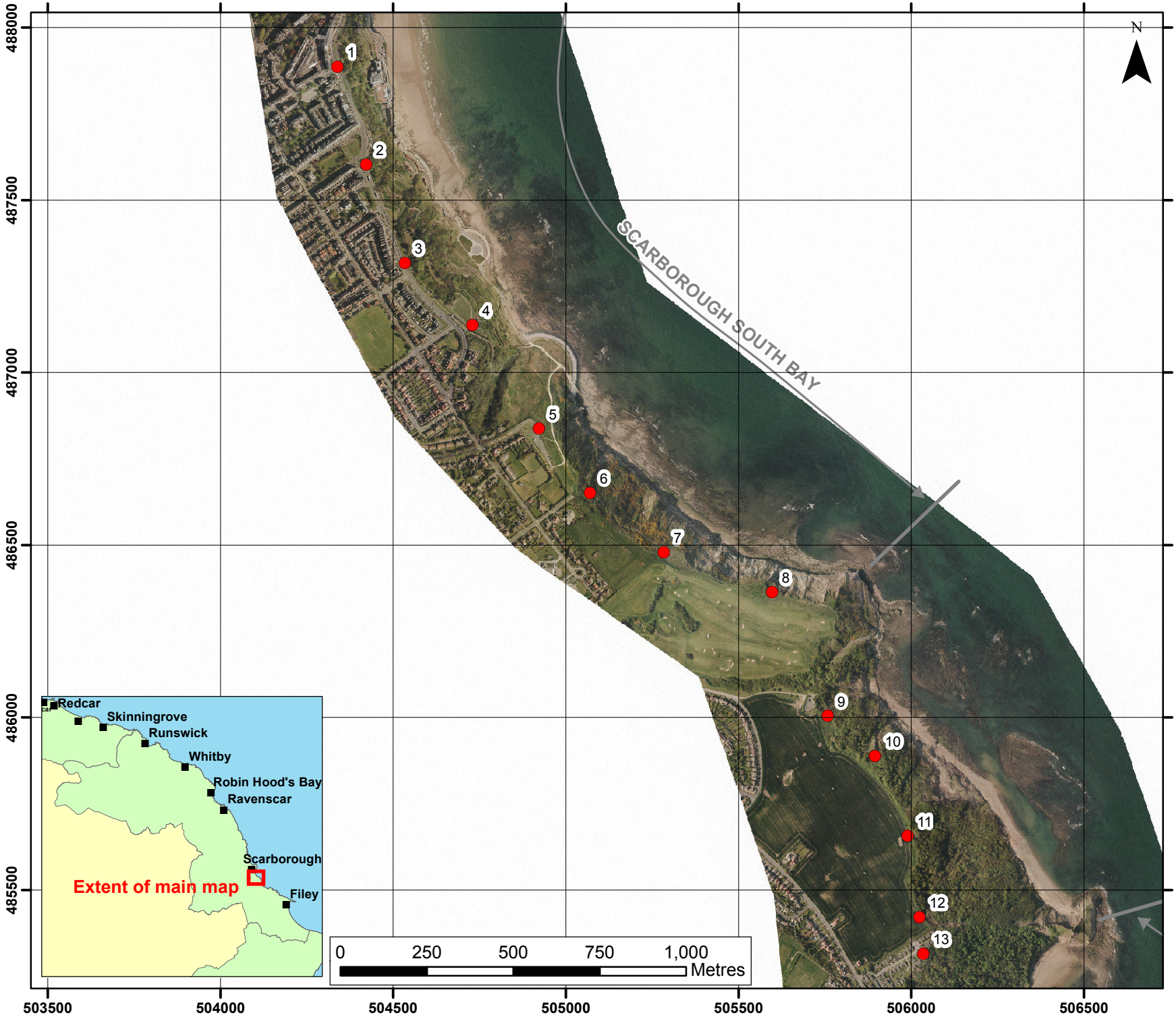
The cliff top surveys at Robin Hoods Bay are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

Table C2 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 C2 – Cliff Top Surveys at Robin Hoods Bay**

| Ground Control Point Details | | | | Distance to Cliff Top (m)* | | | Total Erosion (m)* | | Erosion Rate (m/year)* |
|---|---|---|---|---|---|---|---|---|---|
| Ref | Easting | Northing | Bearing (º) | Baseline Survey (March 2010) | Previous Survey (March 2011) | Present Survey (Sept 2011) | Baseline (March 2010) to Present (Sept 2011) | Previous (March 2011) to Present (Sept 2011) | Baseline (March 2010) to Present (Sept 2011) |
| 1 | 495799.5 | 506002.2 | 130 | 11.6 | 8.3 | 8.3 | -3.3 | 0.0 | -2.0 |
| 2 | 495549.2 | 505807.3 | 135 | 9.3 | 9.3 | 9.3 | 0.0 | 0.0 | 0.0 |
| 3 | 495456.3 | 505740 | 130 | 5 | 4.9 | 5.1 | 0.1 | 0.2 | 0.1 |
| 4 | 495389.9 | 505683.7 | 140 | 6.3 | 6.2 | 6.2 | -0.1 | 0.0 | -0.1 |
| 5 | 495259.4 | 505342.5 | 130 | 11.3 | 11.0 | 10.8 | -0.5 | -0.2 | -0.3 |
| 6 | 495231.2 | 505315.7 | 95 | 5.9 | 5.8 | 5.9 | -0.1 | 0.0 | 0.0 |
| 7 | 495184.8 | 505210.7 | 85 | 6.4 | 6.1 | 6.3 | -0.1 | 0.2 | -0.1 |
| 8 | 495206.5 | 505153 | 75 | 5 | 4.7 | 5.2 | 0.2 | 0.5 | 0.1 |
| 9 | 495287.8 | 505060.5 | 80 | 4.3 | 4.3 | 4.6 | 0.3 | 0.3 | 0.2 |
| 10 | 495187.8 | 504708.8 | 70 | 3.1 | 3.3 | 3.7 | 0.6 | 0.4 | 0.3 |
| 11 | 495226.2 | 504615.7 | 120 | 3.8 | 3.6 | 3.6 | -0.2 | 0.0 | -0.1 |
| 12 | 495297.5 | 504380.2 | 80 | 11 | 11.0 | 10.9 | -0.1 | -0.1 | -0.1 |
| 13 | 495350.4 | 504193 | 55 | 3.7 | 3.8 | 3.6 | -0.1 | -0.2 | 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 3**
**Ground Control Points**
**Scarborough South Bay**
**Scarborough**
**Borough Council**

Analytical Report 4
Full Measures Survey
Winter 2011

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**Scarborough South Bay**

Thirteen ground control points have been established between Scarborough South Bay and Cayton Bay (Figure C1). The maximum separation between any two points is nominally 300m.

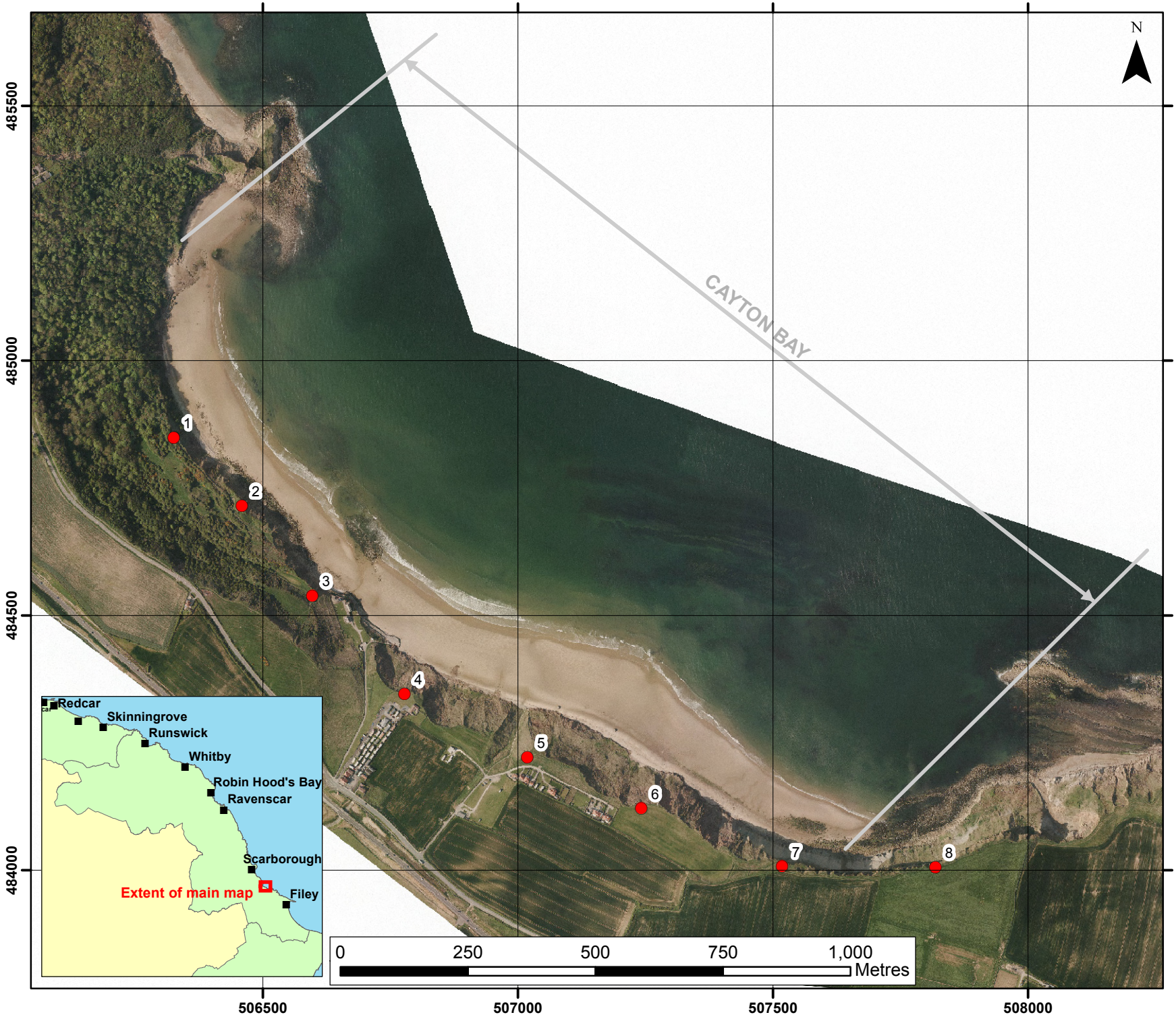
The cliff top surveys at Scarborough South Bay are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

Table C3 provides baseline information about these ground control points and results from the 2010 (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 C3 – Cliff Top Surveys at Scarborough South**

| Ground Control Point Details | | | | Distance to Cliff Top (m) | | | Total Erosion (m) | | Erosion Rate (m/year) |
|---|---|---|---|---|---|---|---|---|---|
| Ref | Easting | Northing | Bearing (º) | Baseline Survey (March 2010) | Previous Survey (March 2011) | Present Survey (Sept 2011) | Baseline (March 2010) to Present (Sept 2011) | Previous (Feb 2011) to Present (Sept 2011) | Baseline (March 2010) to Present (Sept 2011) |
| 1 | 504339.5 | 487887.3 | 70 | 7.0 | 7.0 | 7.0 | 0.0 | 0.0 | 0.0 |
| 2 | 504422.3 | 487603.7 | 80 | 4.8 | - | 4.8 | 0.0 | No data | 0.0 |
| 3 | 504534.8 | 487318.3 | 40 | 15.1 | 15.2 | 15.1 | 0.0 | -0.1 | 0.0 |
| 4 | 504730.2 | 487137.9 | 55 | 9.6 | 9.6 | 9.5 | -0.1 | -0.1 | -0.1 |
| 5 | 504922.9 | 486837.8 | 60 | 8.8 | 8.6 | 8.5 | -0.3 | -0.1 | -0.2 |
| 6 | 505071.1 | 486652.1 | 75 | 3.8 | 3.6 | 3.4 | -0.4 | -0.2 | -0.3 |
| 7 | 505284.3 | 486480 | 35 | 7.0 | 7.1 | 7.0 | 0.0 | -0.1 | 0.0 |
| 8 | 505597.9 | 486363.4 | 30 | 8.6 | 8.7 | 8.6 | 0.0 | -0.1 | 0.0 |
| 9 | 505758.6 | 486005.1 | 45 | 9.1 | 9.1 | 9.1 | 0.0 | 0.0 | 0.0 |
| 10 | 505896 | 485889.6 | 15 | 14.8 | 14.8 | 14.2 | -0.6 | -0.6 | -0.4 |
| 11 | 505990 | 485657.1 | 80 | 4.7 | 4.3 | 4.3 | -0.4 | 0.0 | -0.2 |
| 12 | 506024.9 | 485421.8 | 55 | 6.1 | 5.9 | 5.7 | -0.4 | -0.2 | -0.2 |
| 13 | 506036 | 485315.3 | 90 | 7.0 | 6.1 | 5.9 | -1.1 | -0.2 | -0.7 |

**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 4**
**Ground Control Points**
**Cayton Bay**
**Scarborough**
**Borough Council**

Analytical Report 4
Full Measures Survey
Winter 2011

Halcrow
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**Cayton Bay**

Eight ground control points have been established within Cayton Bay (Figure C1). The maximum separation between any two points is nominally 300m.

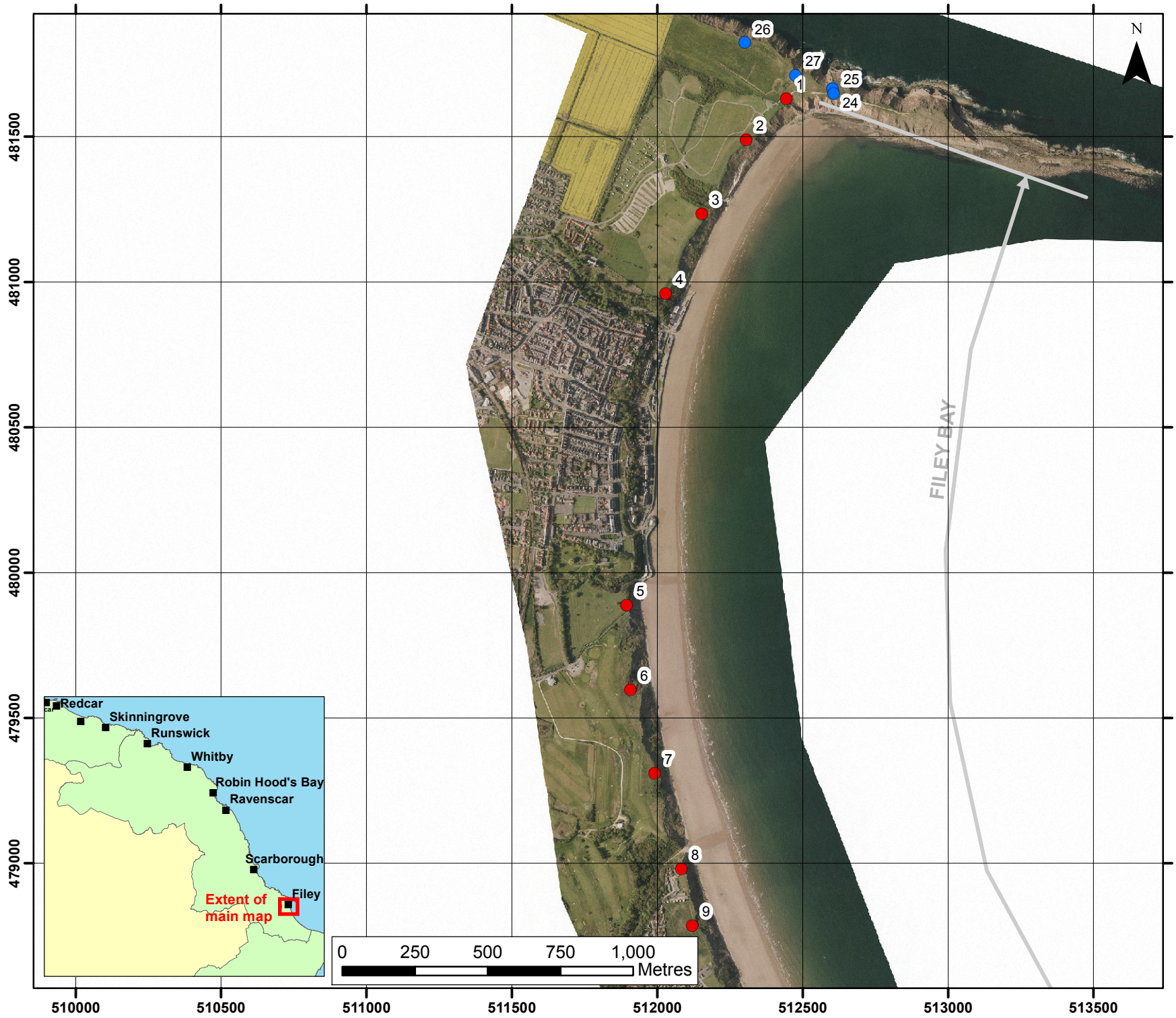
The cliff top surveys at Cayton Bay are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

Table C4 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 C4 – Cliff Top Surveys at Cayton Bay**

| 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 (March 2011) | Present Survey (Sept 2011) | Baseline (Nov 2008) to Present (Sept 2011) | Previous (March 2011) to Present (Sept 2011) | Baseline (Nov 2008) to Present (Sept 2011) |
| 1 | 506325.5 | 484849.7 | 50 | 4 | 3.5 | 3.4 | -0.6 | -0.1 | -0.2 |
| 2 | 506459.4 | 484715.9 | 65 | 5 | -0.1 | 0.2 | -4.9 | 0.3 | -1.7 |
| 3 | 506597.4 | 484538.6 | 65 | 5 | 6.0 | 6.6 | 1.6 | 0.6 | 0.5 |
| 4 | 506778.1 | 484345.5 | 21 | 9 | 9.2 | 9.0 | 0.0 | -0.2 | 0.0 |
| 5 | 507018.6 | 484221.6 | 342 | 7.7 | 8.1 | 8.2 | 0.5 | 0.1 | 0.2 |
| 6 | 507242.3 | 484121.7 | 2 | 7.4 | 7.3 | 7.5 | 0.1 | 0.2 | 0.0 |
| 7 | 507518.2 | 484008.2 | 25 | 7.5 | 7.7 | 7.9 | 0.4 | 0.2 | 0.1 |
| 8 | 507818.7 | 484006 | 1 | 5.5 | 5.8 | 5.3 | -0.2 | -0.5 | -0.1 |

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




**KEY**

Ground Control Points

- Established March 2011
- Established Nov 2008

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

**Appendix C- Map 5**
**Ground Control Points**
**Filey Bay a**
**Scarborough**
**Borough Council**

Analytical Report 4
Full Measures Survey
Winter 2011

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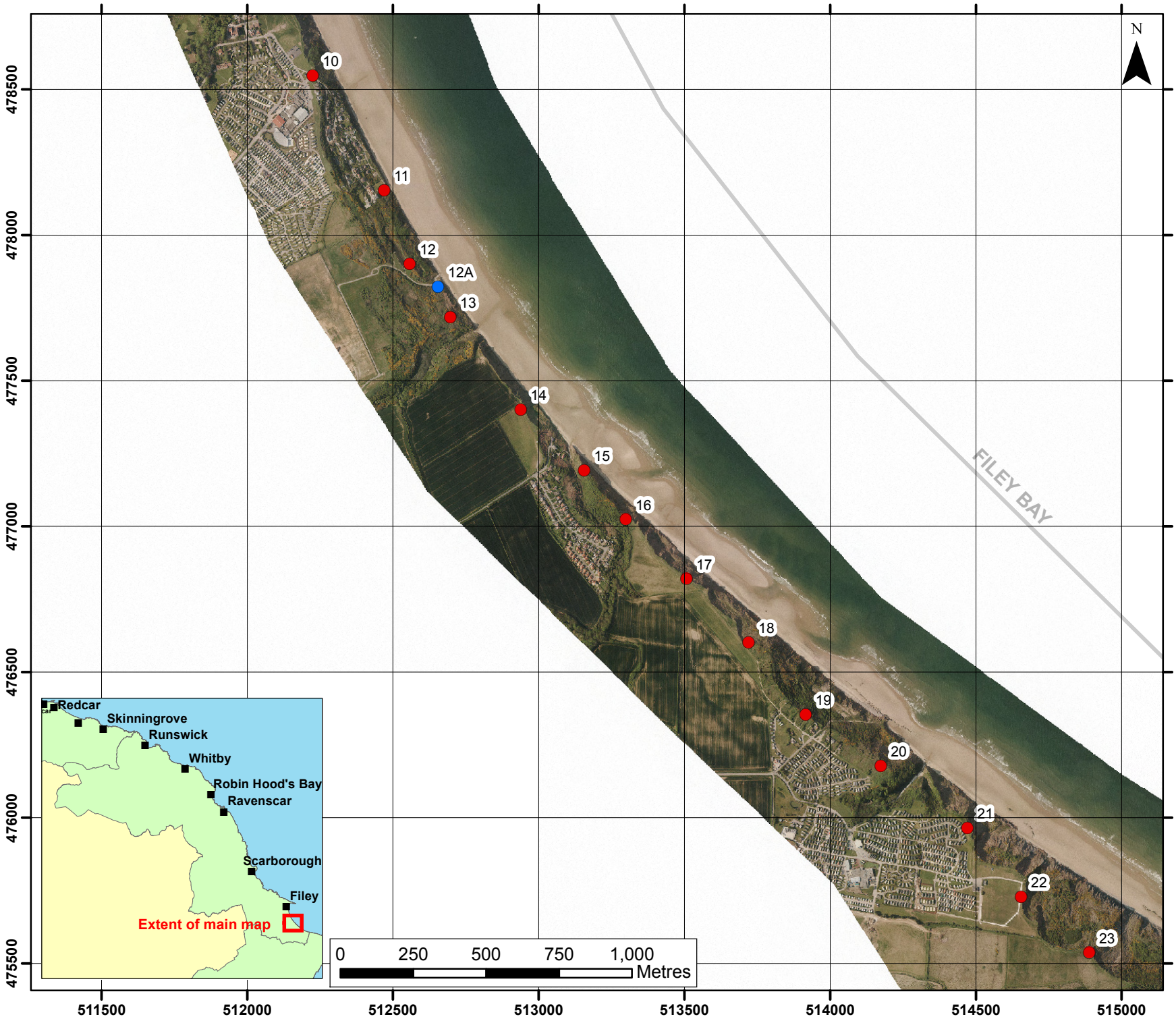


**KEY**

Ground Control Points

- Established March 2011
- Established Nov 2008

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

**Appendix C - Map 6**
**Ground Control Points**
**Filey Bay b**
**Scarborough**
**Borough Council**

Analytical Report 4
Full Measures Survey
Winter 2011

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**Filey Bay**

Twenty-seven ground control points have been established within Filey Bay (Figure C1). The maximum separation between any two points is nominally 300m.

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

Table C5 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 C5 – Cliff Top Surveys at Filey Bay**

| 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 (March 2011) | Present Survey (Sept 2011) | Baseline (Nov 2008) to Present (Sept 2011) | Previous (March 2011) to Present (Sept 2011) | Baseline (Nov 2008) to Present (Sept 2011) |
| 1 | 512444.9 | 481630.9 | 130 | 8.7 | 9.0 | 8.8 | 0.1 | -0.3 | 0.0 |
| 2 | 512306.7 | 481490.3 | 144 | 7.6 | 7.8 | 7.7 | 0.1 | -0.1 | 0.0 |
| 3 | 512153.6 | 481234.6 | 122 | 8.3 | 8.5 | 8.5 | 0.2 | 0.0 | 0.1 |
| 4 | 512029.2 | 480959.9 | 115 | 7.4 | 7.8 | 7.5 | 0.1 | -0.3 | 0.0 |
| 5 | 511895.4 | 479888 | 89 | 7.1 | 1.6 | 1.4 | -5.7 | -0.2 | -2.0 |
| 6 | 511908.5 | 479597.1 | 48 | 6.7 | 7.1 | 6.9 | 0.2 | -0.2 | 0.1 |
| 7 | 511991.4 | 479310.4 | 69 | 6.7 | 6.5 | 5.1 | -1.7 | -1.5 | -0.6 |
| 8 | 512083.4 | 478981.5 | 66 | 10.2 | 10.5 | 10.4 | 0.2 | -0.1 | 0.1 |
| 9 | 512121.3 | 478786.3 | 76 | 8.3 | 8.5 | 8.3 | 0.0 | -0.2 | 0.0 |
| 10 | 512226.2 | 478547.9 | 74 | 7.5 | 7.3 | 7.3 | -0.2 | 0.0 | -0.1 |
| 11 | 512471.4 | 478153.5 | 53 | 6.6 | 6.6 | 6.4 | -0.2 | -0.2 | -0.1 |
| 12 | 512558.9 | 477901.9 | 66 | 7.7 | 7.9 | 8.4 | 0.7 | 0.5 | 0.2 |
| 12A | 512655.8 | 477822.4 | 67 | No data | 13.9 | 13.7 | No data | -0.2 | No data |
| 13 | 512697.6 | 477719 | 34 | 4.2 | 4.4 | 4.4 | 0.2 | 0.0 | 0.1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 512939.4 | 477400.9 | 66 | 8 | 7.3 | 7.3 | -0.7 | 0.0 | -0.3 |
| 15 | 513157 | 477192.7 | 51 | 5.2 | 5.4 | 5.3 | 0.1 | -0.1 | 0.0 |
| 16 | 513299.5 | 477024.6 | 30 | 7.7 | 7.7 | 7.7 | 0.0 | 0.0 | 0.0 |
| 17 | 513507.7 | 476821.1 | 34 | 10.7 | 10.7 | 10.7 | 0.0 | 0.0 | 0.0 |
| 18 | 513721 | 476602.3 | 31 | 7.2 | 7.3 | 7.3 | 0.1 | 0.0 | 0.0 |
| 19 | 513916.6 | 476354.1 | 51 | 6.6 | 6.6 | 6.7 | 0.1 | 0.1 | 0.0 |
| 20 | 514174.8 | 476179.4 | 32 | 7 | 7.3 | 7.2 | 0.2 | -0.1 | 0.1 |
| 21 | 514471.5 | 475965.7 | 66 | 7.6 | 7.6 | 7.5 | -0.1 | -0.1 | 0.0 |
| 22 | 514656.2 | 475728.8 | 101 | 8.1 | 8.3 | 8.1 | 0.0 | -0.2 | 0.0 |
| 23 | 514889.5 | 475537.6 | 60 | 9.1 | 9.1 | 9.1 | 0.0 | 0.0 | 0.0 |
| 24 | 512603.7 | 481665.9 | 14 | No data | 19.9 | 19.8 | No data | -0.1 | No data |
| 25 | 512607.1 | 481648.9 | 184 | No data | 17.2 | 17.3 | No data | 0.1 | No data |
| 26 | 512301.9 | 481825.5 | 18 | No data | 11.0 | 11.0 | No data | 0.0 | No data |
| 27 | 512475.8 | 481712.1 | 20 | No data | 11.6 | 11.6 | No data | 0.0 | No data |

**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.