Scarborough South Bay
Beach Management Plan

February 2012

Final Report
9X2326

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1 INTRODUCTION

1.1 Background

Royal Haskoning was appointed by Scarborough Borough Council (SBC) to prepare a Beach Management Plan for South Bay, Scarborough (Figure 1).

SBC usually undertakes annual beach management on South Bay to meet perceived operational needs in terms of sea defence and beach amenity. However, these activities are currently not supported by a Beach Management Plan.

The purpose of this document is, therefore, to produce a Beach Management Plan based upon available reports, results from previous modelling studies and coastal monitoring data analysis, and other relevant studies. This work ties-in with ongoing work in South Bay at the Spa and existing management regimes within the harbour.

This Beach Management Plan is intentionally prepared before the next beach sand movement activities, which are scheduled for April 2012.

1.2 Methodology

(1) Desk-based Literature Review

We have identified, collated and reviewed existing information on beach management and harbour dredging activities and existing reports that provide information of relevance to the coastal processes and beach morphology changes in South Bay.

(2) Conceptual Understanding

We have reviewed historic and contemporary maps and admiralty charts to develop a conceptual understanding of physical processes operating in South Bay, considering the inputs, movements and outputs of sand, including the potential for material to become deposited in the harbour.

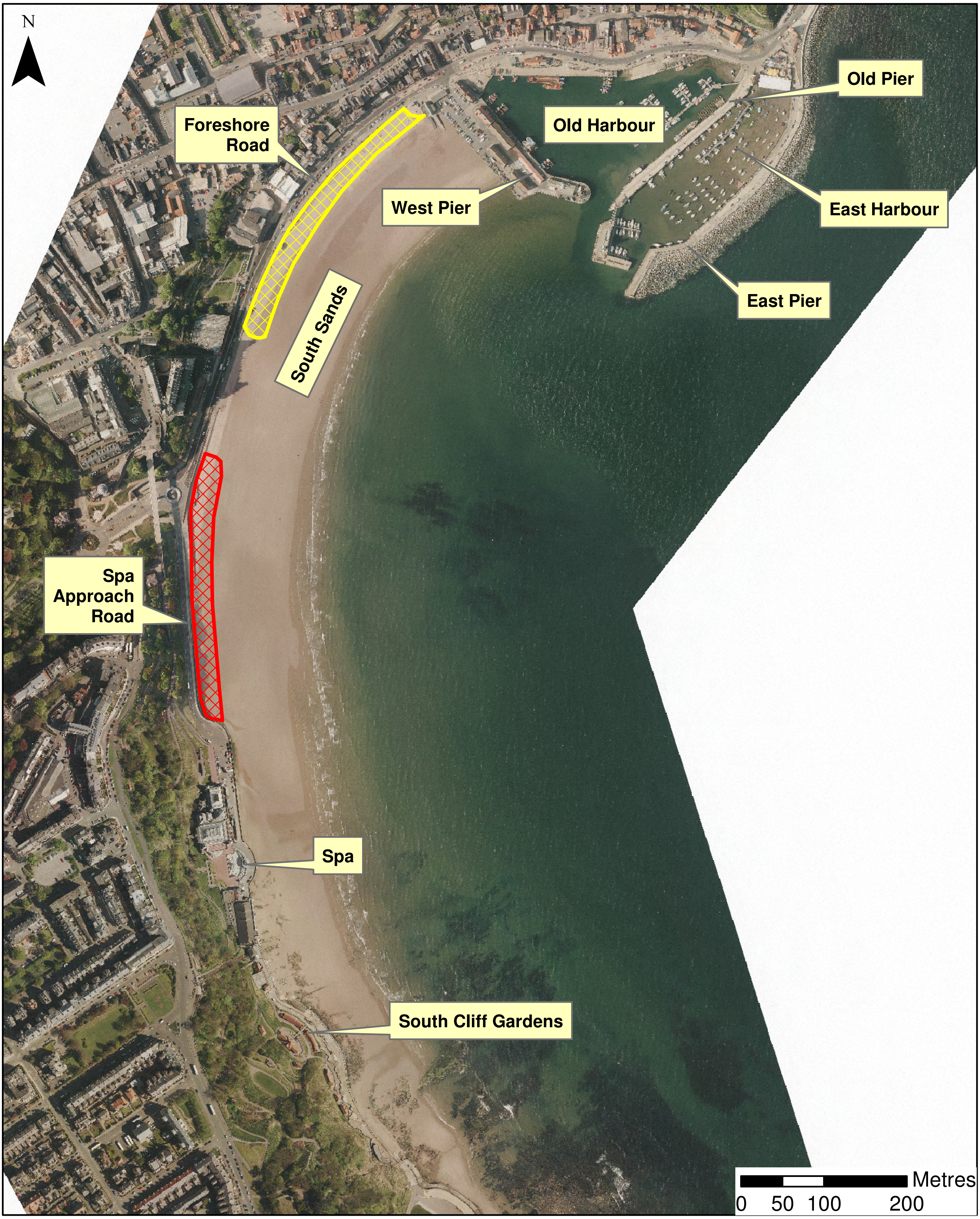
(3) Analysis of Coastal Monitoring Data

We have reviewed previous coastal monitoring data analyses and re-examined the beach data collected since 2008 in South Bay as part of the Cell 1 Regional Coastal Monitoring programme, providing a quantitative analysis of beach volume changes.

(4) Interpretation and Reporting

Results from the above analyses have been synthesised and interpreted to identify beach volume changes in South Bay, including the impact on the harbour and its approach channel, and the effect (and effectiveness) of sand movement operations on these patterns.

The findings from the study are presented within this Beach Management Plan, along with advice and recommendations on future beach management activities in South Bay. These conclusions particularly give consideration to: (i) sea defence and beach amenity needs; (ii) impacts on the operations of the harbour; and (iii) ongoing work at the Spa.



Key:

Beach Management Activity

Source Site

Placement Site

Title:
Location Plan

Project:
Scarborough South Bay
Beach Management Plan

Client:
Scarborough Borough Council

Date: Feb 2011

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Figure: 1

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2 DESK-BASED LITERATURE REVIEW

Over the past fifteen years, a considerable quantity of high quality work has been undertaken in Scarborough South Bay, largely associated with development and subsequent updates of the:

- Shoreline Management Plan;
- Holbeck to Scalby Mills Coastal Defence Strategy; and
- Scarborough Spa Coastal Protection and Slope Stablisation Scheme.

Some of this work has included coastal monitoring data analysis and coastal modelling techniques, using both numerical (computer software) and physical (laboratory) approaches. A full list of the reports incorporated in this desk-based literature review is provided in the references listed in Section 6 of this *Beach Management Plan*, and key findings are incorporated within the conceptual understanding presented in Section 3.

From discussions with staff at SBC, information has been obtained in relation to existing beach management and harbour dredging activities, as described in following sub-sections.

2.1 Beach Management Activities

There is a tendency for sand to accumulate at the north end of South Bay in the lee of the West Pier to Scarborough Harbour. This sand movement is driven by northwards-directed residual sediment transport operating between the Spa and the harbour. When beach volumes reach a critical level in the northern sections, sand is typically excavated from a section of beach in the vicinity of Foreshore Road (Figures 2 and 3) and recycled to become deposited, spread and graded in front of the seawall that protects the Spa Approach Road. In the absence of these beach management activities, beach levels in the north of South Bay will accumulate to the point where waves will ‘ramp’ across the upper foreshore, overtop the seawall and cause local flooding of Foreshore Road (Figure 4).

Beach management activities have been undertaken in this manner since the early 1990s in order to achieve the desired ‘freeboard’ between the upper beach level and the crest of the Foreshore Road seawall of 1m. From empirical experience, this freeboard level tends to prevent flooding from this ‘wave ramping’ effect. The recycling of sand also has the advantage of offsetting the slow erosion that is perceived to have been occurring for some time towards the southern end of South Bay, although this benefit is only temporary as the recycled sand will tend to move back towards the north of South Bay by natural processes or be drawn-down the beach to the nearshore zone during particular storm events.

Typically, the sand excavation from the north of South Bay will be undertaken along approximately 335m length of frontage directly in front of Foreshore Road. Levels will be reduced to around 1.2m below the crest of the seawall directly at its toe, falling to 0m reductions at a distance of 25m from the seawall. These beach management activities are usually undertaken annually, typically involving around 5,025m^3 of sand recycling. The next scheduled activity will be in April 2012. The activities are funded by Grant-in-Aid from the Environment Agency, currently to within a budget of £10,000 per annum.

Figure 2 – Sand excavation in progress (2008)

Figure 3 – Difference in sand levels pre- and post-excavation (2008)

Figure 4 – Flooding of Foreshore Road due to Wave 'Ramping' (20th March 2007)

In addition to these beach management activities for sea defence and amenity purposes, SBC excavated some 2,831m^3 of sand from the north of South Bay in January 2011 for use as 'grit' on the frozen footpaths in the town during the severe winter weather. Some of this material was later returned to the beach after the snow and ice thawed before it was all used.

2.2 Harbour Dredging and Disposal

Scarborough Harbour comprises the inner harbour (Old Harbour), which is primarily used by the fishing fleet and the outer harbour (East Harbour) which primarily contains moorings for leisure vessels. The Harbour Master authorises the dredging of bed material from the inner harbour to maintain sufficient depths for berthing of vessels and dredging of the approach channel (Figure 5) to maintain safe navigation at advertised depths. In recent years this has typically involved around 10,000 tonnes (5,819m^3) per year in total. Of this volume, around 7,000 tonnes of sand is dredged annually from the approach channel (usually during two dredge campaigns each year). Typically up to 2m depth of material is dredged from the side slopes of the approach channel, with around 1m depth of material removed from the channel centreline. In addition, 1,500 tonnes of sand is dredged annually from the harbour entrance and 1,500 tonnes of predominantly silt is dredged annually from within the harbour basin. The most recent dredging campaign was in January 2012. There is little dredging undertaken in the outer harbour.

Scarborough Rock is the disposal site at which maintenance dredging from the inner and outer harbours and the approach channel is licensed to be deposited. This site typically receives around 10,000 tonnes per year, although in 2006 a licence was granted for the disposal of 47,000 tonnes of capital dredging material, comprising mainly sand and silt. The inner harbour area has had a history of contamination (particularly Tri-butyl-tin, often known as TBT) and as a result some material has been removed to landfill.

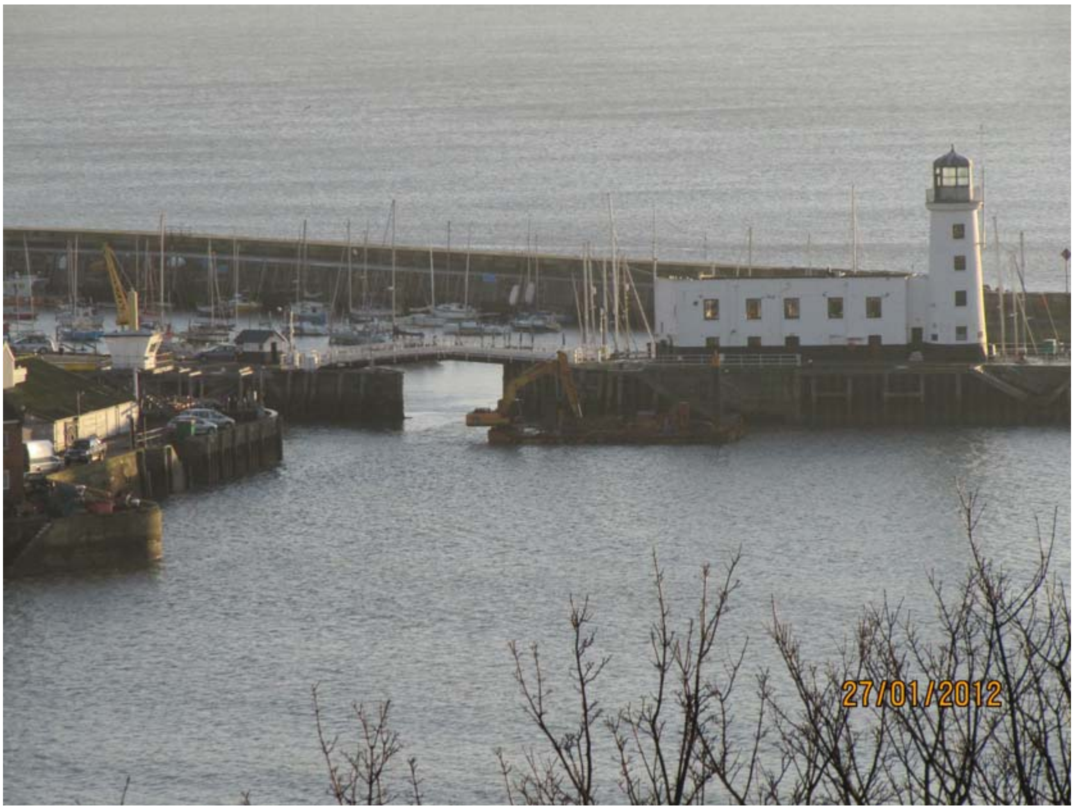

Figure 5 – Dredging of the Approach Channel to Old Harbour (January 2012)

3 CONCEPTUAL UNDERSTANDING

3.1 Background

Scarborough South Bay comprises a wide sandy foreshore in the north and a rock shore platform in the south, backed by near vertical seawalls which protect the backing coastal slopes. The slopes are composed of till towards the centre of the bay with sandstones and mudstones towards its southern end. A continuous promenade extends along the frontage.

Since construction of the seawalls in Victorian times, the supply of sediment to the beaches from coastal slope recession has ceased, although in places the slopes continue to show some signs of degradation.

The beach is relatively 'self contained' between Castle Headland in the north and White Nab in the south. The beach is widest and highest in the north and progressively narrows and lowers to the south, before giving way to rock platform with discrete sand pockets south of the Spa, and then bare rock further south still.

3.2 Physical Processes

The physical processes of wave and tidal action have previously been studied and reported in detail and is not repeated here, although an overview of previous work is summarised in Table 1.

Table 1 – Overview of Previous Work on Physical Processes

Parameter	Summary	Report Reference
Extreme Water Levels	Data was derived from studies by Proudman Oceanographic Laboratory[1], considering both the present day and future sea level rise	Hydrodynamic Assessment (Page 2)
Offshore Waves	Generated from 9 years of Met Office wind records from Spurn Head using HINDWAVE	Hydrodynamic Assessment (Appendix 2)
	Generated from 15 years of Met Office wind records using HINDWAVE	Wave Analysis
Nearshore Waves	Generated using TELURAY (a reverse-track ray model) at six locations on the 2.5mCD (-5.75mOD) contour (including Harbour, Spa and Holbeck)	Hydrodynamic Assessment (Appendix 2)
	Re-run previous TELURAY model to generate data at -18mOD contour just off Castle Headland prior to wave breaking, then WENDIS model to transform to -10mOD contour accounting for random wave breaking and shoaling	Physical Model Study – East Pier and Marine Drive Physical Model Study – South Bay
	Re-run previous TELURAY model to generate data at -18mOD contour, with associated scatter tables for: (i) each month between 1986 and 2001; (ii) typical months; and (iii) a typical year.	Wave Analysis
Extreme Waves	Largest waves are depth-limited at low water levels	Hydrodynamic Assessment (Tables 2 -7)

[1] Now part of the National Oceanographic Centre

Parameter	Summary	Report Reference
Joint Probability Assessment	High waves are reasonably well correlated with storm surges due to wind set-up, but strong winds are independent of astronomical tides so the overall correlation between water level and waves is more modest	Hydrodynamic Assessment (Tables 8 -13)
Wave Overtopping	Overtopping numerical modelling undertaken at 11 sites	Hydrodynamic Assessment (Figures 2 – 14)
	Physical model tests of wave overtopping (and rock armour and accropode stability) at East Pier (and Marine Drive) using a wave basin	Physical Model Study – East Pier and Marine Drive

Previous wave analysis has identified that within South Bay, the foreshore is particularly influenced by waves approaching the shore from nearshore sectors between 20° and 100° (Figure 6).

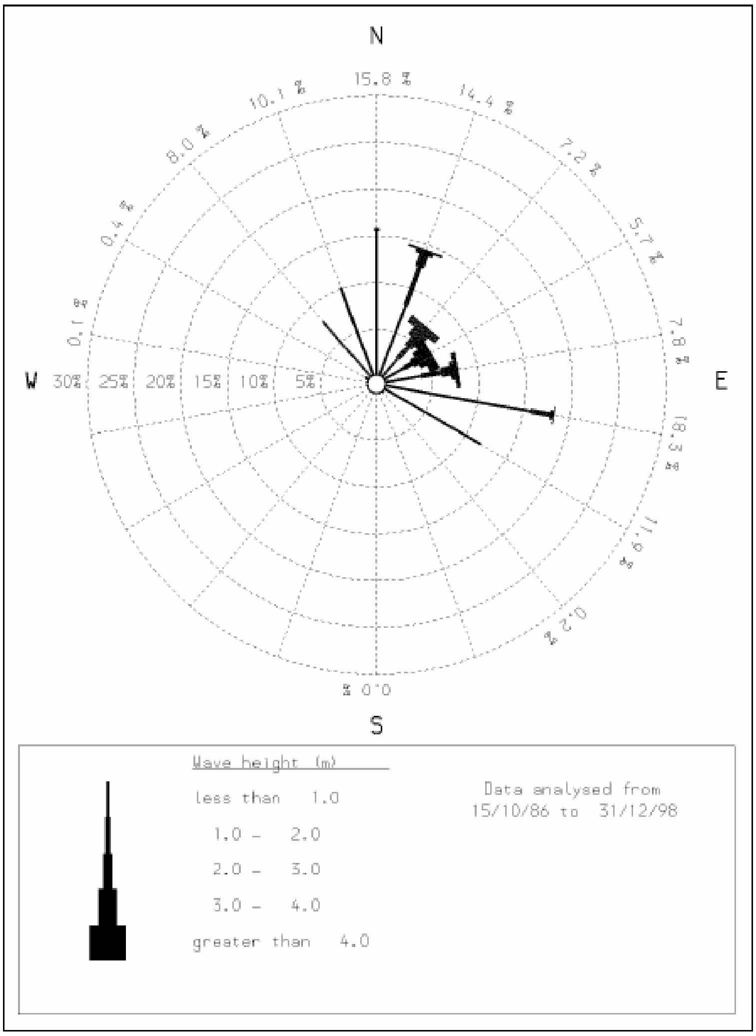

Figure 6 - Nearshore Wave Climate – South Bay (from High-Point Rendel, 2005)

3.3 Sediment Budget

3.3.1 Sediment Inputs

Castle Headland forms a barrier to the transport of sand along the inter-tidal foreshore between North Bay and South Bay. However, tidal currents do transport sand that is carried in suspension in the North Sea around the headland from offshore into South Bay. There is negligible sediment input from eroding cliffs and no sediment input from fluvial sources.

3.3.2 Sediment Transport

Inter-tidal longshore transport of sand is relatively small in the vicinity of Foreshore Road because the headland and harbour arms provide shelter. However, tidal-induced and wave-induced currents tend to draw sand into the lee of the East Pier, where it is deposited and accumulates. These sediment transport processes have previously been investigated using both physical modelling (Box A) and numerical modelling (Box B) approaches.

What is clear from these studies is that a circulation gyre, induced by the presence of the headland, functions across much of South Bay (Figure 7). This has the tendency to split the bay into two distinct sections. Between the harbour and the Spa net sediment transport is predominantly to the north, while south of the disused bathing pool it is to the south.

Due to these complex sand transport processes, a bar has developed at about low water just off the harbour. This is a result of waves diffracting around Castle Headland. Generally, this bar extends towards the harbour mouth, with sand transport along the bar towards the harbour, and the feature requires dredging to maintain safe navigation.

3.3.3 Sediment Outputs

The rock revetment constructed around the toe of the talus slope of the Holbeck Hall landslide acts as a terminal groyne to South Bay, with a small accumulation of sand and shingle on the rock platform north of the defence. However, as material is stripped from the beach to the nearshore during storm events, it becomes suspended in the water column and transported, generally southwards, by tidal currents beyond South Bay.

Box A – Previous physical model studies

Physical model studies were undertaken to investigate beach plan shape response during storm events in South Bay (HR Wallingford, 2002). The events considered were a 1 in 1 year return period event from a north-easterly direction, and a 1 in 1 year return period event from an easterly direction.

The physical model used appropriate scaling techniques to replicate a fine sand (D_{50} ~0.2mm) in the model, as confirmed through a RoxAnn sea bed classification survey which in turn was ground-truthed through laboratory analysis of beach sediment samples (HR Wallingford, 2000).

Beach plan shape changes were measured during the model tests by offsets from the seawall to the water level, with full beach contouring also undertaken. Wave-induced currents were measured using dye tracing techniques.

It was identified that in the northern part of South Bay a circulation gyre was formulated in the shelter of the harbour which tended to result in the deposition of sediment at a slow rate against the western side of the West Pier. There was then a separation point identified in the vicinity of where Foreshore Road joins the Spa Access Road, with a general southwards longshore wave-generated current tending to erode sediment from the Spa southwards, although it was noted that a small volume of sediment was trapped against the northern face of the small promontory at the Spa. It should be noted that the model investigated wave-generated currents only and did not include the effects of tidally-generated currents, which were considered in later numerical modelling studies.

Box B – Previous numerical model studies

Numerical model studies were undertaken using TELEMAC to simulate a mean spring tide and evaluate the peak tidal currents and peak residual current pattern. Results identified that currents are relatively weak (0.2m/s) in the nearshore area.

It was identified that outside the lee of the headland wave-induced currents would stir sand into suspension and tidal currents would then move it generally in a net southerly direction in the nearshore zone. However, in the lee of the headland a strong clockwise circulation gyre was identified, with its zone of influence extending across most of the nearshore area within South Bay. This has a tendency to lead to net northwards transport of sand along the beach and in the nearshore within the shelter of the headland.

BEACHPLAN modelling was then undertaken to assess the long term evolution of beach plan shape (to complement the physical model studies of short term response to storm conditions described in Box A).

Results identified that there are two distinct ‘cells’ within South Bay: (i) between the harbour and the Spa; and (ii) south of the Spa. Net sediment transport tends to be primarily to the north in the first cell and to the south in the second.

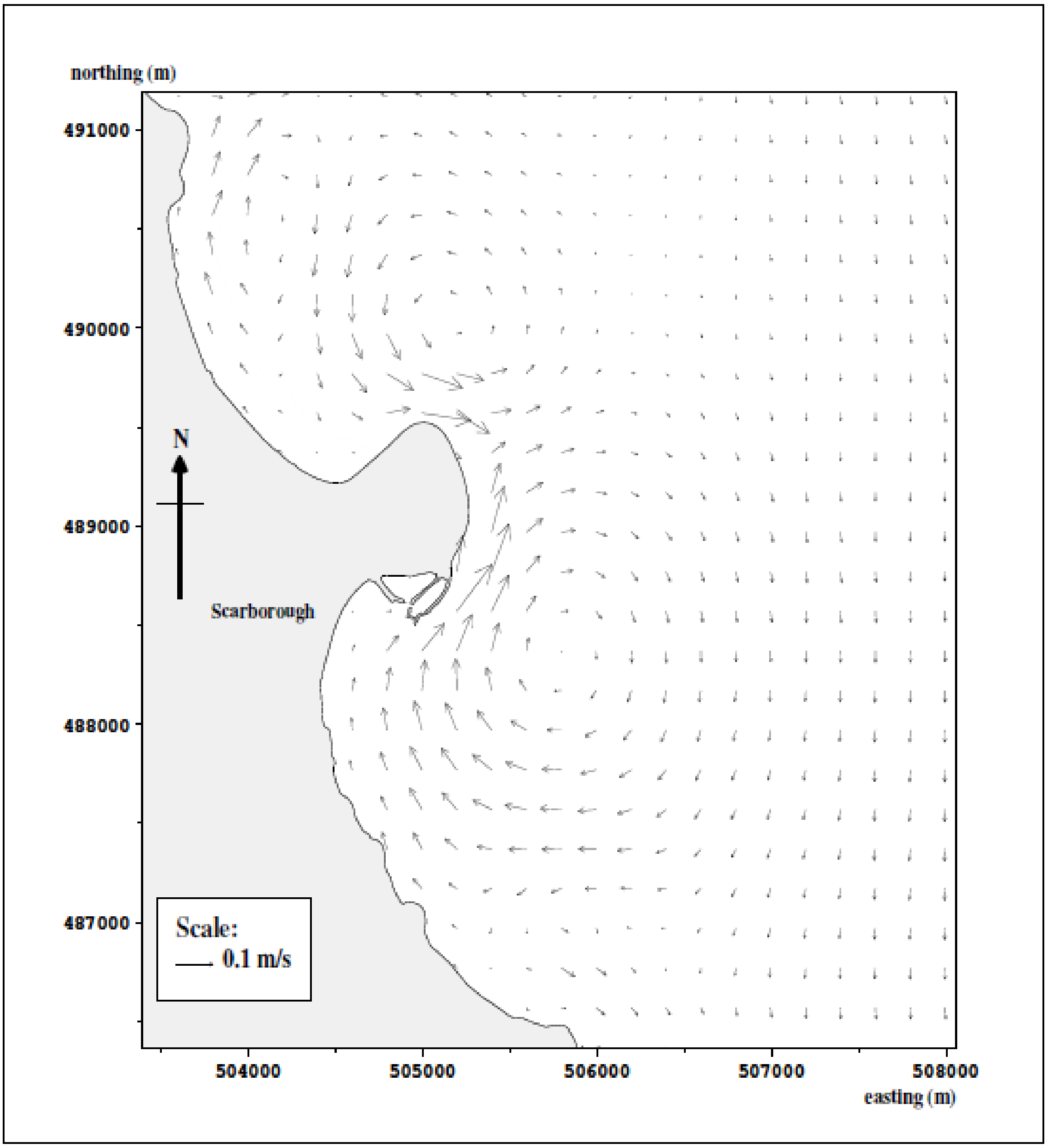

Figure 7 – Residual tidal currents showing clockwise circulation gyre in South Bay (from HR Wallingford 2001)

4 BEACH EVOLUTION

4.1 Historic Evolution

Previous analyses of historic maps and charts has identified that the beach along Foreshore Road has been building up over the past 100 years. Despite some uncertainties with the mapping, especially in the mid-1950s, it was concluded that the beach between West Pier and the Spa has been accreting since the end of the 19th Century, with mean beach elevation increasing by around 0.9m between the 1870s and 1937, becoming more consistent thereafter. Over the past century mean high water has steadily advanced seawards as the accumulation of sand on the upper beach has occurred, although the mean low water marked has retreated landwards. The net effect of these changes is that the beach face has steepened over this time. It has previously been calculated that the average rate of sand accretion in the north of South Bay is of the order of 5,000 – 6,000m^3 per annum (High-Point Rendel, 2005).

In contrast, the beach south of the Spa has experienced a net decline in beach volumes. These have been estimated at around 21,800m^3 between 1953 and 2000 (a long-term average of ~500m^3 per annum).

4.2 Future Evolution

Future beach response to sea level rise over the next century has previously been assessed in South Bay. This work considered three possible future sea level rise scenarios (see Figure 8), namely: (i) continuation of observed historic rates; (ii) Defra 2006 guidance rates; and (iii) UKCP09 medium emissions 50%ile projections.

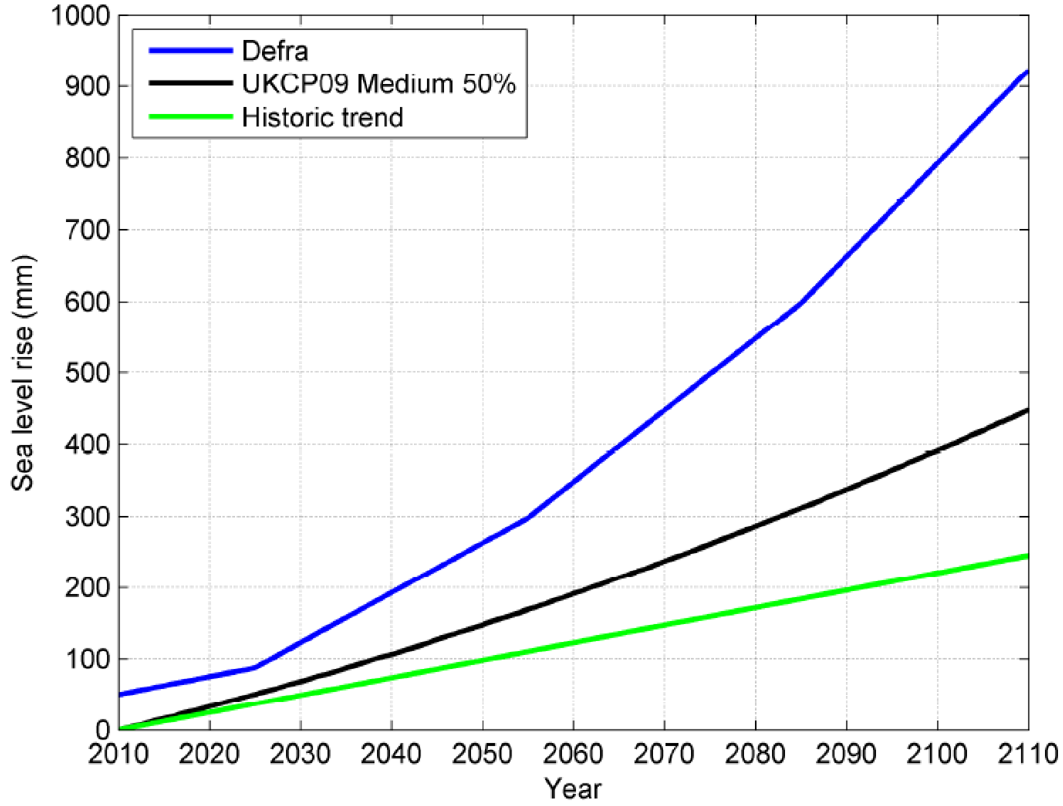

Figure 8 – Sea level rise projections used in modelling of future beach evolution

Based on an empirical representation of a theoretical beach profile for a given sediment grain size by Per Bruun (Bruun, 1954) an 'average annual theoretical beach profile' was fitted to data measured along one profile line in South Bay (Figure 9).

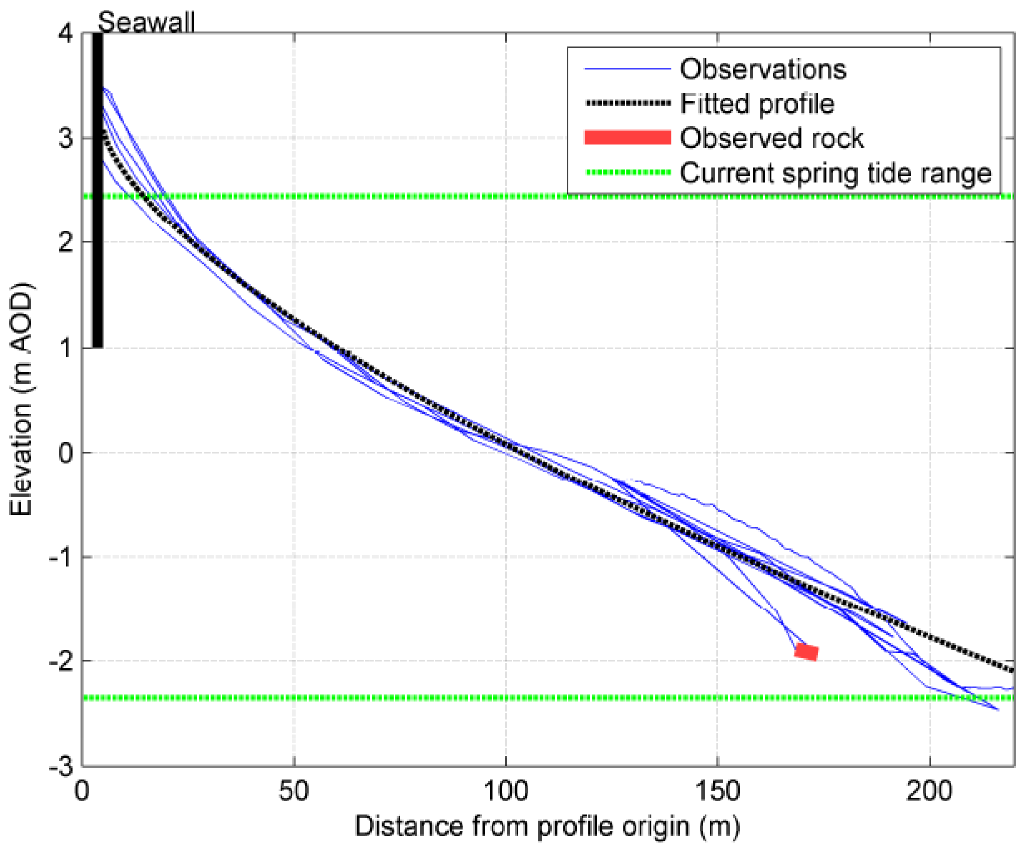

Figure 9 – Theoretical Beach Profile Based on the Bruun Empirical Model

The theoretical profile was then translated landwards in response to each of the three sea level rise scenarios considered (Figure 10). The results revealed that the beaches within South Bay will become 10-60m narrower overall (when measured to the mark of mean low water on spring tides) in response to sea level rise, resulting in reduction of amenity beach area. Also, water depths at time of mean high water on a spring tide would be between 0.6 and 1.5m greater, resulting in much of the beach to be submerged at high tide, with more severe wave conditions acting due to the greater water depths at the toe of the seawalls.

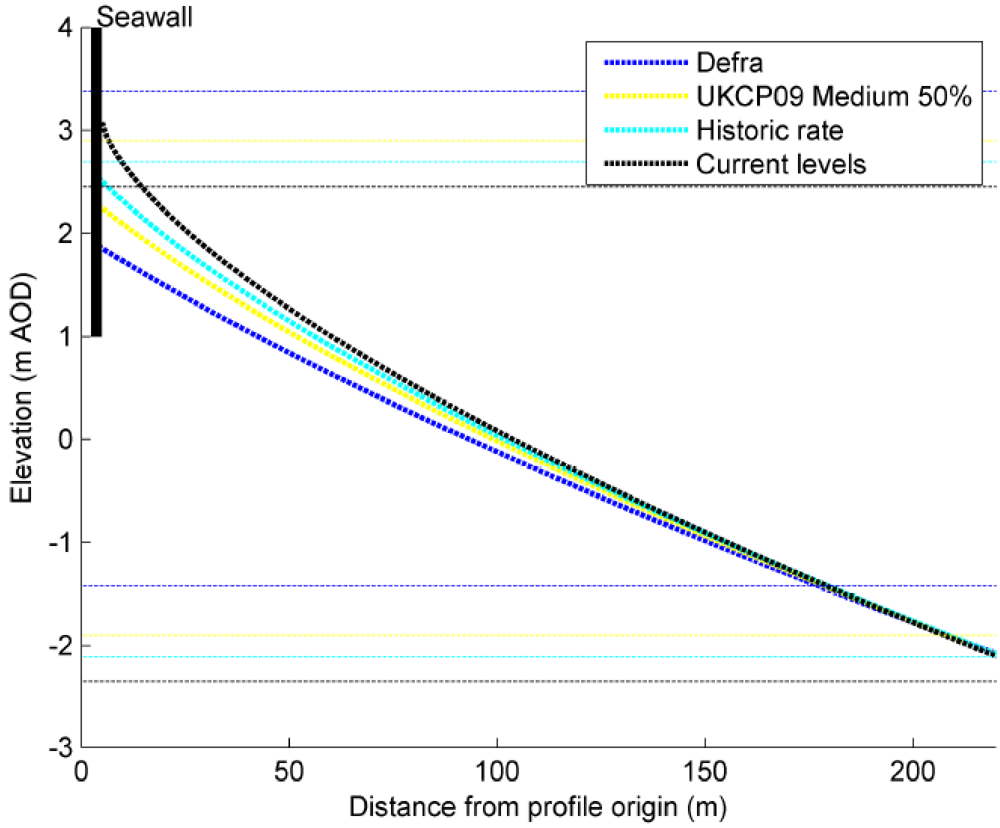

Figure 10 - Beach Profile Response to Sea Level Rise

The results from the theoretical Bruun profile modelling were then translated across the planshape form of South Bay to indicate relative future positions of contours of mean low and mean high water on a spring tide (Figure 11). This shows that under all future scenarios, beach contours are expected to migrate landwards due to sea level rise.

Title:
Beach Plan Form Response
to Sea Level Rise

Project:
Scarborough South Bay
Beach Management Plan

Client:
Scarborough Borough Council

Date: Feb 2012	Scale: 1:8,000	
Figure: 11	Drawn: TC	Checked: NC

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5 ANALYSIS OF COASTAL MONITORING DATA

5.1 Wave Buoy

A directional wave rider buoy was deployed approximately 2km off from Scarborough Headland in around 20m depth of water in May 2003. Analysis of data from the buoy revealed that this nearshore location is subject to waves from 0° to 120° (Figure 12).

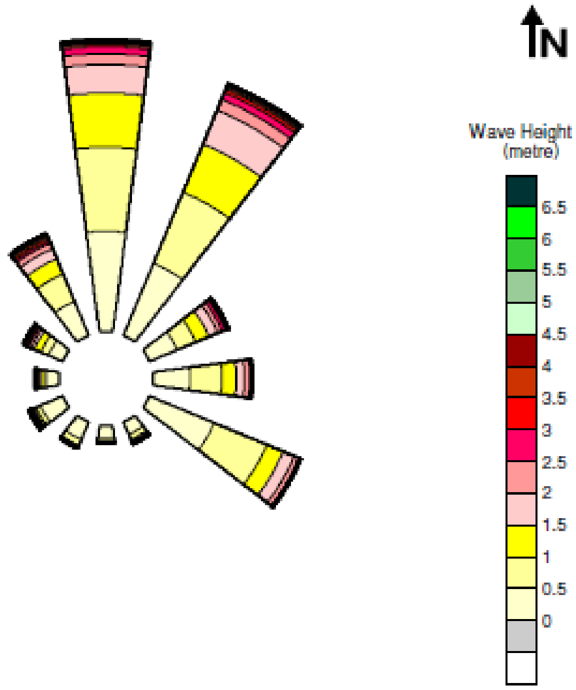

Figure 12 - Measured Wave Data from Scarborough Wave Buoy (from Halcrow, 2004)

As previously discussed, as these waves propagate around the headland, the most common conditions within South Bay are due to waves from 20° to 100°.

5.2 Beach Profiles and Beach Surveys

5.2.1 2001 - 2004

Scarborough Borough Council undertook beach profile surveys on seven occasions between September 2001 and April 2004 along seven transects within South Bay. Analysis of data from these surveys tended to show that storm waves eroded sediment from the beach face and transport it offshore, while calmer weather swell waves rebuilt the beach, creating berms (High-Point Rendel, 2005). Overall, it was estimated that during this period there was a net gain of 75,200m^3 of sand within South Bay indicating that there must be a relatively large supply from offshore (Royal Haskoning, 2005).

5.2.2 2008 – 2011

Since 2008, the South Bay frontage has been surveyed as part of the Cell 1 Regional Coastal Monitoring Programme, providing useful beach profile and beach topographic, data of the frontage. This comprises four beach profile transects, shown in Figure 13.

Key:

Cell 1 Topographic Profile Location

Title:
Cell 1 Beach Profile Locations

Project:
Scarborough South Bay Beach Management Plan

Client:
Scarborough Borough Council

Date: February 2012	Scale on A4: 1:6,000

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Figures 14 – 17 show the changes in beach level along each of these beach profile transects from successive surveys in: November 2008; April 2009; October 2009; January 2010; March 2010; September 2010; and February 2011. Over this period beach regarding occurred in April and May 2009, and in January 2010 some sand was temporarily removed from the beach for use in 'gritting' frozen footpaths, but a substantial proportion of this was later returned to the foreshore. Therefore due to only limited beach management activity, the datasets show relatively natural trends in behaviour.

Figure 14 shows that along beach profile 1dSBS1 towards the north of South Bay, beach levels at the toe of the seawall have, in recent years, been variable but have not reached the level of the seawall crest. For this reason beach management activities have not needed to be undertaken in 2009, 2010 or 2011. However, the most recent available survey, from February 2011, shows accumulation to be occurring at the toe of the seawall, reducing the freeboard effect. As this effect is known from visual observations to persist to the present time it is anticipated that beach management activity will be undertaken in spring 2012 to 'skim' the beach sand back down to a level that reduced the risk of wave 'ramping' and associated sea flooding.

Across beach profile transects 1bSBS2 and 1bSBS3 (Figures 15 and 16, respectively), towards the centre of South Bay, the foreshore level shows signs of considerable variability over time along much of the inter-tidal foreshore. This supports the conceptual understanding that storm events can remove notable quantities of sand from the beach to the nearshore zone, while calmer sea states then tend to progressively build the beach back up. This is typical behaviour of a foreshore subject to variations in wave climates between 'winter' and 'summer' seasons. The placement of sand during typical beach management activities in the vicinity of beach profile transect 1bSBS3 would help reduce some of this volatility although its effectiveness would be temporary as material would still tend to move offshore during storms and northwards in South Bay due to residual tidal currents during typical prevailing conditions.

Beach profile transect 1dSBS4 (Figure 17) is located further south within South Bay and it is immediately notable by comparison with the three other beach profile transect lines how much lower in level the foreshore is at the toe of the seawall. This gives rise to some problems with overtopping and undermining of the seawall in the vicinity of the Spa. It can be seen from Figure 18 that the scale of any sand placement that would be needed in this vicinity to raise beach levels at the toe of the seawall to similar values in the north of South Bay would be massive. Such a large scale foreshore recharge would most likely result in transfer of significant volumes of placed material away from this frontage towards the north of South Bay, worsening problems associated with excessive accretion in front of Foreshore Road and within the harbour and its approach channel. Depending on the wave conditions experienced, some material may also move offshore and to the south of the Spa towards Holbeck. This confirms that a structural approach to the problems being experienced at the Spa is the most suitable way forward and that foreshore recharge would not necessarily be effective in the medium or longer term and may indeed cause unwanted problems elsewhere in South Bay.

Figure 14 – Changes Along Beach Profile 1dSBS1

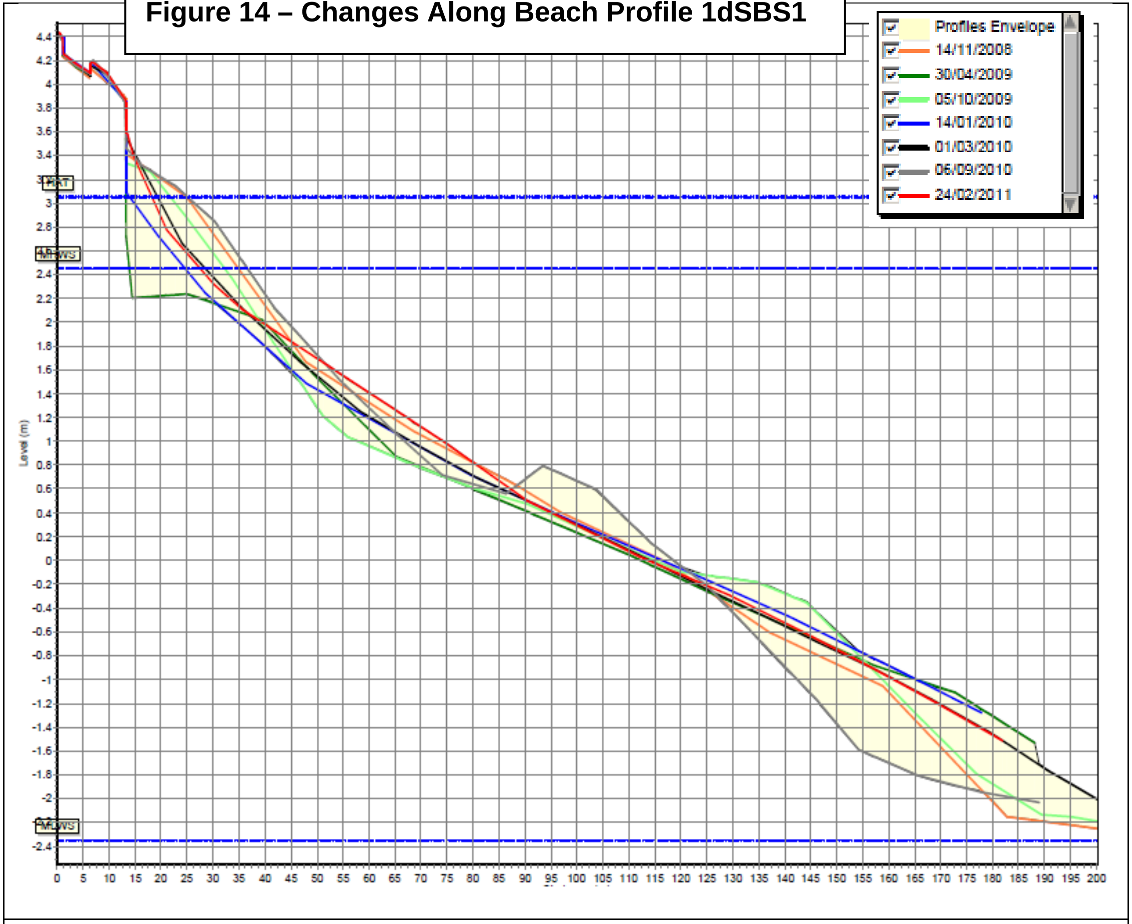


Figure 15 – Changes Along Beach Profile 1dSBS2

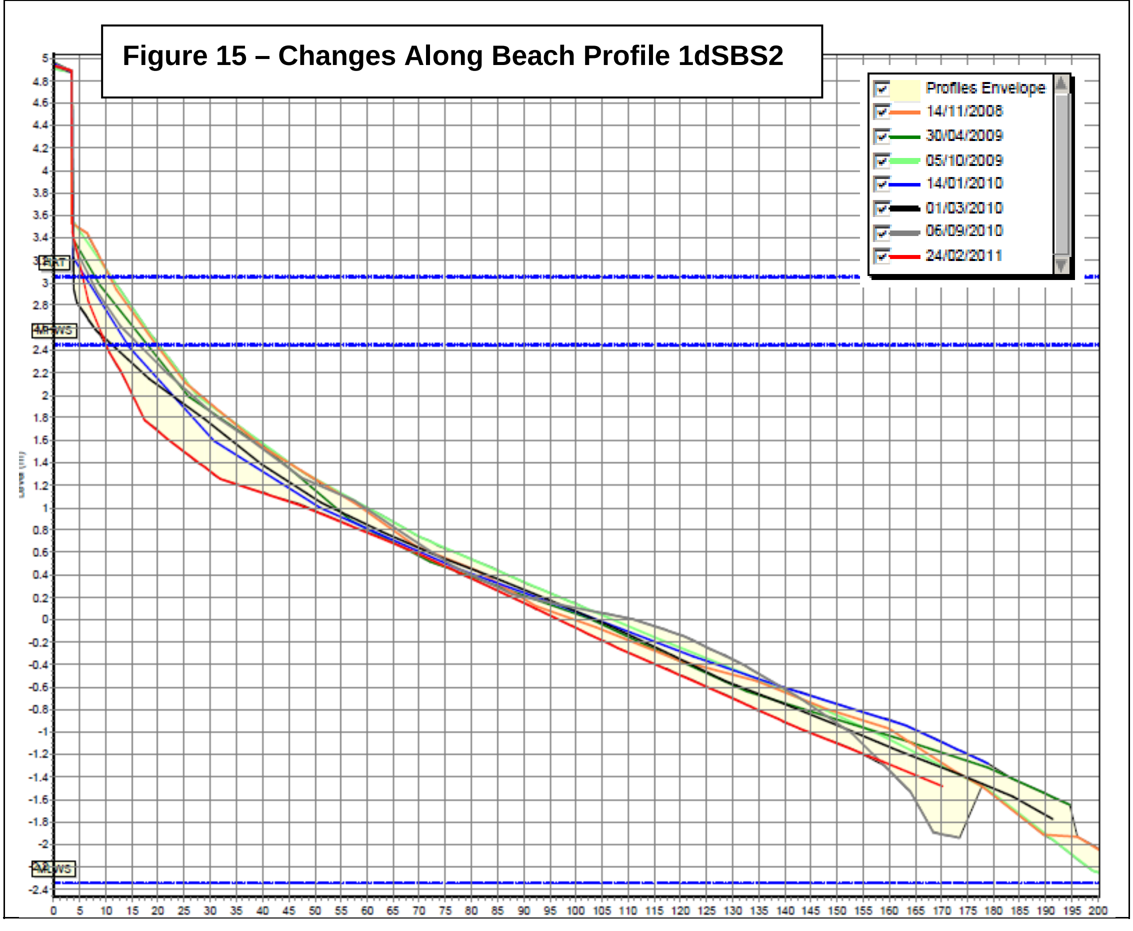


Figure 16 – Changes Along Beach Profile 1dSBS3

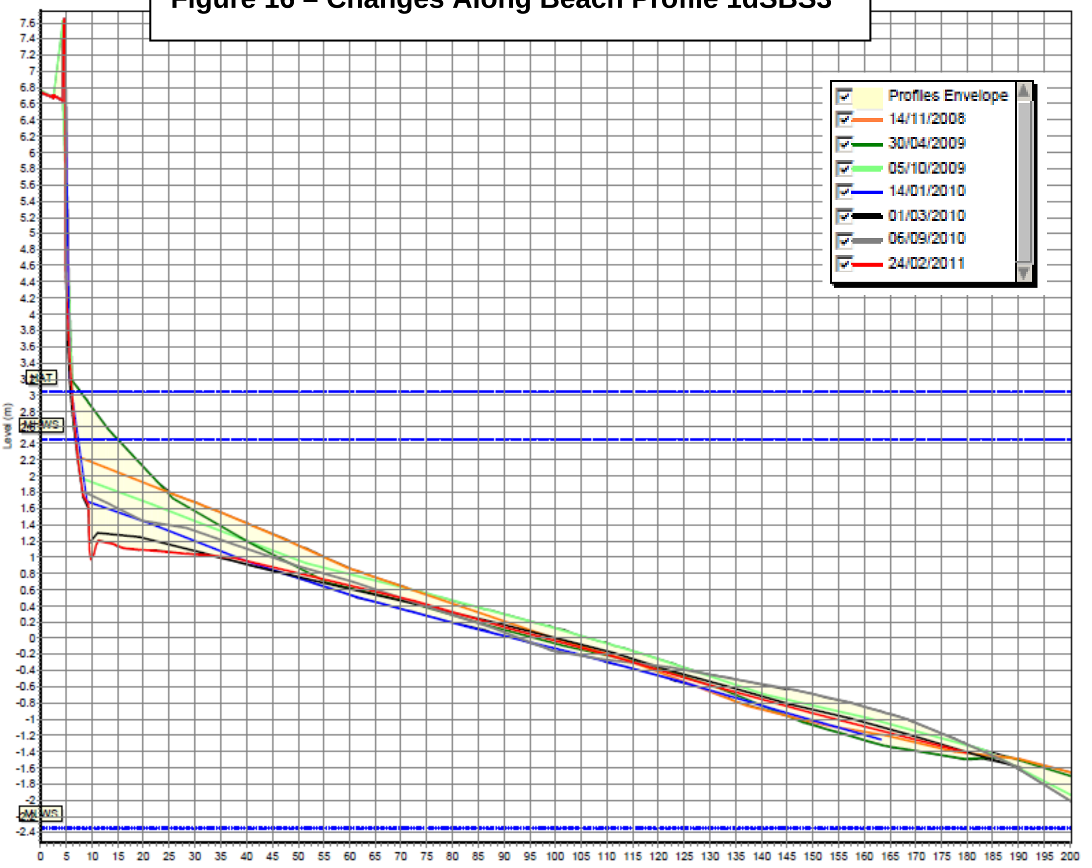
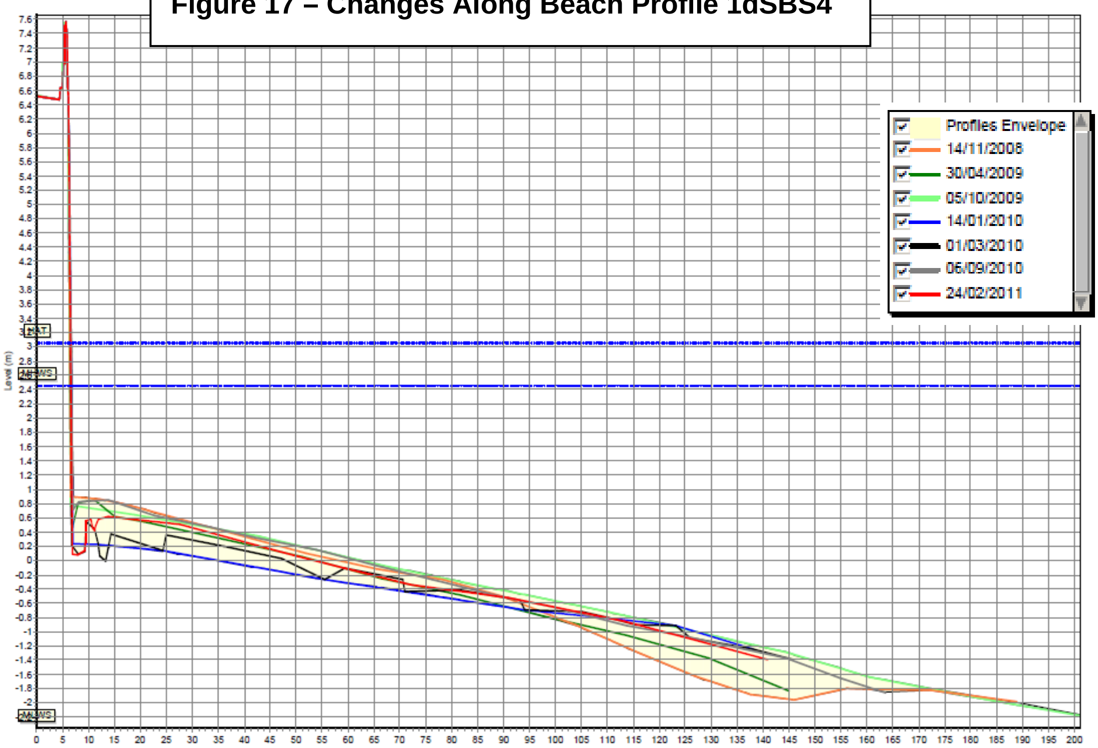


Figure 17 – Changes Along Beach Profile 1dSBS4



In addition to the beach profile transects, the whole of South Bay has been covered by a beach topographic survey since November 2008.

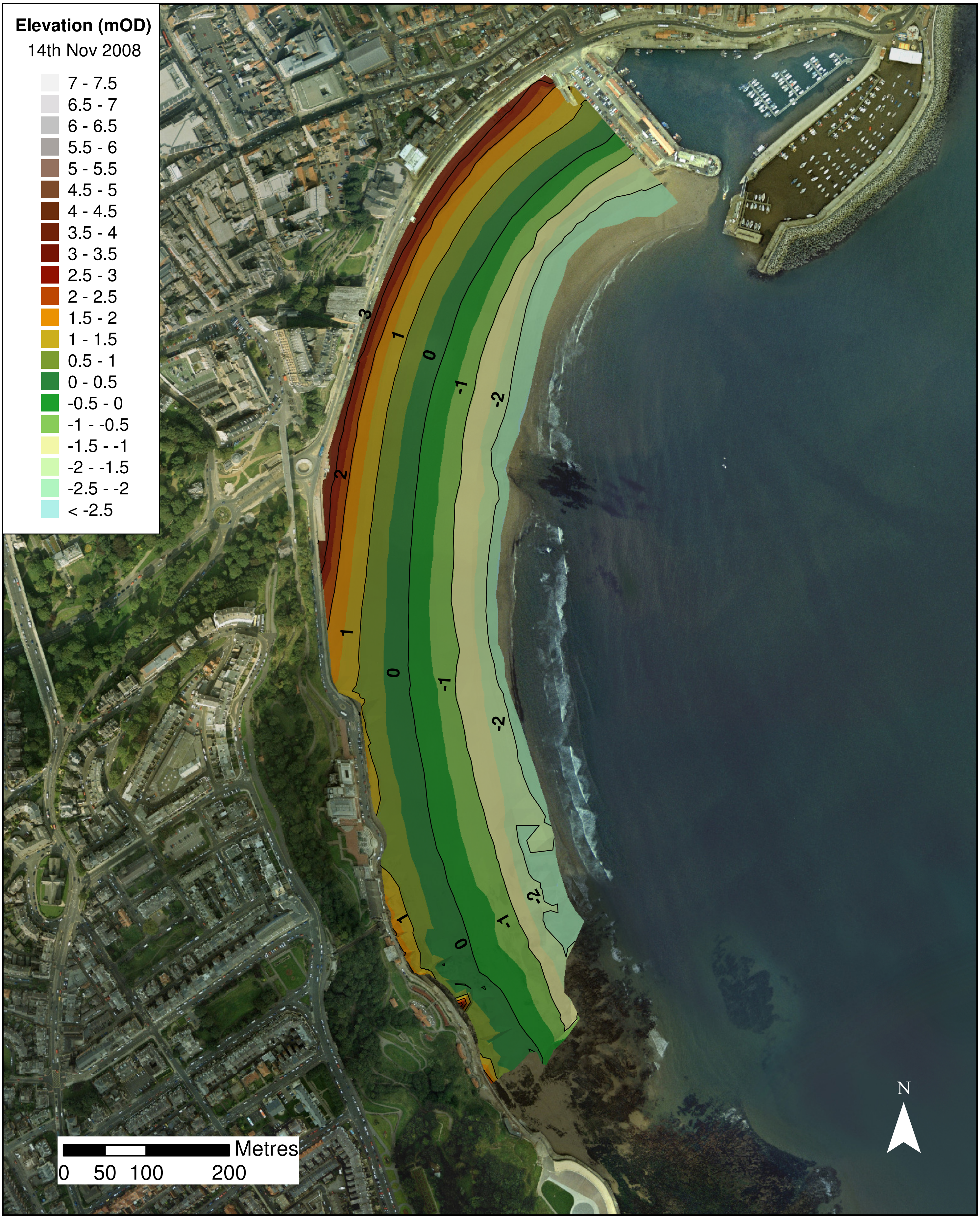
Initially this was undertaken annually around September/October/November but an extra survey was introduced in January 2010 to monitor the effect of extracting sand from the beach for use in 'gritting' the footpaths and due to the benefits of capturing the seasonal behaviour, has been undertaken twice a year since. This means that beach topographic surveys are available from the following dates: November 2008 (Figure 18); October 2009 (Figure 19); January 2010 (Figure 20); September 2010 (Figure 21); and February 2011 (Figure 22).

From these figures it is particularly notable that the beach contours attain higher levels in the north of South Bay than in the South. It appears that this may be due to the Spa Approach Road and the Spa protruding seawards from the more embayed alignment of the 'natural' shore.

For example, in tracing the line of the 1mOD beach contour on Figure 18 it can be seen that it becomes intercepted by the seawall at the Spa Approach Road. The higher beach levels observed in this figure along the north of South Bay are totally absent further south.

Data from each of the topographic surveys have been used to create a Digital Ground Model (DGM) within GIS software. Each DGM has then been compared against that from the successive survey to identify locations of beach level change (Figures 23 – 26). These figures show that when a particular trend affects part of the frontage, that trend is felt across the majority of South Bay, further supporting the concept of material drawdown during storms, followed by slow progressive build up during calmer wave conditions.

In addition, South Bay has been divided into seven distinct 'zones' based upon the Management Units presented in the Holbeck to Scalby Mills Coastal Strategy (Figure 27). The beach volume changes between successive surveys (or areas of 'cut' or erosion and of 'fill' or accretion) have also been identified.



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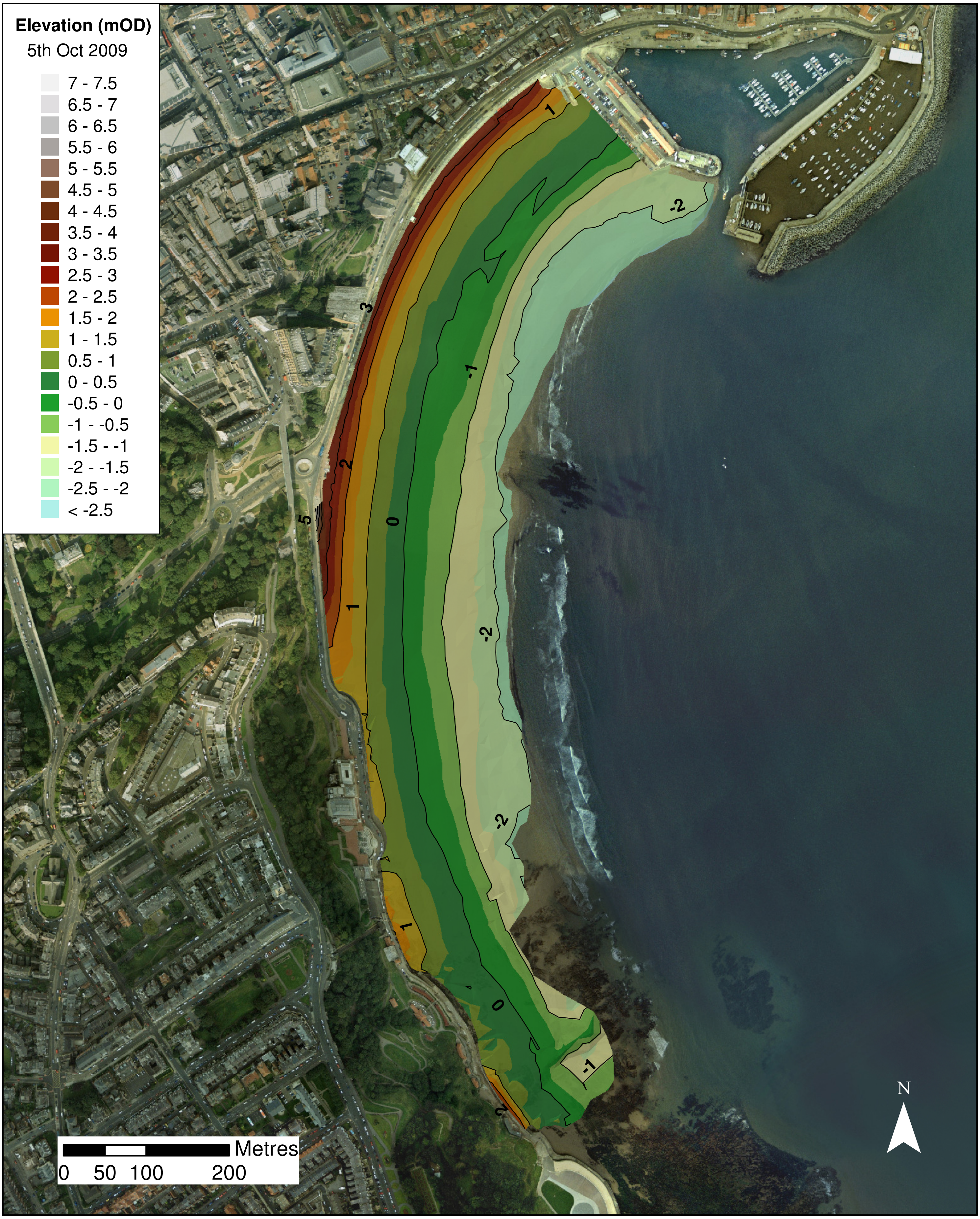
	Project: Scarborough South Bay Beach Management Plan	Figure: 18	Drawn: TC	Checked: NC
	Client: Scarborough Borough Council			



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Beach Contours (Oct 2009)

Project:
Scarborough South Bay
Beach Management Plan

Client:
Scarborough Borough Council

Date:
February 2012

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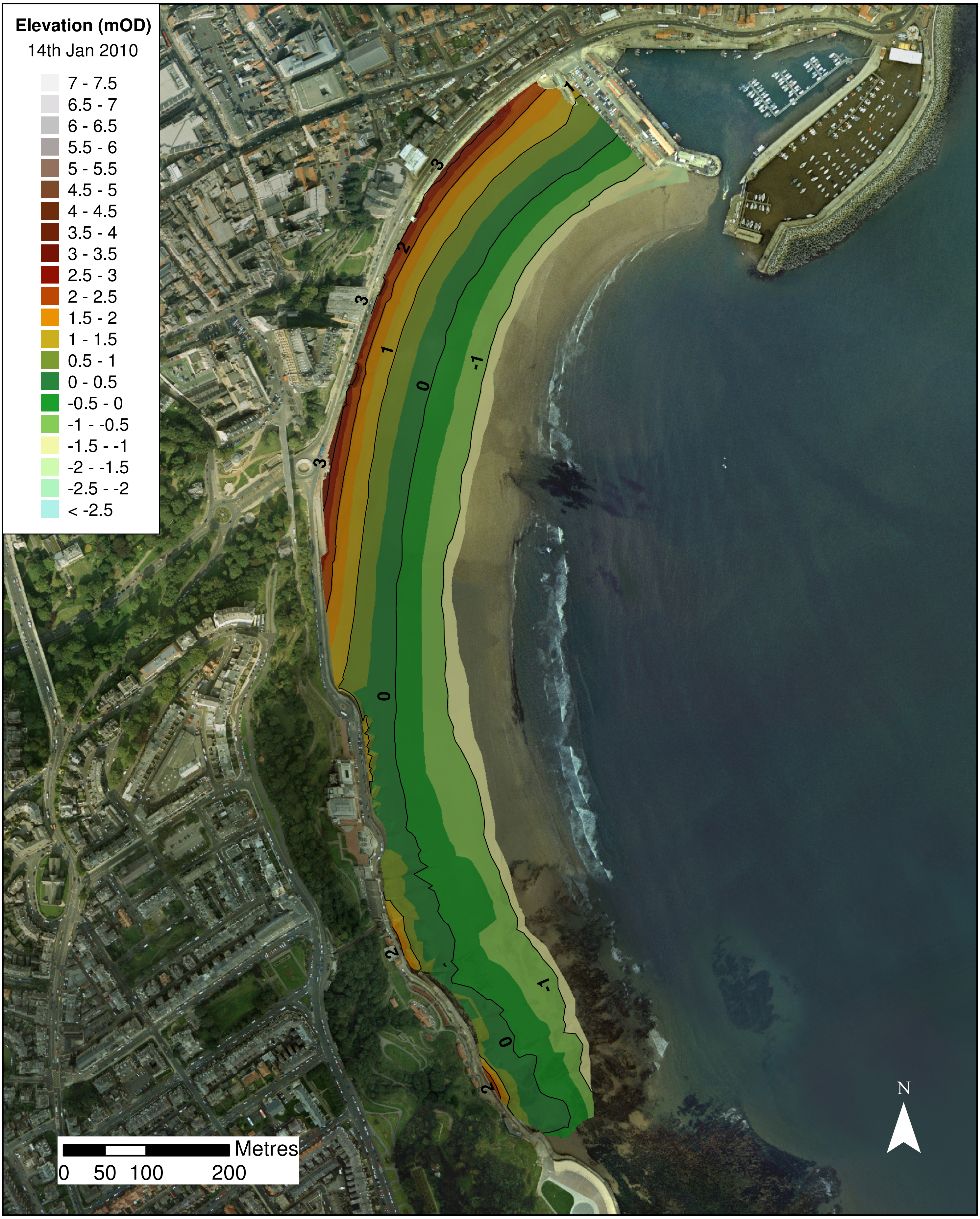

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Project:
Scarborough South Bay
Beach Management Plan

Client:
Scarborough Borough Council

Date: February 2012		Scale on A4: 1:6,000
Figure: 20	Drawn: TC	Checked: NC

ROYAL HASKONING

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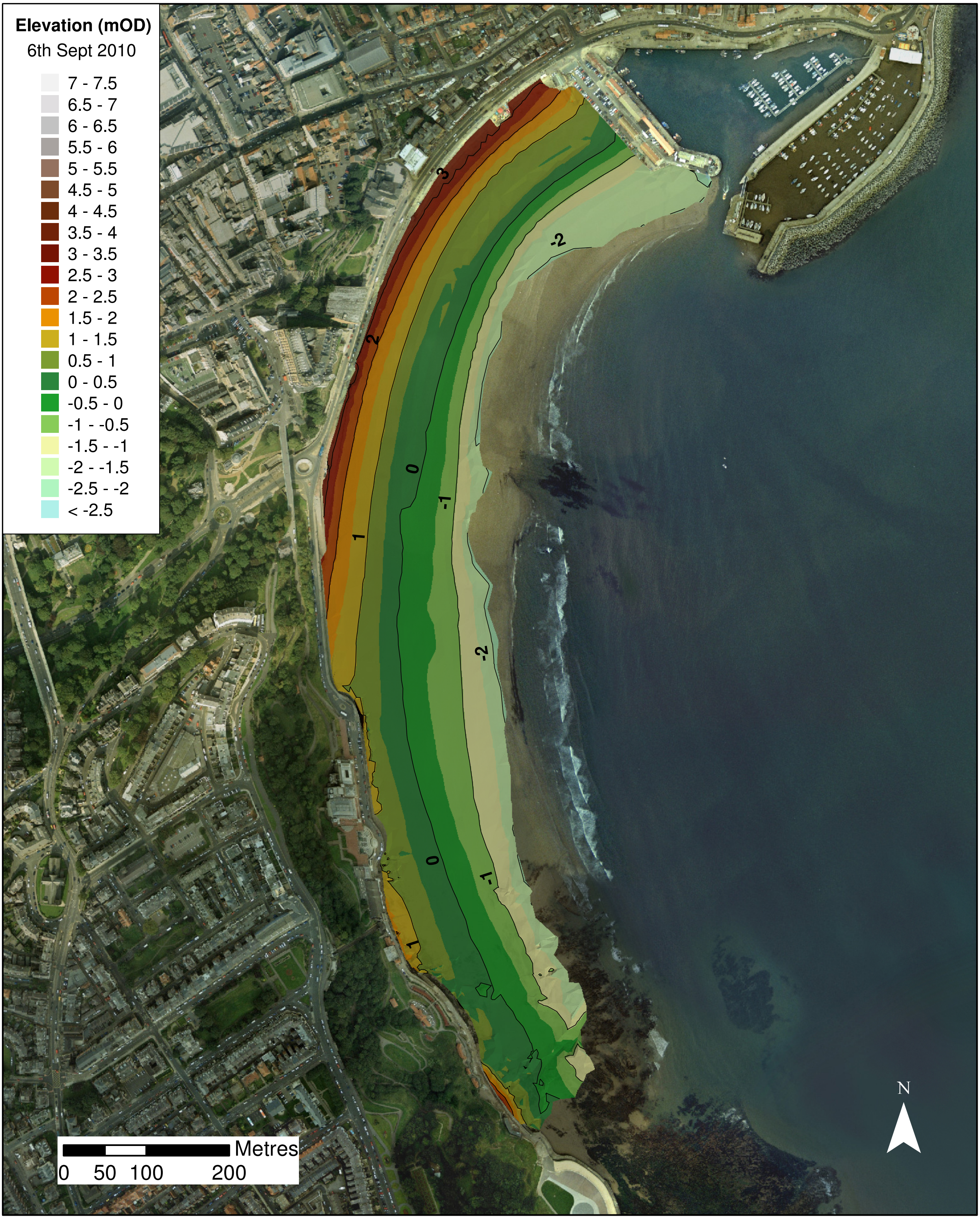

Key:	Title: Beach Contours (Sep 2010)	Date: February 2012	Scale on A4: 1:6,000
	Project: Scarborough South Bay Beach Management Plan	Figure: 21	Drawn: TC / Checked: NC
	Client: Scarborough Borough Council		ROYAL HASKONING

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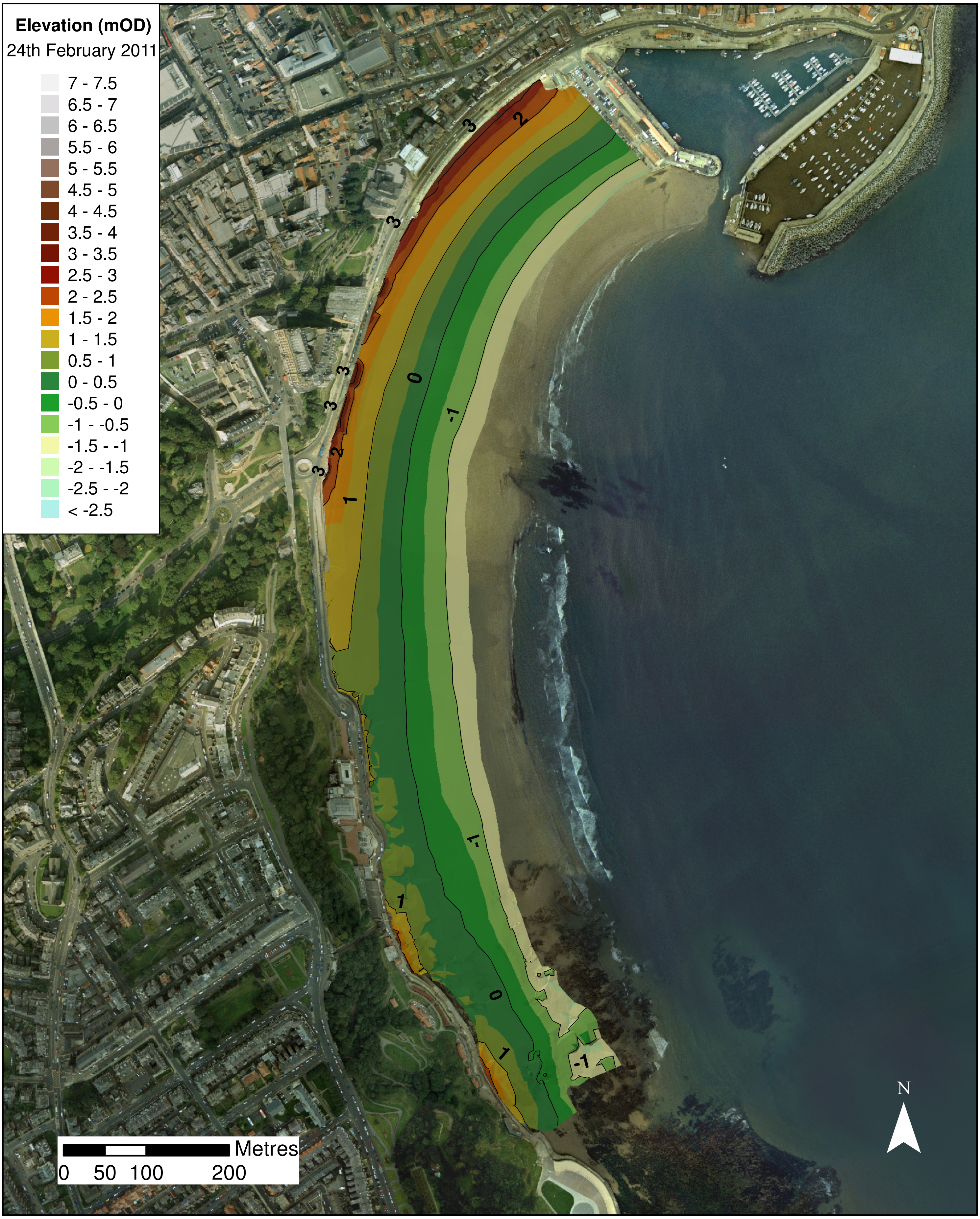

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Title:
Beach Contours (Feb 2011)

Project:
Scarborough South Bay
Beach Management Plan

Client:
Scarborough Borough Council

Date: February 2012	Scale on A4: 1:6,000	
Figure: 22	Drawn: TC	Checked: NC

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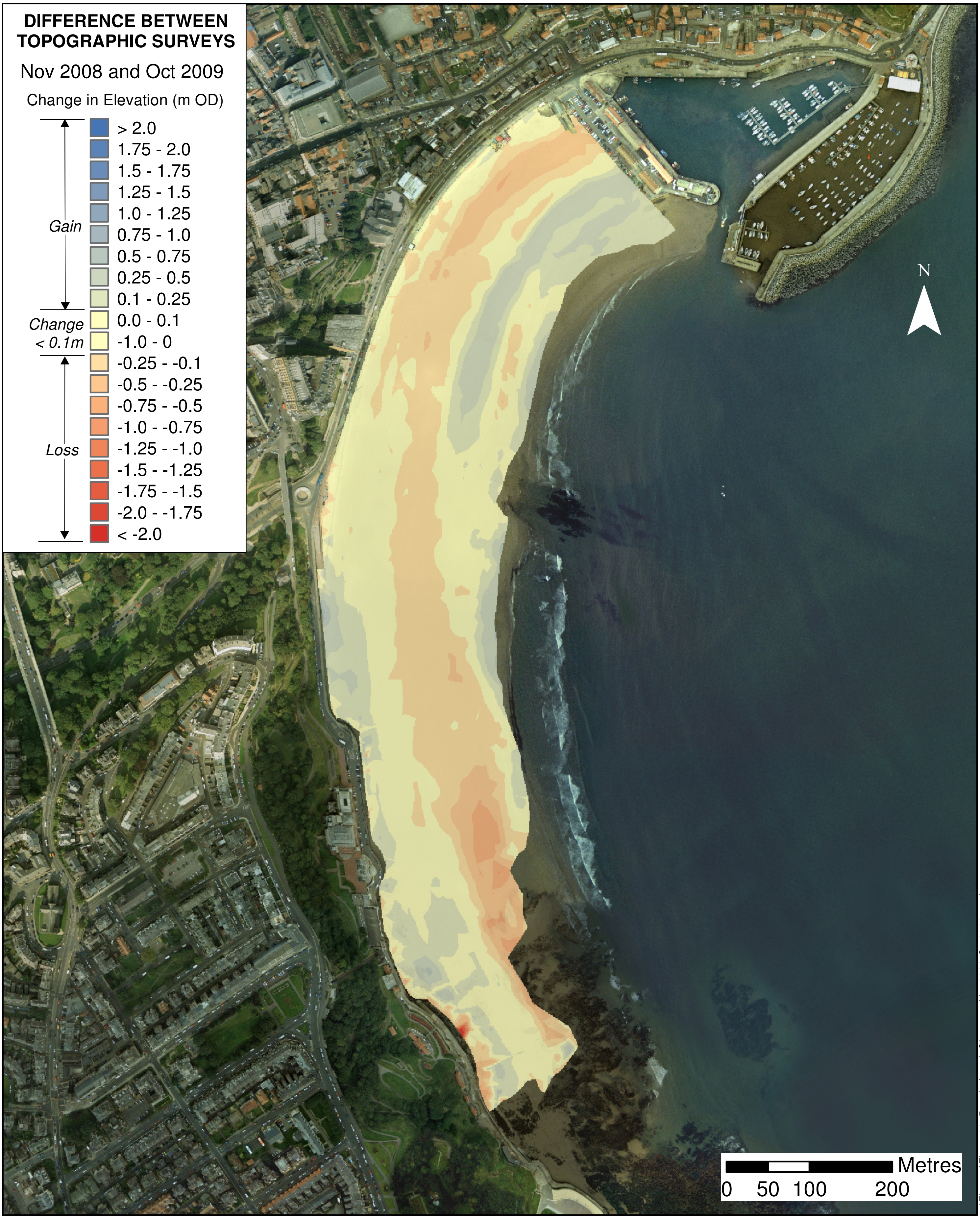

Key:	Title: Beach Level Changes between Nov 2008 and Oct 2009 Project: Scarborough South Bay Beach Management Plan Client: Scarborough Borough Council	Date: February 2012	Scale on A4: 1:6,000		ROYAL HASKONING
		Figure: 23	Drawn: TC	Checked: NC	

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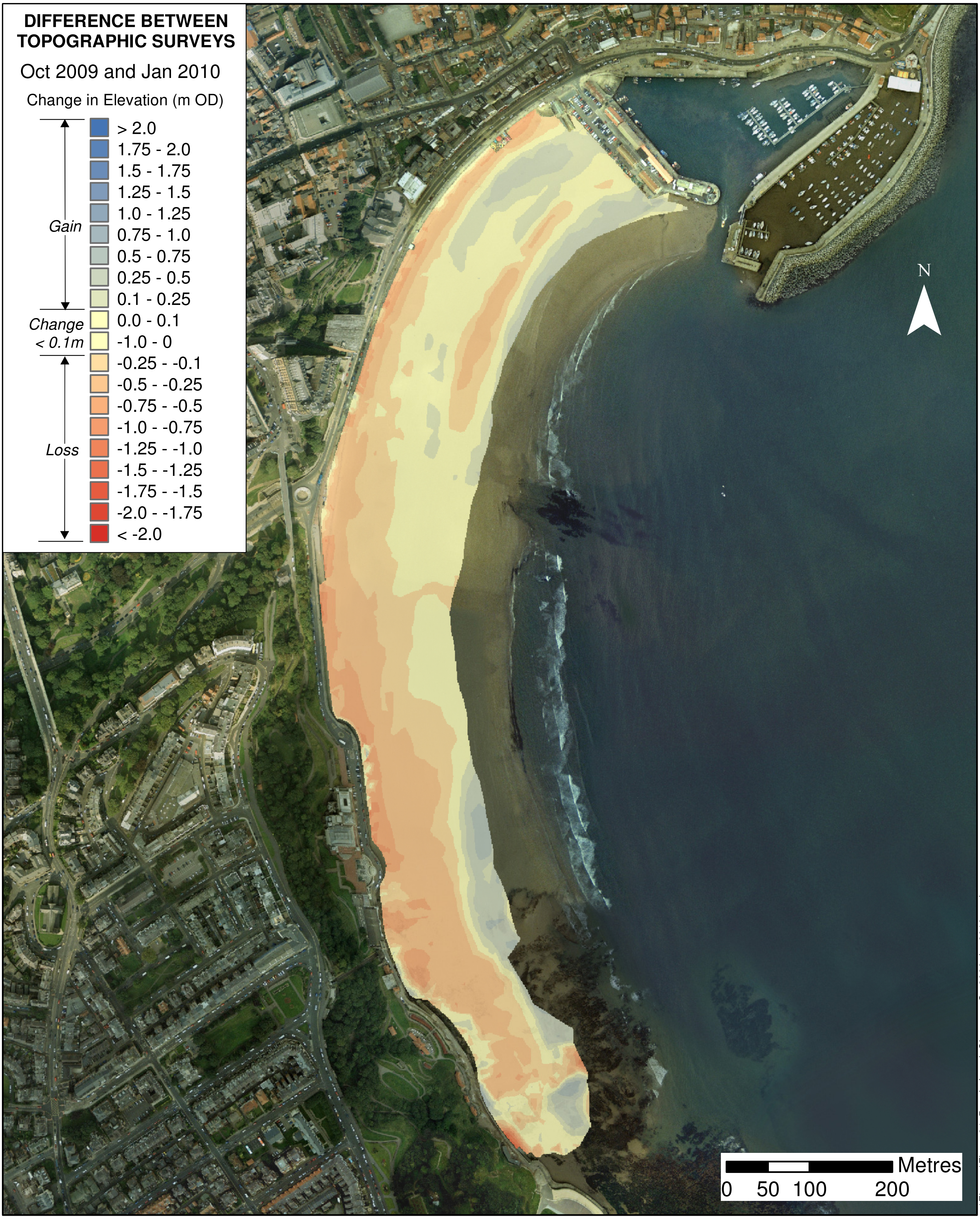

Key:

Title:
Beach Level Changes between
Oct 2009 and Jan 2010

Project:
Scarborough South Bay
Beach Management Plan

Client:
Scarborough Borough Council

Date: Feb 2011

Scale on A4: 1:6,000

Figure: 24

Drawn: TC

Checked: NC

ROYAL HASKONING

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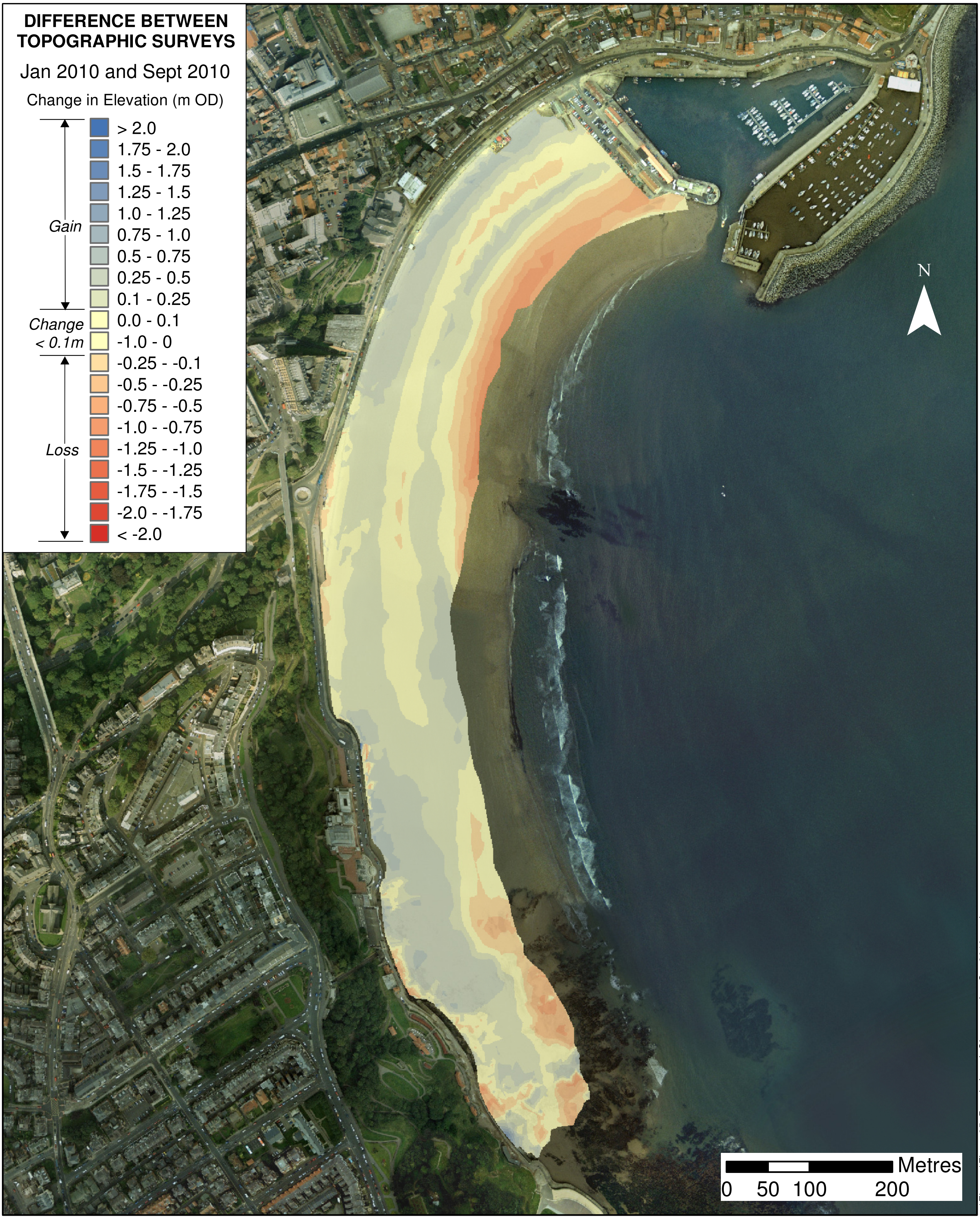

Key:	Title: Beach Level Changes between Jan 2010 and Sept 2010	Date: Feb 2011	Scale on A4: 1:6,000	ROYAL HASKONING
	Project: Scarborough South Bay Beach Management Plan	Figure: 25	Drawn: TC / Checked: NC	
	Client: Scarborough Borough Council			

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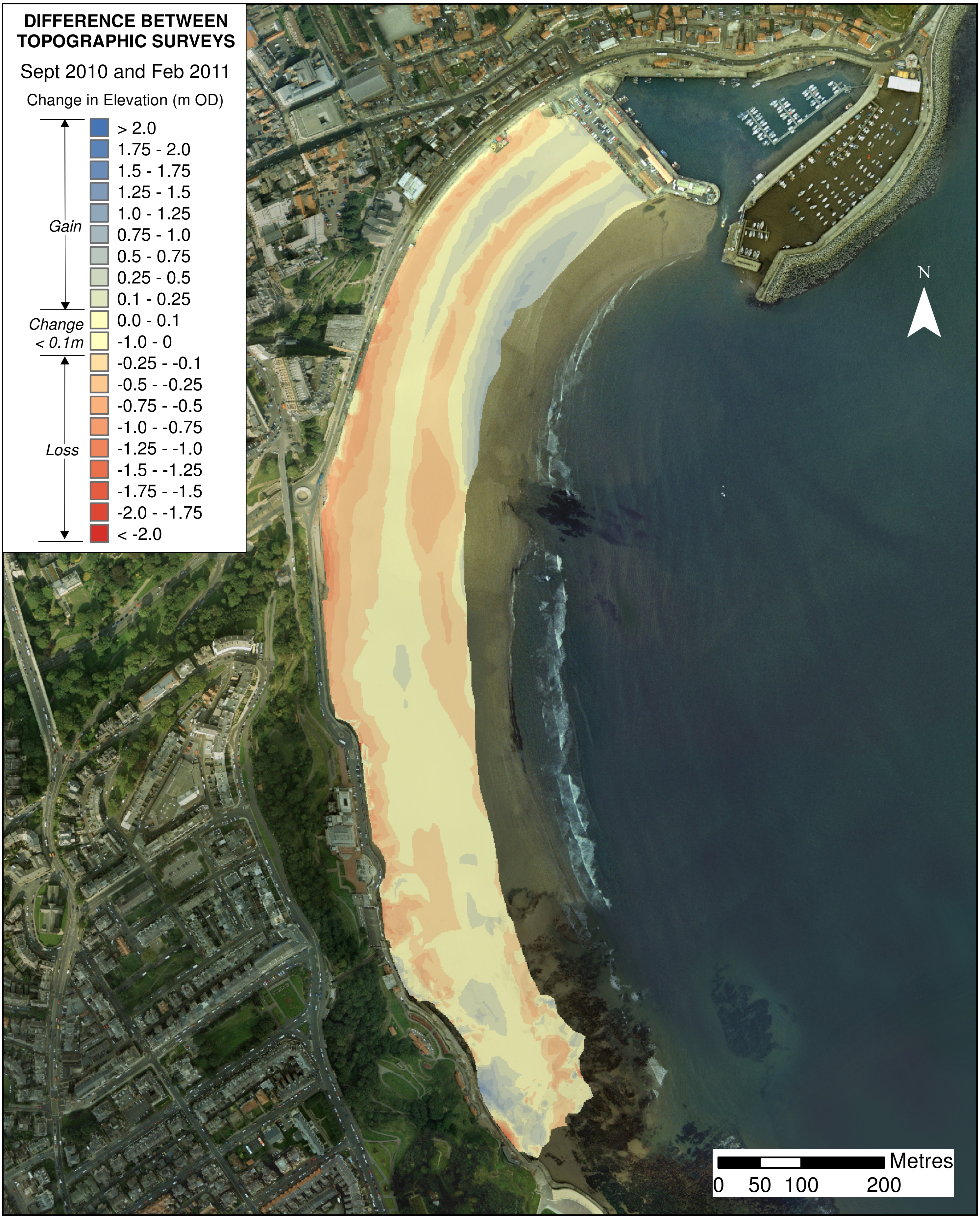

Key:	Title: Beach Level Changes between Sept 2010 and Feb 2011	Date: Feb 2011	Scale on A4: 1:6,000	ROYAL HASKONING
	Project: Scarborough South Bay Beach Management Plan	Figure: 26	Drawn: TC	Checked: NC
	Client: Scarborough Borough Council			

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Key:

Title:
Beach Zones for Volumetric Analysis

Project:
Scarborough South Bay Beach Management Plan

Client:
Scarborough Borough Council

Date: Feb 2011

Scale on A4: 1:6,000

Figure: 27

Drawn: TC

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Between each successive survey the beach volume changes have been quantified for both South Bay as a whole (Figure 28) and for each individual Management Units (Figure 29).

Figure 28 shows that since the first beach topographic survey in November 2008 beach volumes have fluctuated over time, with the severe winter of 2009/10 (as measured by the January 2010 survey) causing particularly low values. However, by the time of the next survey in September 2010 beach volumes had recovered and in fact were in excess of the values originally recorded during the first survey. This further demonstrates the concept of beach volatility that was discussed previously.

Figure 28 - Volume Changes in South Bay (Nov 2008 to Feb 2011)

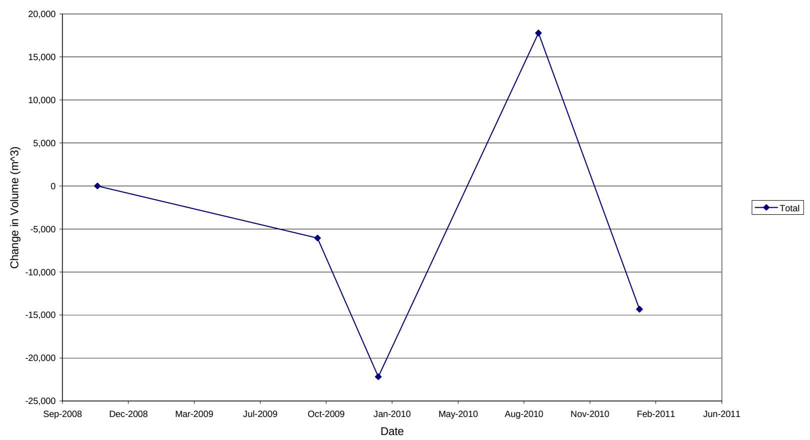
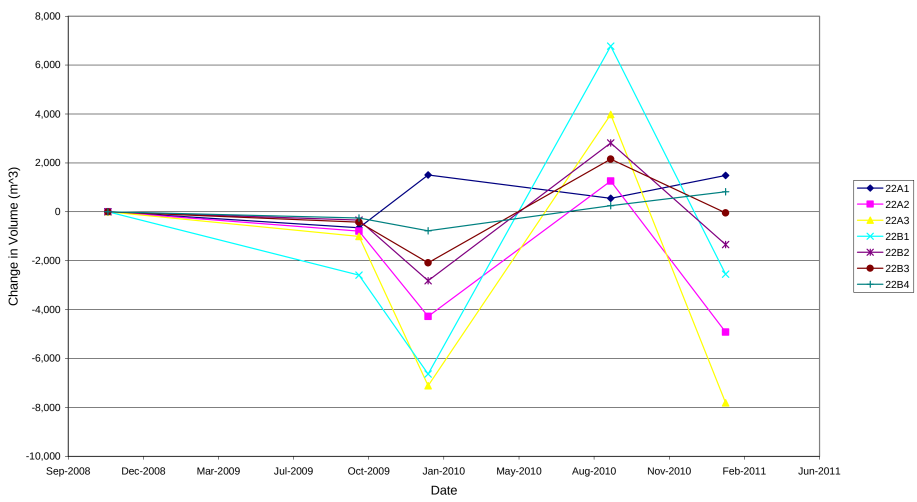


Figure 29 shows that with the exception of Management Unit 22A1, beach volume changes are experienced relatively uniformly across South Bay. This supports earlier discussion identifying that material can be moved offshore from the beaches during storm events but generally returns during periods of calmer wave action. The exception to this generalisation presented by Management Unity 22A1 is particularly interesting since it generally shows a trend of more modest variability and net accretion since the first survey, even when other areas of the frontage are particularly affected by erosion during storms. This supports earlier evidence of a net accumulation of sand within this zone, caused by the net northwards transport of sand along the foreshore and maintained by the sheltering effect of the headland and harbour structures. This also suggests that natural processes alone will not remove unwanted accretion in this zone and therefore commitment to beach management activities and harbour dredging will continue to be needed into the future.

Figure 29 - Volume Changes in South Bay (Nov 2008 to Feb 2011)



5.3 Bathymetry and Sea Bed Characterisation

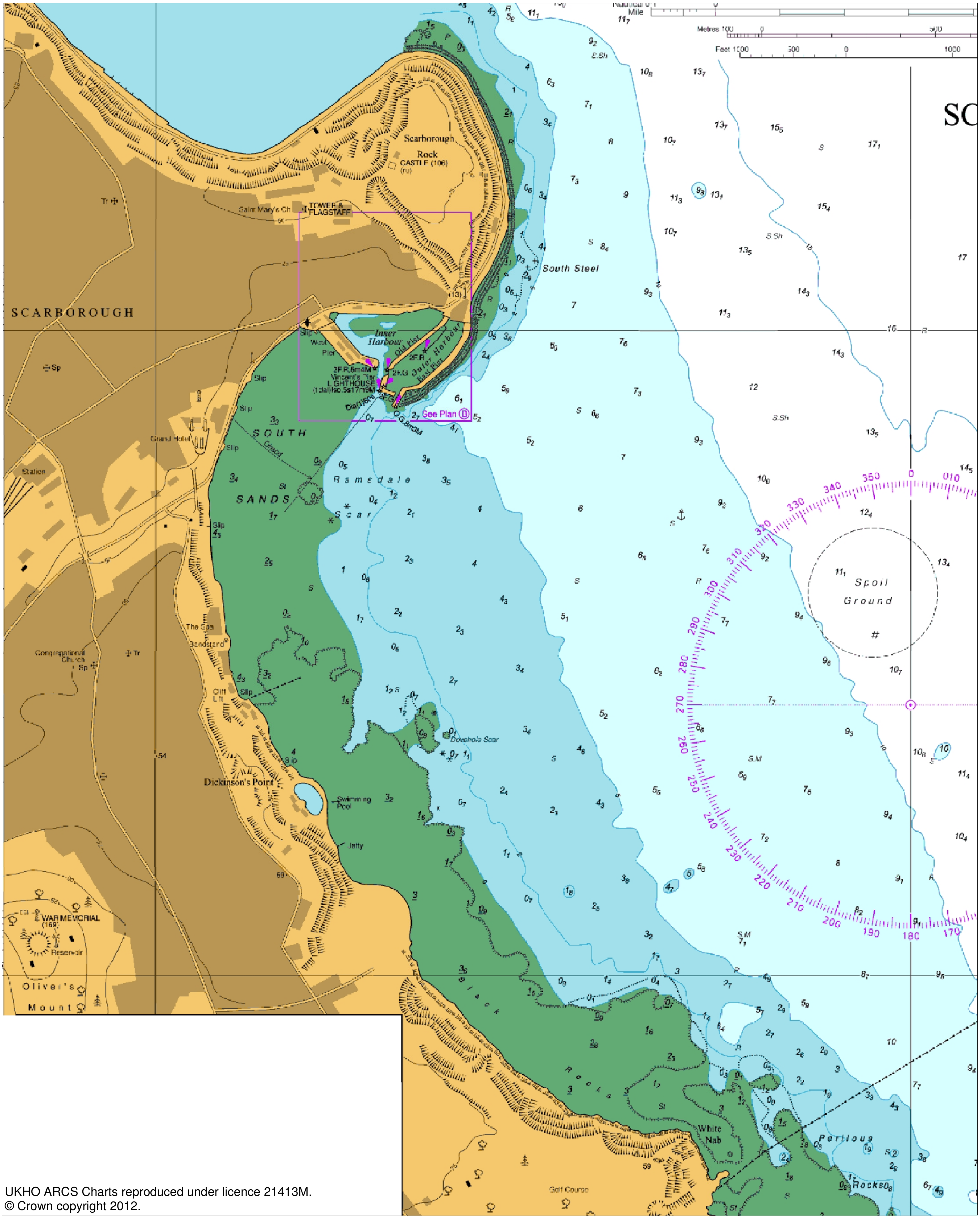
Figure 30 is a licensed reproduction of the Admiralty Chart covering South Bay. This shows that the nearshore bathymetric contours are relatively parallel to each other offshore of the headland, but become progressively more embayed with movements into South Bay. However, there remains control exerted on the contours by areas of outcropping rock, such as in the vicinity of the Spa, offshore from the swimming pool and offshore from White Nab. The figure also shows that there are areas of accumulated material proud of the surrounding sea bed in the vicinity of the harbour mouth, which has a very narrow approach channel.

A bathymetric and sea bed characterisation survey was undertaken between 28th April and 18th May 2000 to inform the numerical and physical modelling that was undertaken as part of the original Holbeck to Scalby Mills Coastal Strategy. It has not been possible to present the survey in this *Beach Management Plan* as digital data were not available, but a hard copy A2 plot of the bathymetric contours and individual soundings reveals in more precise detail the presence of the rock outcrops and sandbars within South Bay. The corresponding hard copy A2 plot of the sea bed characterisation reveals ubiquitous presence of fine sand across South Bay, except for the discrete areas of rock outcrop and occasional patches of stones and boulders.

A bathymetric and sea bed characterisation survey was undertaken along one transect line in 2010 as part of the Cell 1 Regional Coastal Monitoring Programme. Figure 31 shows these data, indicating how the shore shelves off into deeper water at the seaward end of the transect, and providing supporting evidence of the presence of fine sand on the inter-tidal foreshore, nearshore sea bed and offshore sea bed.

A full bathymetric survey of South Bay was undertaken in 2011 as part of the Scarborough Spa Coast Protection and Slope Stabilisation scheme. Figure 32 shows a contour plot derived from a DGM of the inter-tidal area and sea bed that was created for specific purposes of this *Beach Management Plan* from the bathymetric data. Again the important presence of rock outcrops and the embayed nature of the nearshore contours can be discerned, with deeper contours being aligned more linearly.

It has also been possible to use the DGM to ‘zoom’ and view the bathymetry just offshore of the harbour mouth to reveal the presence of the bars. Figure 33 shows the sea bed contours in this vicinity. A profile transect has also been extracted from the DGM and plotted as a profile transect on this figure, revealing how a bar builds up both immediately landward and immediately seaward of the very narrow approach channel to the harbour. It is easy to understand from these data the importance of dredging to maintain navigational safety. Note that the Scarborough Rock spoil ground used for the disposal of dredged material can be seen on Figure 30.



Key:

Title:
Admiralty Chart

Project:
Scarborough South Bay Beach Management Plan

Client:
Scarborough Borough Council

Date:	Scale:
February 2012	NTS

Figure:	Drawn:	Checked:
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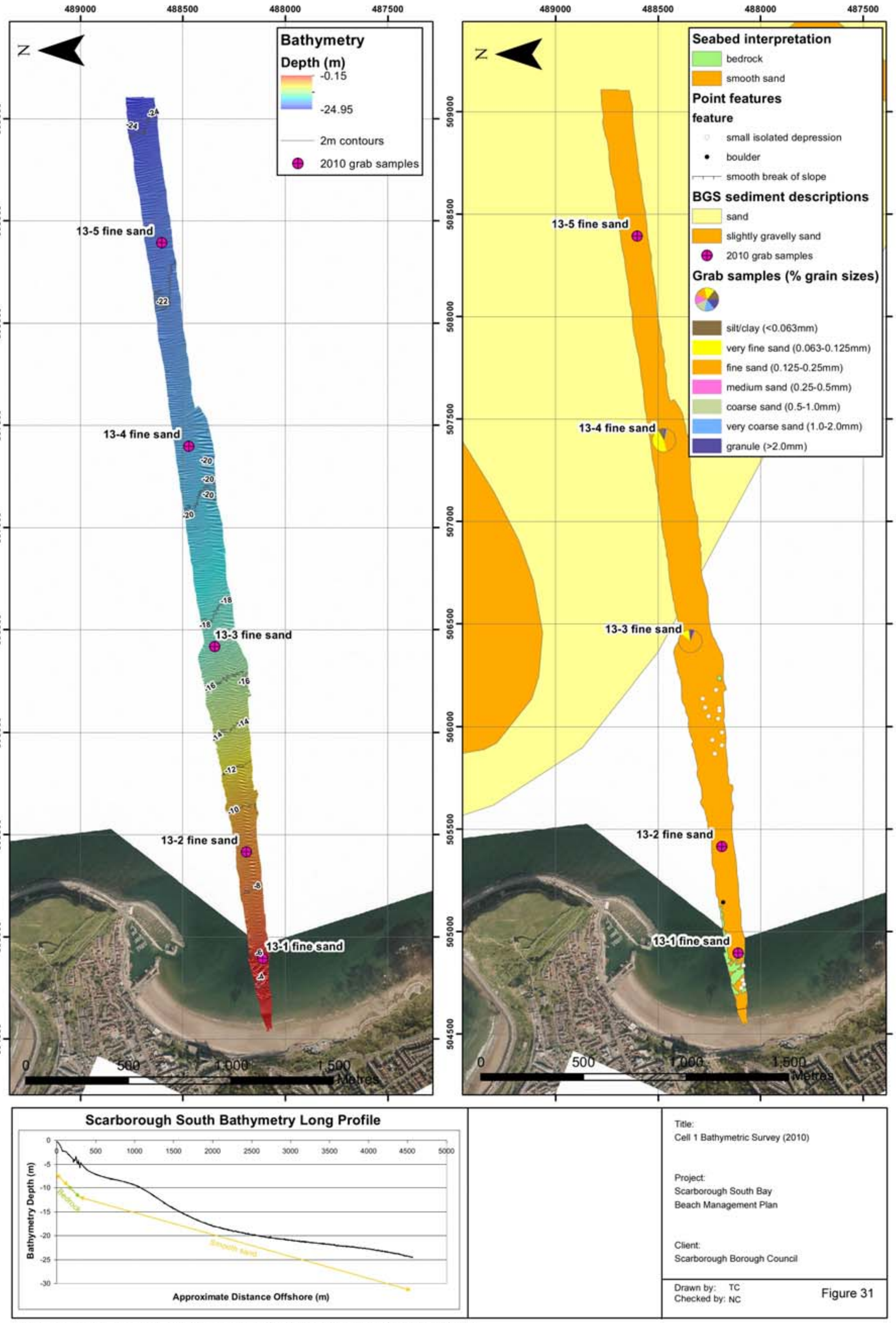
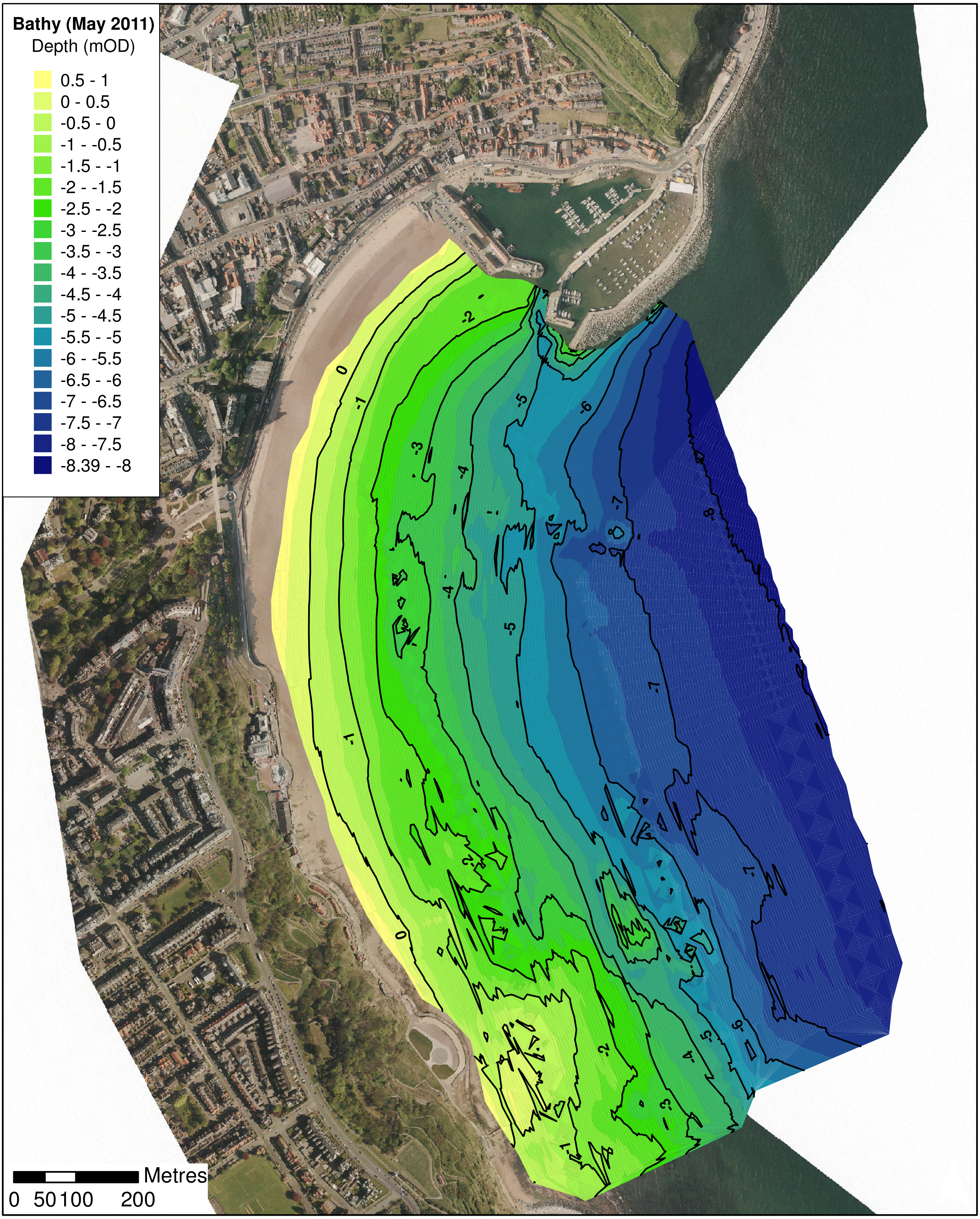


Derived from 1:250,000 scale BGS Digital Data under Licence No 2010/041A British Geological Survey. © NERC.



Key:	Title: Bathymetric Survey (May 2011) - South Bay Project: Scarborough South Bay Beach Management Plan Client: Scarborough Borough Council	Date: February 2012 Figure: 32 Drawn: TC	Scale on A4: 1:8,000 Checked: NC	ROYAL HASKONING

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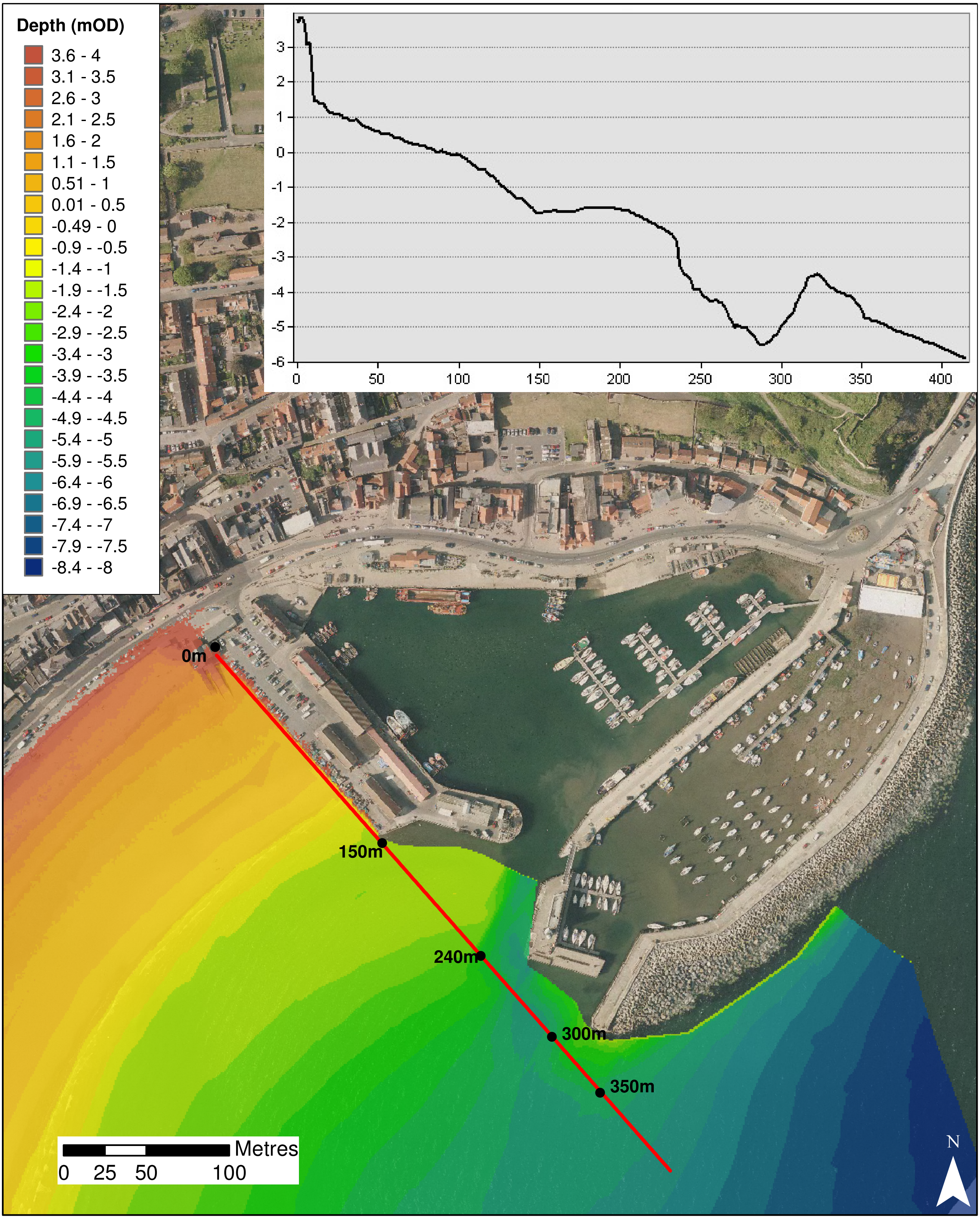

Key:	Title: Bathymetric Survey (May 2011) - Harbour Mouth	Date: February 2012	Scale on A4: 1:3,000
		Figure: 33	Drawn: TC
		Checked: NC	
	Project: Scarborough South Bay Beach Management Plan		
	Client: Scarborough Borough Council		

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5.4 Lidar and aerial photography

An aerial photography campaign with a corresponding airborne-Lidar survey was undertaken in 2010 as part of the Cell 1 Regional Coastal Monitoring Programme. This has enabled three-dimension DGMs to be produced of South Bay, over which aerial photographs have been draped. A series of resulting images have been produced to help visual the hinterland and inter-tidal regions of South Bay. Such images are useful for appreciation of scale and context and future repeat surveys will assist with identification of changes over time.

Figure 34 – Visualisation of South Bay

Figure 35 – Visualisation of Scarborough Harbour

Figure 36 – Visualisation of Castle Headland

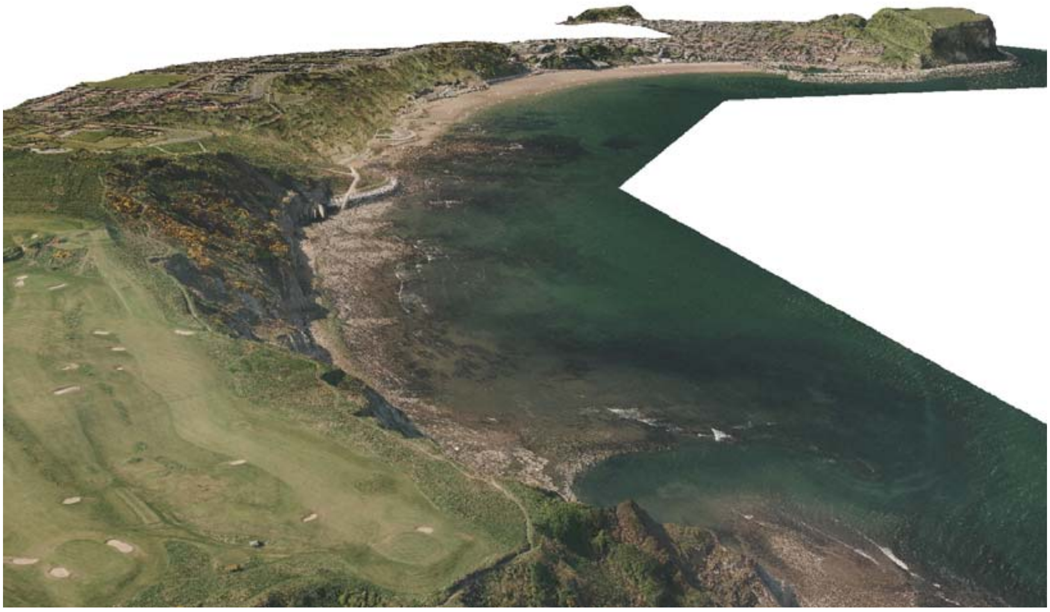

Figure 37 – Visualisation of White Nab and Wheatcroft Cliffs
(looking towards Holbeck)

6 CONCLUSIONS AND RECOMMENDATIONS

The physical presence of Scarborough Headland induces a clockwise circulated gyre effect within South Bay during typical tidal conditions that leads to progressive transport of beach sand northwards along the shore from the vicinity of the Spa. This sand ultimately becomes deposited towards the northern end of South Bay where it accumulates due to the sheltering effect provided to this section of frontage by the harbour arms and the headland itself. Wave-induced currents tend to accentuate this sediment transport pattern.

When sand builds to such an extent that upper beach levels become particularly high, it can lead to problems of local flooding due to waves ‘ramping’ across the beach face and overtopping the crest of the seawall. Additionally during times when upper beach levels are high, wind-blown sand can cause amenity problems and lead to blockage of the surface water drainage system so that when flooding does occur, the consequences are worsened due to less than optimal drainage.

Due to these problems, Scarborough Borough Council has, in the past, undertaken beach management activities, involving the excavation of beach sand from accreting areas in the north of South Bay and its recycling to areas with lower beach levels in the vicinity of the Spa Approach Road.

The sand build up is not confined to the inter-tidal foreshore, but also occurs at the mouth of the harbour in the form of a bar. In order to ensure continued safe navigation of vessels, the approach channel and parts of the Old Harbour are periodically dredged, with the arisings being deposited at the Scarborough Rock offshore disposal ground.

Whilst typical wave and tidal conditions tend to drive the northwards transport of beach sand along the foreshore, storm events tend to strip sand from much of the upper foreshore and transport it seawards, where it either becomes deposited on the sea bed or remains suspended in the water column and becomes transported southwards by residual tidal currents. This typically results in beach lowering at the toe of the seawalls during these storm events which can increase the likelihood of waves overtopping the defences and causing local flooding.

Given these findings, it is recommended that beach management activities should be continued in South Bay as and when monitoring data and visual observations identify that sand levels reduce the freeboard effect between the upper beach level and the crest of the Foreshore Road seawall to less than 1m.

Excavation of sand from this northern area of South Bay has the advantages of:

- Reducing flood risk to 78 properties by removing the potential for a wave ‘ramping’ effect (empirical experience has shown that a minimum freeboard of 1m between the upper beach level and the crest of the seawall is effective).
- Reducing the risk of wind-blown sand (which in turn would lead to blockage of the highway drainage system and increase flood risk).
- Reducing the volume of sand deposited on the bar offshore from Scarborough Harbour which could cause impediment to navigation of vessels (including the lifeboat) and which, in turn, reduces the potential for sand transport along the bar into the harbour where is becomes deposited and requires dredging from berths.

- Ensures continue safe functionality of the foreshore as an amenity beach

The recycling of excavated sand to enable its placement, spreading and grading in front of the Spa Approach Road has the advantage of temporarily improving beach levels in an area where beaches are both generally lower in level and more prone to erosion of material.

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