

# Ongoing Analysis and Interpretation of Coastal Monitoring Data

Seventh Review of Full Suite Monitoring

## Geotechnical Interpretative Report

August 2012

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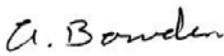
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## EXECUTIVE SUMMARY

In October 2008, Mouchel were instructed by Scarborough Borough Council (SBC) to provide services relating to an Analysis and Interpretation of Coastal Monitoring Data from sites (Runswick Bay, Whitby, Scalby Ness, Scarborough North and South Bay, Knipe Point, Killerby, Filey Town & Brigg and Filey Flat Cliffs) along the North Yorkshire coastline. Mouchel were required to review, analyse and interpret existing data, provided in electronic and hardcopy format, held by SBC for all the sites mentioned above. This data covered previous plans, monitoring records, strategies, ground investigations, borehole records, groundwater information, laboratory test data and geomorphological mapping.

The findings of this analysis and interpretation were presented in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL”, March 2009. This report presented an understanding of the problems at each site based upon the existing data, identified current and potential risks associated with ground movements at each specified site, a series of early warning signs and trigger levels which needed to be related to the findings of an Ongoing Monitoring regime, a series of appropriate response actions in relation to the findings of the above monitoring and recommended frequencies for the Ongoing Monitoring at each site related to the findings of the monitoring.

The ongoing analyses are to be undertaken in accordance with the recommendations of monitoring frequency detailed in Mouchel Report No. 721228/001/GR/01/02/FINAL. Site specific monitoring regimes have been planned to take place at intervals of one, two, three and six months beginning in July 2009. Table 2 details the frequency of Full and Restricted Suite monitoring to be carried out over the three year period until July 2012.

This report describes and details the findings of the **Seventh Full Suite** monitoring event undertaken, in late May and early June 2012, as part of the monitoring regime recommended in a previous report of March 2009. This monitoring event was accompanied by additional monitoring of replacement borehole instrumentation located at the sites of Scalby Ness, The Holms at Scarborough North Bay and Scarborough South Cliff which was completed in February 2011. The site of Robin Hood’s Bay was included into the Full Suite monitoring regime following instructions from SBC, in early 2011, to monitor this site on three occasions between June 2011 and June 2012.

Recommendations are included within the Conclusions section at the end of each chapter pertinent to that site. These recommendations are summarised below.

**Runswick Bay** – No additional measures recommended other than continue to observe and monitor the coastal slopes for additional slope failures and development of any existing failures.

**Whitby West Cliff** – No additional measures recommended other than continue to observe and monitor the coastal slopes for additional slope failures and development of any existing failures particularly west towards Sandsend.

**Scalby Ness** – No additional measures recommended other than continue to observe and monitor the coastal slopes for additional slope failures and development of any existing failures.

**Scarborough North Bay** – Piezometers in BH8 and BH9 to be flushed with clean water as they may be blocked with silt or other debris

**Scarborough South Cliff** – Increase the monitoring frequency interval of inclinometers BH 12, 13, 14 and 16A should the next monitoring event results display continued ground movements. A judgement on the monitoring frequency to be adopted should be made according to how much displacement is observed.

**Knipe Point** – The existing road pins and red & white bunting tape should be replaced with a more robust ‘barrier system’ with warning signs and, be moved inland a further metre from their current position and replaced with a more robust barrier with warning signs, along the cliff edge between survey pins H06 to H11.

**Filey Town** – Piezometer in BH04 to be flushed with clean water as this may be blocked with silt or other debris

**Filey Flat Cliffs** – No additional measures recommended other than continue to observe and monitor the coastal slopes for additional slope failures and development of any existing failures.

**Robin Hood’s Bay** - Monitoring frequency of inclinometer BH2 to be increased from six monthly intervals to three monthly intervals over a 12 month period and review monitoring frequency after each event.

At each monitoring event conducted by Mouchel, the depth of individual piezometer tubes has been recorded as well as depth to water to gain an indication of the instrument’s condition. In general, the dipped base depth of piezometers does not tally with the installed depths probably due to silt ingress. Therefore, the majority of the piezometers would benefit from being flushed / cleaned out to remove the build-up of silt which has accumulated at the base of each instrument since their initial instalment.

A summary of the observations made from the start of monitoring (July 2009) and, a comparison of observations made on the last Full monitoring event of June 2012 are presented below in Table 1.

**Table 1 Summary of Site Observations**

SITE	Observations made at the 7 <sup>th</sup> Monitoring Event (June 2012)*	Total observed movement since first Monitoring Event (July 2009)
<b>Runswick Bay</b>	Slopes indicated as stable. Groundwater levels variable across site in inclinometers.	5mm movement indicated in A001 between 22.0 and 20.0 metres depth and in A004 from 10.0m depth increasing to 15mm at 2.0m depth. Groundwater relatively static
<b>Whitby West Cliff</b>	Survey pins show a total of 3mm movement in the top one metre of ground. Inclinometer indicates local slopes are stable	Survey pins show -7mm movement in the top one metre of ground. Inclinometer indicates local slopes are stable
<b>Robin Hood's Bay</b>	Inclinometer BH2 shows further movement at 22m depth. Groundwater levels reduced.	<b>New instruction for June 2011</b>
<b>Scalby Ness</b>	No further cliff recession observed from survey pins. Slopes indicated as stable though movement noted at 12m BGL in BH7. Variable groundwater levels across site.	10mm cliff recession recorded at MP3 between July-August 2009, none at other three stations
<b>Oasis Café</b>	Slopes indicated as stable. Groundwater levels increased in boreholes above café.	Slopes stable, limited movement of <4mm indicated in BH1 and 3
<b>North Bay</b>	Unreliable groundwater results from BH8 & 9. Inclinometer indicates local slopes are stable.	Slopes stable as Oasis Café, no coverage of The Holms area
<b>South Cliff</b>	AA10 and 08 show slight ground movements at shallow depths. Movements at depth in BH12, 13, 14 & 16A. No ground movements indicated in remaining inclinometers. Generally variable groundwater levels except towards south of site where water levels are decreased.	AA04 shows 2mm movement in top 7.0m of ground AA07 and 08 no movement AA10 shows 4mm movement in top 3.50m of ground AA11 shows <3mm movement in top 3.0m of ground
<b>Knipe Point</b>	Five metres of cliff recession along Cornelian Headscarp, cessation of recession along A165 headscarp. And mudslide below pin H06. Knipe Point Headscarp remains active and heavily undercut in places. Groundwater low in BH1.	Recession rates slowing down from March 2010 at Cornelian and Knipe Point Headscarps and limited along A165 headscarp.*
<b>Filey Town</b>	Slopes indicated as stable around Glen Gardens above Royal Parade. Ground water levels variable across site.	Slight ground movement indicated in BH06 between 10.5 and 7.0 metres depth. Slopes indicated as stable, BH03 'lost' to vandalism
<b>Filey Flat Cliffs</b>	Slopes indicated as stable. Data not available from additional installed inclinometers. Decreased groundwater level in BH B1.	Slopes indicated as stable though very limited coverage of site

\* - Landslip along A165 in January 2010 is outside of monitoring area.

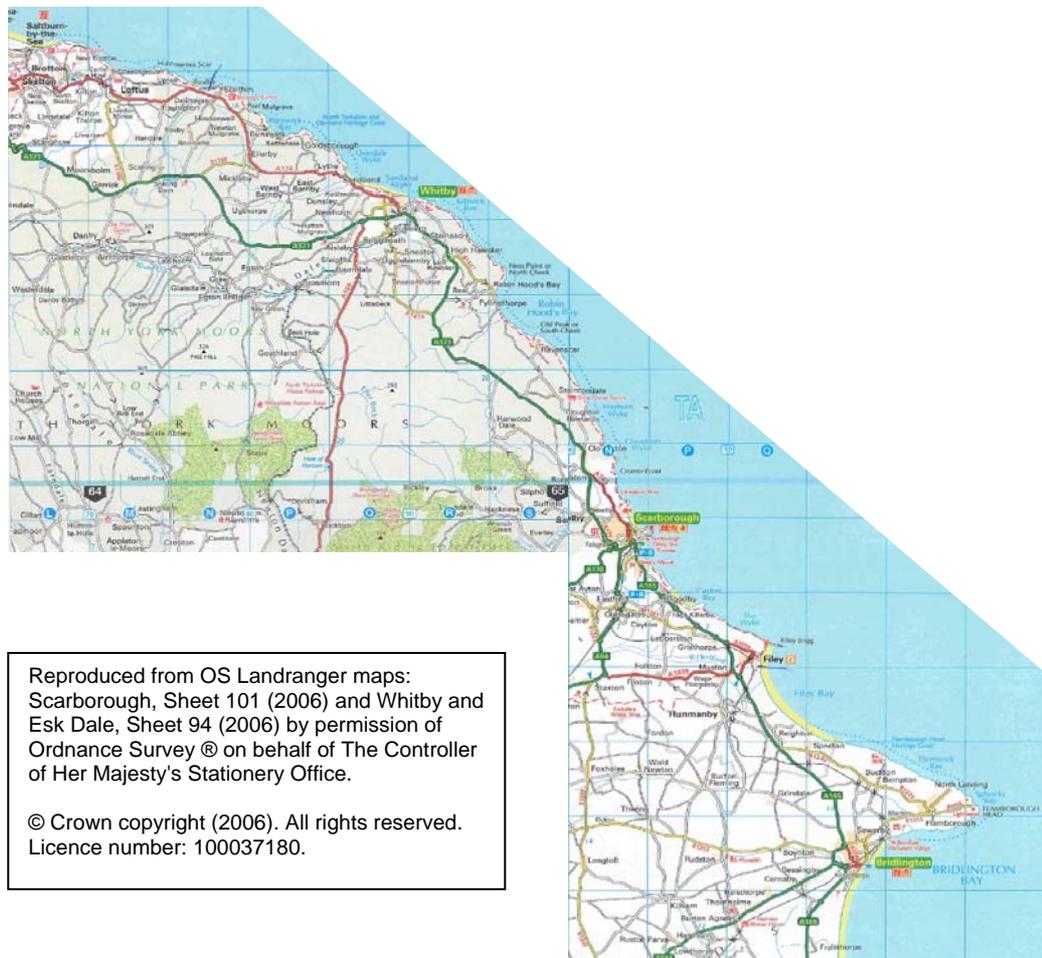


# 1 Introduction

## 1.1 Description of the Project

The extent of the potential monitoring area (Figure 1) considered for the ongoing analysis is along the full length of Scarborough Borough Council's coastline from Staithes to Speeton. Through the Shoreline Management Plan 2007 (SMP2) and the Coastal Strategy process, several sites within this area have been identified as experiencing ground movements and are either subject to an on-going monitoring regime or have been monitored in the past.

Figure 1 Scheme Location



The ongoing monitoring and analyses have been undertaken in accordance with the recommendations of monitoring frequency detailed in Mouchel's Report No. 721228/001/GR/01/02/FINAL. Site specific monitoring regimes were originally planned to take place at intervals of one, two, three and six months beginning in July 2009. As some of the monitoring events for particular sites coincide throughout the

three years period, they have been grouped together to be undertaken as 'Full' and 'Restricted' Suites. Table 2 details the frequency of Full and Restricted Suite monitoring to be undertaken over this period.

**Table 2 Frequency of Ongoing Monitoring**

YEAR	MONTH	SCOPE OF MONITORING
ONE (2009-10)	July (1)	Full Suite
	Aug, Sept, Oct, Nov (2,3,4,5)	Restricted Suite
	Dec (6)	Full Suite
	Feb, Apr (7, 8)	Restricted Suite
	June (9)	Full Suite
TWO (2010-11)	Dec (10)	Full Suite
	June (11)	Full Suite
THREE (2011-12)	Dec (12)	Full Suite
	June (13)	Full Suite

The sites and frequency of monitoring covered by the Full Suite of ongoing analysis are:

**Runswick Bay** - Six monthly intervals (Bi-annual) for three years.

**Whitby West Cliff** - Monthly intervals for six months then every two months until month twelve, reverting to bi-annual intervals for remaining two years if no significant movement detected. Install a single line of survey pins down slope at 5 metre intervals in line with BH2 and monitor these at monthly intervals for six months then reverting to bi-annual intervals for the remaining two and a half years if no significant movement detected.

**Scalby Ness** - Three monthly intervals for three years. Install 4 no. recession points along north west and north east facing crests and monitor every month following installation, in July 2009, for six months and bi-annually for the remaining two and a half years.

**Scarborough North Bay and Oasis Cafe** - Monthly intervals for six months then every two months until month twelve. Revert to bi-annual intervals for the remaining two years if no significant movement detected.

**Scarborough South Cliff** - Monthly intervals for six months then every two months until month twelve. Revert to bi-annual intervals for the remaining two years if no significant movement detected. Install a line of survey pins down slope at 5 metre intervals in line with boreholes E3, BH2 and H4 and monitor together with other instrumentation at this site.

**Filey Town and Brigg** - Monthly intervals for six months then every two months until month twelve. Revert to bi-annual intervals for the remaining two years if no significant movement detected.

**Filey Flat Cliffs** - Monthly intervals for six months and then every two months until month twelve. Revert to bi-annual intervals for the remaining two years if no significant movement detected.

Following a period of heavy rainfall experienced in December 2009, recommendations were made to SBC to undertake additional 'Full Suite' monitoring events in order to comply with recommendations of monitoring frequency previously stated (Mouchel Report No. 721228/001/GR/01/02/FINAL). This additional monitoring was carried out (after receiving instructions from SBC) in January and February 2010. Reports detailing the findings of the First and Second Additional Suite monitoring events were published in February and April 2010, respectively.

In addition to the monitoring frequency undertaken at the sites stated above, monitoring at Runswick Bay was increased to monthly intervals from February 2010 extending through to July 2010 due to suspected ground movements observed within inclinometers A001 and A004 in December 2009.

SBC initially instructed Mouchel that the site at Knipe Point and recession point sites as well as the site at Killerby were to be removed from our remit until further notice and were not originally under consideration for analysis at the time of writing this report. However, the coastal site of Knipe Point was re-introduced into the coastal monitoring regime as a new instruction, issued by SBC, beginning in March 2010 and extending until December 2012. No further instructions have been received from SBC to monitor other recession sites along the coast.

Mouchel Report "*Feasibility Study into the Replacement of Damaged Monitoring Equipment*" 721229/017/GIR/002/FINAL issued in October 2009 detailed recommendations to replace damaged inclinometers and piezometers previously installed at strategic sites along the North East coast. Scarborough Borough Council followed these recommendations and instructed a third party to undertake the installation of the majority of these instruments. The instruments were installed at the sites of Scalby Ness, The Holms at Scarborough and Scarborough South Cliffs during late 2010. Mouchel were subsequently instructed to monitor these replacement instruments in early February 2011 and to incorporate this data into the Full Suite Report for January 2011. The results of this monitoring event and borehole location plans are presented within the relevant Appendices of this report.

The site of Robin Hood's Bay was included into this monitoring regime following instructions from SBC, in early 2011, to monitor this site on three occasions between June 2011 and June 2012.

Site location plans are presented as Figures 2 to 10 within the relevant chapters for each site. Exploratory hole location plans illustrating the locations of the original instrumentation (automated piezometers, piezometers / slip indicators and inclinometer installations) are presented in Appendix A and the replacement installations in Appendix B.

Following each monitoring event, the Arcview GIS layer, showing AGS data in a layered format, is up-dated with the information (inclinometer and piezometer readings and survey data) retrieved from each of these events.

## 1.2 Installation Monitoring Procedures

### 1.2.1 Survey Marker Points

At Knipe Point taped measurements and observations are made from survey marker points at regular intervals; measurements are taken from a back pin to a particular feature i.e. a cliff edge. At Whitby West Cliff, Scalby Ness and Scarborough South Cliff surveying of recession points is carried out, in line with scheduled site monitoring, with monitor point co-ordinates derived directly from Global Positioning System (GPS) observations and slope distances are calculated from separate Total Positioning Station (TPS) observations. A comparison of the data can provide rates of cliff recession at different times over the year and comparing these rates with recorded rainfall a relationship can possibly be established between the two.

### 1.2.2 Inclinometers, Piezometers and Slip Indicators

Inclinometer installations are read using a Vertical Digital Inclinometer probe (Bluetooth system (MkII) with a TDS Recon 200 PDA). This is lowered to the base of the tubing, allowing the probe to temperature stabilise, measurements are recorded at half metre intervals as the probe is raised up the tubing and readings of inclination are recorded in two directions (A0 and A180) within the inclinometer tube; A0 being the principal direction of interest in ground movements (normally in a downslope direction) and A180 is in the opposite direction to this. B0 and B180 readings are also recorded automatically, B0 represents +90 degrees to the A0 direction and B180 is +90 degrees to A180 direction.

Groundwater levels within piezometers have been recorded using a dip meter. A comparison of the known installed instrument depth with the dipped depth gives an indication as to whether the tubing is clear to its base or is blocked / impeded at that recorded depth.

Where slip indicators are present, they consist of a one metre length mandrel that is attached to a chord at ground level resting at the base of piezometer tubes. Each mandrel is lifted from the base to the top of the tube to indicate if any distortion or blockages have occurred within the tubing. Where a mandrel is found to be jammed within a tube, a reading is taken from ground level to the top of the mandrel to give an indication of the depth at which possible failure of the ground has taken place. A second mandrel is then lowered down the tube until it can proceed no further. This distance is measured from ground level and the depths give an indication of the region of ground movements. Where this has occurred, the installation ceases to be of use since it has served its purpose in demonstrating failure or movement of the ground. Other installations continue to be read if the inserted mandrels function free of any obstacles. Hence, fully functioning instruments continue to demonstrate that no discernible ground movements are occurring.

## 1.3 Interpretation Views

### 1.3.1 *Cumulative displacement*

The most commonly used plot type is the Cumulative Displacement plot, which shows a displacement profile down a borehole. The plot shows the change in the position of the casing since the initial set of readings. If a user error has occurred during reading, the error will be accumulated through successive readings. If this is suspected, or anomalies occur, the data can be examined using the Incremental Displacement function.

### 1.3.2 *Incremental Displacement*

Another form of data presentation is the Incremental Displacement plot. This shows displacement over each probe length during the period since the initial reading sets.

Unlike the Cumulative Displacement plot, operator error or instrument malfunction do not accumulate, as the data are compared to the 'base line' reading.

### 1.3.3 *Absolute Position*

This type of plot shows the absolute position of the casing and will determine the verticality of the installation. It does not pick up movement, but can be used for assessing installation error.

## 1.4 Rainfall Data

Under the Framework agreement, rainfall data records have been made available to Mouchel by SBC and the Environment Agency as part of the Framework Agreement. Data supplied is referenced to stations throughout the region in particular at Loftus,

Fylingdales, Whitby School, Scarborough, Mulgrave Castle, Ruswarp and Knipe Point. Within Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data*" 721228/001/GR/01/02/FINAL, reference was made to 'periods of heavy and / or prolonged rainfall' in terms of considering such an event with respect to their possible effects upon slope stability.

The definition of heavy and / or prolonged rainfall has been developed through the analysis of rainfall data records made available by the EA and SBC. Unfortunately it was not possible to determine how much rainfall would trigger a landslide event. Instead a quantity of rainfall was determined that would be likely to produce a significant rise in groundwater levels that might trigger a landslide. A definition of heavy / prolonged rainfall events was investigated in terms of determining statistically derived values of daily rainfall each month for the period 1995/8 to 2008/9. To this end the 75<sup>th</sup> percentile was calculated as a determining threshold value. A rainfall value, for a specific day, at the 75<sup>th</sup> percentile would be equal to or greater than 75 percent of the daily rainfall values recorded on that day of the year during all years that measurements have been recorded.

In the event that the 75<sup>th</sup> percentile of daily rainfall values (a period of heavy / prolonged rainfall) are exceeded, it was recommended to carry out monitoring one week after the end of the rainfall event and at monthly intervals thereafter for three months. Further to the heavy rainfall experienced in December 2009, these recommendations were followed by SBC who instructed Mouchel to undertake additional monitoring at selected locations along the coast in order to comply with monitoring recommendations.

## 2 Runswick Bay

### 2.1 Site Location and Description

Runswick Bay is situated on the north east coast of England some 16 km north west of Whitby town at NGR NZ 800 160. It is formed between the headlands of Caldron Cliff to the north and Kettleness to the south and comprises a deeply indented sandy bay approximately 2 km in length. The bay is backed mostly by cliffs and steep glacial till coastal slopes. The village of Runswick Bay is developed within the general valley formed by the Runswick and Nettle Dale Becks. The village straddles the boundary between the glacial till slopes which occupy most of the bay and the Jurassic shale and sandstone cliffs to the north. Most of the village is founded on weathered shale but properties near the southern edge and the access road (Runswick Bank) and car parks are founded on glacial till landslide debris. The village is fronted by four separate sea defences, of varying age and construction, which stretch from Runswick Beck north of Caldron Cliff around to Nettle Dale Beck to the south.

Figure 2 Site Location - Runswick Bay



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### 2.1.1 *Historic Review of Problems*

Runswick Bay has a long history of slope instability, the first recorded slope failures occurred in 1682 when the whole village, located further north than at present, collapsed towards the shore. Successive landslips of varying severity occurred in 1873, 1953 and, in 1958 when the old road was closed twice in one week due to landslides. This road was abandoned in 1961 with the construction of a new access road constructed further to the west between 1961 and 1963, on its present alignment. Around the same time a sea wall extension and new car park were constructed at the base of this road. Landslips and rock falls were experienced immediately north of the village during the 1970's, including a landslip at Rose Cottage in 1975, resulting in the loss of various, limited assets.

A mass concrete sea-wall constructed in 1970 provided coastal protection to the southern edge of the village, access road and car park areas. Since its' construction, the sea-wall was subjected to a combination of marine and land based erosional mechanisms causing the wall to move in a seaward direction with backwards rotational tilting. Sea-wall deterioration and failure has been caused by earth pressure loading from slope failures behind the wall, beach erosion exposing the toe of the wall and wall toe failure of the fractured and folded shale bedrock.

Three areas of slope instability have been identified within Runswick Bay which have influenced the failure of the previous sea-wall and other sea defences and are still having an effect. These areas are identified in Figure 2 and are described as being:

- Upgarth Hill – The Upper Lias shales and sandstones of the Saltwick Formation forming the cliffs below Upgarth Hill are covered by a thin mantle of glacial clay. Intact cliffs stand at angles of 50 to 70 degrees whereas previous failures have led to slopes of talus debris standing at 20 to 30 degrees with light vegetation cover. The toe of the east facing slopes are protected by a concrete sea-wall and the toe of the south facing slopes are continually being undercut by Runswick Beck which forms an incised valley with over steepened sides to the north east of Runswick village.
- Topman End – is located immediately north of the village, with heavily vegetated, glacial slopes characterised by a network of scarps and transverse tension cracks behind small superficial failures. Slope angles vary between 30 and 40 degrees, decreasing to 5 to 10 degrees mid-slope. These superficial failures are caused by the entrapment of excessive ground water.

- Ings End – this area extends from south of Nettledale Beck to Limekiln Beck a distance of approximately 500 metres over an area known as Dother Pits. Sub-vertical headscarps, formed in glacial tills, are present below the cliff tops between the two becks. Below this scarp are a series of undulating slopes formed by the retrogressive failure of deep seated basal shear planes along the shale bedrock. The slopes can be divided into three distinct zones characterised by uneven ground, ponding water, irregular springs and streams and dense vegetation. Slope angles vary between 15 and 20 degrees with the crests of individual landslide blocks well defined by breaks of slope at lesser angles of between 5 and 10 degrees. Subsequent failures have been triggered by the destabilising effect of an initial failure caused by undercutting of the leading block by progressive coastal erosion. The back scarp areas of the landslip complex has been found to contain saturated sand layers and lenses which are thought to be supplied by a sandstone aquifer (Saltwick Formation) present further inland. Groundwater seepages have been experienced, during ground investigations, from the basal backscarp areas and from within disturbed shales immediately below the glacial tills some distance from the slope toe.

Due to the ground movements detailed, it became evident by 1998 that the sea-wall was in danger of imminent collapse which would have lead to large scale landslip failures and loss of amenities in the village. Accelerated movements of the sea-wall, particularly at the southern end, eventually lead to the structure being replaced by a rock armoured revetment and an intermediate compressible buffer zone.

### 2.1.2 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL, pp9-10. Additional reports were provided by SBC for further consultation by Mouchel for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 2.2 Stratigraphy

The published geological map of the area 1:50,000 British Geological Survey (BGS) Sheet 34 Solid and Drift Guisborough indicate the site is underlain by superficial deposits of glacial till (Boulder Clay). These comprise stiff silty sandy clays, sands and gravels and laminated stiff silty clays. The solid succession of the area is indicated as Middle Jurassic sandstones (Saltwick Formation) and ironstones (Dogger Formation) (rocks of the high cliff headland north of the village) which lie unconformably on Lower Jurassic shales (Whitby Mudstone Formation). The shales are exposed as a wave cut platform, dipping at 2° in a southerly direction, at the front of the cliffs along the north of the bay. The map indicates a north-south trending

fault passing beneath the village and across the upper beach area to the south, with down throw and inclination to the west.

## 2.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Non-Aquifer because of the soil and rocks negligible permeability. These formations are generally regarded as containing insignificant quantities of groundwater. However, groundwater flow through such soils, although imperceptible, does take place and needs to be considered in assessing the risk associated. Some Non-Aquifers can yield water in sufficient quantities for domestic use. Major and Minor Aquifers may occur beneath Non-Aquifers.

## 2.4 Instrumentation

### 2.4.1 *Definition of Existing Problems*

Since the failure mechanisms affecting the old sea-wall and car parks were identified during the late 1990's, remedial works were instigated and completed in 2001.

The reduction in the rate of displacement of the land-slipping is evidence that the permanent works which comprised of drainage, piling and earthworks, undertaken on the slopes to the north of and at the toe of the slopes below Ings End, have had a positive effect upon slope stability. The greater significance has been the re-orientation of the vector angle of slope movement in a clockwise direction from northeast, in a more easterly direction. It is envisaged that following prolonged periods of heavy rainfall, the slopes will probably continue to fail. However, the probability and risk to village infrastructure of deep seated failures occurring in the future is considered low, as a result of the stabilising effects of the piling and earthworks.

## 2.5 Monitoring Regime

### 2.5.1 *Recommended Monitoring Regime*

As a consequence of the analysis and interpretation of monitoring data and reports made available by SBC, a regime of future monitoring was formulated. These recommendations have been reported in Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data*" 721228/001/GR/01/02/FINAL.

The recommendations for Runswick Bay were that a regime of regular monitoring and inspection be undertaken at six monthly intervals (bi-annually). This should be carried out over a period of three years to retrieve long term data for analysis in order to determine any seasonal patterns of rainfall, ground water levels and ground movements. The monitoring encompasses recording readings of inclination in two directions (A0 and A180) within the inclinometer tubes and also measuring groundwater levels.

### 2.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 2.5.1, above. Following on from the findings of the *Condition Survey Report*, the monitoring regime consists of existing inclinometers (A001, A002, A003 and A004) located along the edge of the main access road leading down into Runswick village (See Appendix A, Drawing 1). Groundwater was measured in the inclinometer tubes with a dip meter.

### 2.5.3 Ongoing Monitoring Results

#### *Inclinometer Readings*

Monitoring of inclinometers has been undertaken in accordance with the procedures detailed in Section 1.2 of this report. Incremental readings of June 2012 indicate that no ground movements have occurred within inclinometers installed in boreholes A001, A003 and A004. Data recorded in June 2011 from A002 would indicate that 10 mm ground movement has occurred between 17.0 metres and ground level. However, the readings are most likely to be due to an erroneous reading rather than actual movements of the ground. Data recorded in December 2010 seemed to indicate ground movements in A001 although this was due to a discrepancy in the readings recorded from 22.0 to 20.0 metres depth. The erroneous readings were attributed to dirt within the tube tracks and subsequent readings have confirmed this by indicating no further development of suspected movements.

Inclinometer readings are presented in Appendix C of this report.

#### *Groundwater Readings*

Groundwater levels at this site have been recorded from 16<sup>th</sup> June 2009 up to the present. A comparison of the groundwater readings of December 2011 and June 2012 shows decreases of 30 mm and 3290 mm in A001 and, A002 and increases of 50 mm and 90 mm in A003 and A004 respectively over this period. Groundwater readings are presented in Appendix E.

## 2.6 Conclusions

Inclinometer instrumentation installed within selected piles of a portal frame shear key system was constructed as part of remedial works to restrict ground movements within the Runswick Bay area. Inclinometers were installed in piles in order to indicate shear stresses within them caused by ground movements. Within Report No. 136 (from SBC) reference has been made to the determination of the piles' response to loading between successive inclinometer readings. It has not been stated how this was to be done or how it was to be achieved. To date, Mouchel Ltd have been made aware by the Client that this information is not available and therefore no further comment can be made relating to this. Hence, initial and successive inclinometer readings are only related to any general ground movements indicated by instrument readings.

The results from monitoring the inclinometers have so far shown that no ground movements have taken place within the vicinity of these instruments. Movements previously interpreted from data recorded within the inclinometers have now been attributed to erroneous readings. As the data bank from the inclinometers has increased, more information has been available to analyse and refine the on-going interpretation. The inclinometer graphs have, in the majority, plotted an identical path of inclination and indicate a steady state with no ground movements apparent.

A comparison of current groundwater levels with those of December 2011 do not indicate any definite relationship with increased rainfall experienced in the region of Runswick Bay up to June 2012.

## 3 Whitby West Cliff

### 3.1 Site Location and Description

Whitby is located on the north east coast of England approximately 30 miles south of the industrial town of Middlesbrough and 20 miles north of Scarborough. West Cliff is part of a long stretch of exposed cliffs running west-east forming soft, glacial till cliffs to the west of Whitby harbour, see Figure 3. The West Cliff site is bounded by The Spa complex to the east and the Cliff Lift towards the west.

The natural slope morphology of the protected cliffs has been modified by several phases of slope stabilisation works which included drainage and slope re-profiling that has been undertaken since the 1960's. The slopes attain a height of up to 40-45 metres at slope angles of 25 to 35 degrees. Set back approximately 10 metres from the crest of the slopes is a main road (North Terrace) and beyond this are large terraced, residential and commercial properties. The faces of the slopes are criss-crossed by pedestrian footpaths which give public access from the top of the cliffs to the beach below. Other features present over the slopes are low retaining walls, gabion walls and relict slip failure scars. At the base of the slopes is a sea wall with a promenade, forming a sea defence, with a wide sandy beach foreshore.

Figure 3 Site Location – Whitby West Cliff



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### 3.1.1 *Historic Review of Problems*

There is evidence of small scale failures along much of the coastal section being investigated, both in the past and at present. The first sections of coastal defences along this stretch of coast were constructed in the 1930's. These defences comprised vertical concrete and masonry seawalls with a promenade, slipways and access ramps to the beach, possibly founded on glacial till materials. Slope stabilisation measures involving slope re-profiling, placement of gabion baskets and drainage improvements have been undertaken over the coastal slopes of West Cliff in an attempt to reduce the probability of slope instability occurrences since the late 1960's.

### 3.1.2 *Existing Information*

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data*" 721228/001/GR/01/02/FINAL, pp33-34. Additional reports were presented by SBC for further consultation for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 3.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheet 35 Solid & Drift, Whitby, indicates the site to be underlain by glacial till of Devensian (Quaternary) age. The glacial till is typically comprised of over-consolidated, red-brown sandy silty clays with lenses and discontinuous beds of sands and sandy silts. Within the protected cliffs along West Cliff, there is a persistent mid-slope exposure of fluvio-glacial sand and gravels up to 5 metres in thickness. The underlying solid geology is indicated as the Middle Jurassic Scalby Formation, consisting of limestone, sandstone and mudstone.

## 3.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Minor Aquifer, overlain by soils of Intermediate Class 1. Minor Aquifers are variably permeable rocks, usually fractured rocks with a low primary permeability or unconsolidated deposits. They rarely produce large quantities of water for abstraction but often provide important base flow supplies to rivers. Major Aquifers may occur beneath Minor Aquifers.

## 3.4 Instrumentation

### 3.4.1 Definition of Existing Problems

The West Cliff area has been modified by slope stabilisation measures which included the re-grading of slopes and the installation of drainage, carried out during the 1960's and 1970's. These remedial works are now showing signs of distress and appear to be near the end of their design life. During a site walkover there was evidence of slope instability with visible back scars on the slopes and cracks present in the footpaths; drainage problems were also evident as seepages emanating from retaining walls. However, it is not known whether the seepages were from slope drainage or burst water pipes.

The existing problems on site relate to the instability of the glacial till slopes of West Cliff site which have been the subject of modifications by remedial works over a period of seventy years. The slopes are susceptible to shallow failures of varying size and extent, being 1 to 2 metres in depth and up to 5 metres in extent. Their size has often been determined by the spacing of vertical drainage trenches. Without remedial measures, small and medium sized slope failures can develop into more serious deep-seated failures which may cause substantial damage and cliff top recession leading to the loss of amenities and possible danger to the public.

## 3.5 Monitoring Regime

### 3.5.1 Recommended Monitoring Regime

As a consequence of the analysis and interpretation of monitoring data and reports made available by SBC, a regime of future monitoring was formulated. These recommendations have been reported in Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data*" 721228/001/GR/01/02/FINAL.

The recommendations for Whitby West Cliff were that a regime of regular monitoring and inspection should be undertaken at monthly intervals for six months then reverting to bi-annual intervals for the remaining two and a half years if no significant movement was detected.

A line of survey pins was installed in July 2009 at 5 metre intervals down the line of the coastal slope from beyond the crest and in line with the existing inclinometer (BH2) near the base of the slope (See Appendix A, Drawing 2). The survey stations were measured at a monthly frequency from July to December 2009 for six months to build up base data. As there was no significant movement (>5 mm) between each survey point, (between each monthly monitoring event), the monitoring frequency was reduced to that in line with the inclinometer monitoring i.e. on a bi-annual frequency, beginning June 2010 onwards, for the remaining period of monitoring.

### 3.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 3.5.1, above. Following on from the findings of the *Condition Survey Report*, monitoring consists of a single inclinometer (B001 / BH2) located within a path near the base of the coastal slope of West Cliff and the monitoring of surveying points. Groundwater in the inclinometer tube was measured with a dip meter.

### 3.5.3 Ongoing Monitoring Results

#### *Inclinometer Readings*

Monitoring of the inclinometer has been undertaken in accordance with the procedures detailed in Section 1.2 of this report and data is presented in Appendix C. Readings have so far shown that little or no ground movements have occurred within the slopes around BH2 at West Cliff.

#### *Groundwater Readings*

Groundwater levels were recorded during the Condition Survey (16<sup>th</sup> June 2009) and the initial set of Ongoing monitoring readings (9<sup>th</sup> July 2009). From an initial reading of 6.05 metres consecutive readings recorded successive rises in water levels up to January 2010. An increase in depth to groundwater was recorded in March 2010 followed by subsequent decreases leading up to a reading of 6.02 m for June 2010 and a further increase of 3.04 m to 9.06 m in December 2010. The last two readings of June and December 2011 recorded decreases in groundwater level of 710 mm and 1320 mm, the last reading (June 2012) indicated a rise of 1.41 m to a current depth of 8.44 m. Given that the tidal position is known and observed at the time readings are taken, this data can be interpreted as reflecting the changes in tidal levels at the time of monitoring rather than the groundwater regime in the slopes. Groundwater readings are presented in Appendix E.

#### *Survey Point Readings*

A single line of 6 No. survey pins were set out from the crest extending down slope to borehole BH2 in order to supplement the monitoring of any slope movements at these locations. The pins have been surveyed between July 2009 and June 2012 and showed that over a distance of 49 metres, +3 mm of surface movement has occurred during this period. The latest readings of June 2012 also indicated that up to -3 mm of movement has occurred since December 2011. Readings from the survey points are presented in Appendix G.

### 3.6 Conclusions

Monitoring data from the inclinometer in BH2 has so far shown no discernible ground movements of the slopes at West Cliff. A slight deviation was evident in the second set of inclinometer readings and subsequently interpreted as being attributed to the use of a different probe for the recording of readings rather than an indication of ground movements. Successive readings from October, November and December 2009 confirmed this to be the case as these plots followed the first set of readings and indicate that no ground movements had occurred. The inclinometer data, recorded up to June 2012, currently indicate the slopes within the vicinity of BH2 to be in a stable state.

Groundwater levels within BH2 are influenced by and reflect the changing tidal regime. Successive results would seem to confirm this as the tidal condition is known and observed at the time readings are recorded.

Previous inclinometer data (22 March 2001 to 28 November 2005) illustrated the occurrence of surface creep taking place within the top metre of ground. Although current inclinometer readings do not show this type of movement, ground movements of up to +13 mm, in a down slope direction, were recorded from survey pins within the surface of the slopes between October and November 2009. During the previous period, from September to October, a difference of +11 mm was recorded illustrating that there is some differential fluctuation in ground movements. The total recorded ground movement over the slope distance monitored is **+3 mm**, measured between July 2009 and June 2012. The variations in spacing between the survey pegs can most likely be attributed to seasonal temperature fluctuations and the resulting discrepancies in the survey data rather than actual ground movements.

Due to the limited coverage of the site offered by the single inclinometer, there is the possibility of undetected ground movements occurring elsewhere within the site. Such occurrences have been identified as shallow slip failures observed to the west of this area, towards Sandsend. These slope failures have been reported to and have been recorded by SBC who are apparently observing and monitoring these features independently of Mouchel.



## 4 Scalby Ness

### 4.1 Site Location and Description

Scalby Ness forms a broad promontory to the north of Scarborough North Bay, approximately 3 km north of Scarborough. The headland is incised by Scalby Beck which acts as an overflow from the River Derwent when in flood. The beck flows in an east-north easterly direction through Scalby, where at Scalby Mills it changes direction sharply through 90 degrees to flow south easterly at Scalby Ness and outfalls to the sea between Scalby Ness headland and the Sea Life Centre (See Figure 4).

A housing development was constructed during the 1970's and 1980's on land forming a plateau approximately 25-30 m above the beck at Scalby Ness. Over-steepened glacial till cliffs are present, on the north west and north east sides of the development, falling down towards the beck. The beck contributes to toe erosion of these slopes and is a contributing factor of the mechanism of slope instability. Scalby Mills Road bounds the southern edge of the north east slopes. This road was constructed to give access to the Sea Life Centre on the coast. Part of the works involved re-profiling slopes with toe protection offered by rock outcrops at Scalby Beck and emplaced toe protection around the Sea Life Centre.

Figure 4 Site Location – Scalby Ness



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#### 4.1.1 Historic Review of Problems

A review of the available data detailed in Section 5.1.4 covers previous ground investigations and interpretative report work on the site of Scalby Ness. An interpretation of the over-riding mechanisms acting upon the slopes has identified three landslide behavioural units.

- Behavioural Unit I (North west slopes) – Intermittently active non-circular failure within the glacial till unit, characterised by over-steepened slopes which have been subjected to shallow translational movements accompanied by localised mudslide / debris flows. The head scarp (crest) is undergoing periodic movement giving rise to blocky detachment with cracks forming in mid-slope. Active erosion at the toe is leading to unloading of the slope with a reduction of support for the material above.
- Behavioural Unit II (North east slopes, northern part) – This is an episodically active unit characterised by an over-steep head scarp with cracking and shallow surface movements. A mid-slope deep seated, back-tilted block is present across the unit. The location and morphology of this block suggest that it is part of a large, ancient deep-seated translational or rotational landslide. Localised active toe unloading is present within parts of the lower slopes which are also characterised by ponding surface water, tension cracks and hummocky ground. Active toe erosion is taking place by the tidally influenced beach.
- Behavioural Unit III (North east slopes, southern part) – The slopes have been re-profiled during earthworks as part of construction works for the access road into the Sea Life Centre and car park. These slopes show no signs of instability and are currently considered to be stable.

#### 4.1.2 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL, p50. Additional reports were presented by SBC for further consultation for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 4.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheets 35 and 44 Solid & Drift, Whitby and Scalby, indicates that the site is underlain by superficial deposits of glacial till of Quaternary age. The underlying solid geology is indicated as the Long Nab Member of the Scalby Formation (Middle Jurassic) characterised by interbedded mudstones, siltstones and sandstones.

## 4.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the northern area of Scalby Ness as a Minor Aquifer, overlain by soils of low leaching potential. Soils of class L are those in which water movement is largely horizontal.

Minor Aquifers are variably permeable rocks, usually fractured rocks with a low primary permeability or unconsolidated deposits. They rarely produce large quantities of water for abstraction but often provide important base flow supplies to rivers. Major Aquifers may occur beneath Minor Aquifers.

The southern part of Scalby Ness is classified as a Minor Aquifer, overlain by class HU soils. Due to the less reliable nature of data collected in urban areas, the worst case scenario is assumed and soils are classified as having a high leaching potential.

## 4.4 Instrumentation

### 4.4.1 *Definition of Existing Problems*

It has been known that there is a risk of slope failure on the north west and north east slopes (in Behavioural Unit I and II) of Scalby Ness if groundwater levels were to rise significantly particularly following periods of prolonged / heavy rainfall. The presence of more permeable layers of sand and gravel within the glacial tills could lead to localised failures and the possibility of this could be increased if these layers are prevented from draining freely due to slipped soils from above.

The main threat to slope stability and the assets located above comes from tidal erosion of the river banks at the toe of the slopes and, to a lesser degree from crest erosion caused by surface water flowing down the slopes.

Behavioural Unit III is considered to be in a stable state since undergoing re-profiling and re-grading works as part of earthworks for the access road to the Sea Life Centre to the south of this site.

## 4.5 Monitoring Regime

### 4.5.1 Recommended Monitoring Regime

As a consequence of the analysis and interpretation of monitoring data and reports made available by SBC, a regime of future monitoring was formulated. These recommendations have been reported in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL.

The recommendations for Scalby Ness were that a regime of regular monitoring and inspection be undertaken at three monthly intervals. Monitoring is to be carried out over a period of three years to retrieve long term data for analysis in order to determine any seasonal patterns of rainfall, ground water levels and ground movements. In addition to this, survey pins set out at four locations on the upper plateau area are to be monitored at monthly intervals for six months and then bi-annually for the remaining two and a half years.

### 4.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 4.5.1, above. Following on from the findings of the *Condition Survey Report*, monitoring at Scalby consists of 3 no. inclinometers (I1, I2 and I3), 4 no. automated piezometers (P1, P2, P3 and P4) and 4 no. piezometers (B6, B9, Sn1 and Sn2 a & b) located within the inner headland of Scalby Ness (See Appendix A, Drawing No. 3). Monitoring of installations BH114, Sn4, B1, B2, B3, B10 and B11 has not been undertaken as they were proven to be broken / damaged at some depth below ground level. This regime was enhanced with the inclusion of the replacement monitoring equipment, monitored from February 2011 onwards, which was installed at this site in late 2010. The additional installations consist of 6 no. driven piezometers (WS1 to WS6) and an inclinometer (BH7). Monitoring data is presented within the relevant sections of this chapter and the Appendices to this report.

### 4.5.3 Ongoing Monitoring Results

#### *Inclinometer Readings*

Monitoring of inclinometers has been undertaken in accordance with the procedures detailed in Section 1.2 of this report and data is presented in Appendix C and D of this report. Readings from the three original inclinometers have so far illustrated that little, if any, ground movements have occurred since baseline readings were taken on 16<sup>th</sup> July 2009.

The replacement inclinometer graph for BH7 consists of seventeen readings recorded by the contractor during site works from 8<sup>th</sup> September to 22<sup>nd</sup> October 2010 and separately, a baseline reading recorded by Mouchel on 4<sup>th</sup> February 2011 and follow-up readings in June, 2011, December 2011 and June 2012.

### *Groundwater Readings*

Groundwater levels have been recorded since the Initial Full Suite Survey (16<sup>th</sup> July 2009) up to June 2012. Generally, piezometers have reflected decreases in ground water across Behavioural Unit I of the site ranging from a minimum of 1 mm (WS1) to a maximum 32 mm (WS3). Elsewhere across the site, Behavioural Unit II, elevated groundwater levels have been recorded at levels of between 49 mm (WS6) and 1950 mm (WS5). However, none of the piezometers are located close to or at a depth relative to the inclinometer in BH7 to illustrate any increase (or otherwise) in pore water pressures around the slip plane (at 12.0 m BGL) within this instrument. Groundwater levels recorded within inclinometer tubes all indicated decreases of between 310 mm (I1) and 880 mm (I3) compared to previous readings taken in December 2011.

Piezometric data has also been downloaded from data loggers operating in P1, P2A, P3 and P4 and made available by SBC. Groundwater level details have been recorded by the instruments at six hourly intervals from the date of installation 29<sup>th</sup> June 2004 to 5<sup>th</sup> November 2009 and from 3<sup>rd</sup> February and 16<sup>th</sup> March 2010 to December 2011. Gaps in the data record have been the result of data logger malfunction and servicing when the loggers were out of commission. Within the upper piezometers, groundwater levels are affected by rainfall. At various times over the monitoring period, peaks in groundwater levels have been experienced. An analysis of rainfall data indicates that peaks in groundwater levels have been the result of periods of increased precipitation. This phenomenon is illustrated in graphical data from BH P4 where the peaks and troughs of groundwater levels are more pronounced than in the other graphs. The piezometers, within this borehole, have been installed at shallower depths than the other instruments and are therefore more sensitive and responsive to groundwater fluctuations.

Groundwater levels within the lower piezometer of P1 (P2 and P3 also), installed to target a lower water table; have remained reasonably constant at a level of approximately 17.20 mBGL over the monitoring period. A similar situation can be seen within P2 and P3 where the lower piezometers have regularly recorded groundwater levels at approximately 33.50 mBGL and 16.10 mBGL, respectively within separate, unconnected water tables. Since servicing and re-calibration of data loggers in November 2009, readings from these instruments have changed slightly due to differences in ground water levels when the loggers were initialised and re-initialised. P1 is slightly decreased, P2 increased by a metre, P3 increased by almost three metres and P4 decreased by 700 mm, as can be seen from the relevant graphs for each instrument; although the data follows a similar pattern to that previously described. Groundwater readings are presented in Appendix E and F.

### *Survey Point Readings*

Survey pins were set out at four locations on the upper plateau area around the existing houses, some distance from the slope crest. Measurements are taken, in the same direction at each event, from these points to the slope edge in order to monitor cliff recession rates and slope movements at these locations. Survey data readings show the slopes at this site are currently stable and are presented in Appendix G.

## **4.6 Conclusions**

The survey pins were measured at monthly intervals from July to December 2009 and at six monthly intervals from June 2011 onwards. A comparison of the measurements taken from stations (MP1, MP2, MP3 and MP4) showed that zero cliff recession rates had occurred during the period August to November 2009. At recession point MP3 it was noted that a cliff recession loss of 10 mm had occurred between July and August 2009, though zero recession rates have been recorded from August 2009 onwards. Over the period June 2009 to June 2012 survey data shows there has been no cliff recession along the surveyed locations. Despite site photographs illustrating some degradation of the headscarp of Behavioural Unit II, the cliffs would currently seem to be in a stable condition.

The results of the long-term inclinometer monitoring (I1 to I3) indicate both slopes, where instrumentation is installed on Behavioural Unit II and III, are in a stable condition. The replacement instrumentation BH7, located mid-slope of Behavioural Unit II, has shown that no ground movements have occurred between 8<sup>th</sup> September and 22<sup>nd</sup> October 2010. However, a comparison of the baseline reading taken by Mouchel of February 2011 and follow up readings up to June 2012 show that 26 mm (an increase of 6 mm since December 2011) of movement has occurred at 12.0 metres BGL, along a possibly developing slip plane, which coincides with the

interface of a gravelly SAND overlying SANDSTONE. It is evident that there is some ground movement occurring at depth within Behavioural Unit II although degradation of these slopes has yet to be translated up slope as the headscarp have remained intact without further recession so far evident.

Generally, piezometers have reflected decreases in ground water across Behavioural Unit I of the site ranging from a minimum of 1 mm (WS1) to a maximum 32 mm (WS3). Elsewhere across the site, Behavioural Unit II, elevated groundwater levels have been recorded at levels of between 49 mm (WS6) and 1950 mm (WS5).

An analysis of rainfall data illustrates that graphical peaks in groundwater levels were preceded by periods of increased precipitation resulting in raised groundwater levels and increased pore water pressures. This is clearly illustrated in graphical data from the shallow piezometers of P1, P2, P3 and P4 where the peaks and troughs of groundwater levels are more pronounced than in the graphs of the deeper instruments. The deeper instruments in P1, P2 and P3 have been installed to target a deeper water table below the site which has remained at approximately the same level throughout the period of monitoring and is not so susceptible to variations in rainfall. Variations in ground water levels between boreholes reflect the installation depths of piezometers in key strata of contrasting hydrogeological character.

A site visit to Scalby Ness was conducted on 21<sup>st</sup> April 2010. During this visit a slope failure (Plate 15, Appendix I) was noted as having occurred near the base of the North West facing slopes of Behavioural Unit I. This failure had developed between two scheduled monitoring visits of 2<sup>nd</sup> March and 21<sup>st</sup> April 2010.

Observations (with recommendations on further monitoring) made at the time of a site visit in May 2010 are presented in a previously published Mouchel report (*Report No. 721229-002-GIR-009-Final, May 2010*).

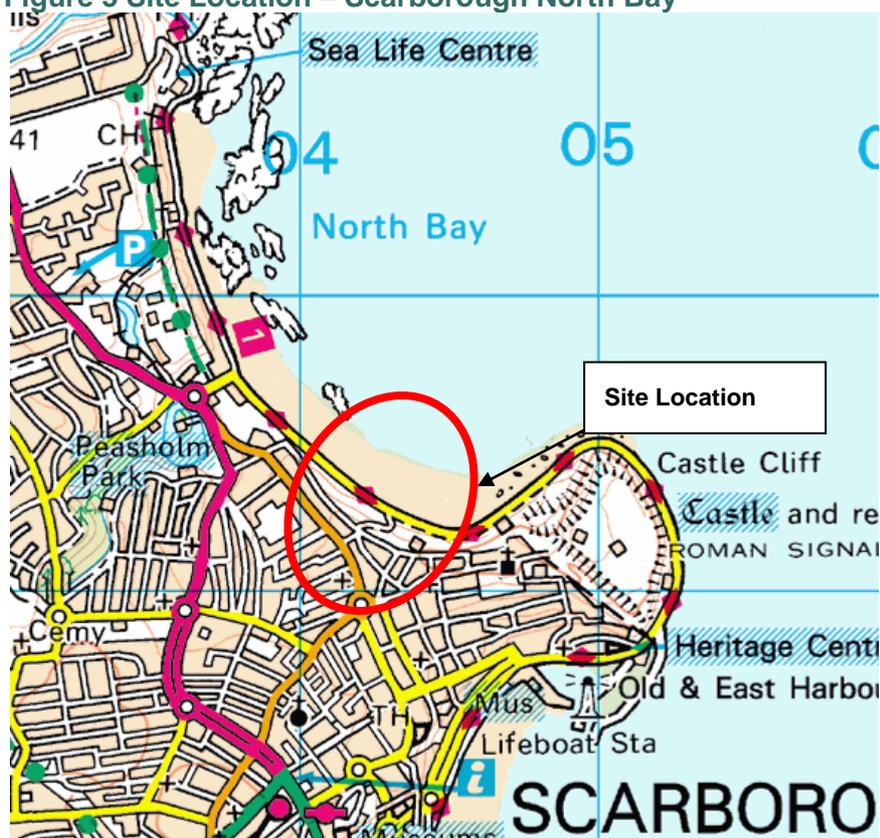


## 5 Scarborough North Bay

### 5.1 Site Location and Description

Scarborough North Bay is one of two bays either side of a headland around which the town of Scarborough has developed on the north east coast of Yorkshire. Scarborough North Bay extends from Castle Cliff northwards to Scalby Ness. The site is known as The Holms, an area of sloping, open parkland between the Castle above and Royal Albert Drive (Marine Drive) along the coast. The parkland consists of open grassed areas with groups of semi-mature trees and shrubs and, meandering tarmac footpaths which increase in steepness from the sea front leading up to the south western flanks of Castle Headland. Discrete rock outcrops are clearly visible across the slopes, see Figure 5.

Figure 5 Site Location – Scarborough North Bay



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#### 5.1.1 Historic Review of Problems

In 2000, a 200mm displacement of the seawall was monitored. These movements were caused by the widespread reactivation of a deep-seated, pre-existing landslide system at The Holms. Although this caused extensive damage to footpaths and cracking of the seawall, movements were relatively minor, with ground

displacements of the main landslide body probably in the order of 10's of centimetres. Following this event, a programme of Preventative Emergency Works was undertaken in 2000-2001. This pre-empted the main works of improvement and reconstruction of the seawall defences under the Coastal Protection Scheme.

The underlying landslide system comprises 10 to 17 metres of landslide debris overlying intact Scalby Formation of inter-bedded sandstone, siltstone and mudstone. Two units have been identified from ground investigations carried out in 2000.

An eastern unit, comprising a deep-seated landslide 'daylights' close to foreshore level.

A western unit, composed of a shallower landslide which 'daylights' approximately 1.50 metres above Marine Drive.

### 5.1.2 Topography and Geomorphology

The Holms is an area of public open space laid over to informal gardens with a network of tarmac footpaths which provide access from the sea front up to the Castle Headland above. The slopes are heavily terraced, displaying hummocky, irregular ground comprising glacial till and possible landslide debris with a wide mid-slope bench feature dominating the slopes. The glacial slopes rise from Marine Drive, at approximately 7.0 mAOD, at angles of 20-35 degrees to a mid-slope bench and terrace at 35.0 mAOD, beyond this terrace the slopes composed of rock debris and scree rise to approximately 50 to 55.0 mAOD to very steep cliff faces. These cliff faces rise to the pinnacle (83.31 mAOD) of Castle Hill on which the remains of Scarborough Castle are evident. A thin mantle of top soil, up to 0.17 m thick directly overlying bedrock, is present in the mid-slope plateau of the site where glacial till is absent. Glacial till is present over the remainder of the site varying in thickness between 16.0 m in the west section and 2.50 m to 2.95 m in the eastern section. Outcrops of the Cornbrash Limestone Formation are prominent on the lower and middle slopes of The Holms.

### 5.1.3 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data*" 721228/001/GR/01/02/FINAL, pp67-68. Additional reports were presented by SBC for further consultation for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 5.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheets 35 and 44 Solid & Drift, Whitby and Scalby, indicate that the northeast of the site is underlain by superficial deposits of glacial till of Quaternary age. This directly overlies Scalby Formation deposits of mudstones and sandstones. A north west –south east trending fault and a north – south trending fault gives rise to glacial tills underlying Oxford Clay, which in turn overlies the Hackness Rock Member sandstones of the Osgodby Formation. The Scalby Formation sandstones and mudstones are unconformably overlain by the Cornbrash limestones and the Osgodby Formation. The strata generally dip at an angle of 7 degrees in a south easterly direction.

## 5.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Minor Aquifer, overlain by class HU soils. Due to the less reliable nature of data collected in urban areas, the worst case scenario is assumed and soils are classified as having a high leaching potential. Minor Aquifers are variably permeable rocks, usually fractured rocks with a low primary permeability or unconsolidated deposits. They rarely produce large quantities of water for abstraction but often provide important base flow supplies to rivers. Major Aquifers may occur beneath Minor Aquifers.

## 5.4 Instrumentation

### 5.4.1 *Definition of Existing Problems*

Widespread reactivation of a deep-seated landslide system at The Holms occurred during 2000. This caused extensive damage to footpaths and cracking of the seawall.

Ground displacements of the main landslide body were in the region of 10's of centimetres although monitoring of the seawall revealed movements of 200 mm had occurred.

## 5.5 Monitoring Regime

### 5.5.1 Recommended Monitoring Regime

As a consequence of the analysis and interpretation of monitoring data and reports made available by SBC, a regime of future monitoring was formulated. These recommendations have been reported in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL.

Inclinometer and piezometer monitoring was to be carried out at monthly intervals for six months then every two months until month twelve. If no significant movement was revealed during this twelve month period then monitoring should revert to six monthly intervals (bi-annually) for the remaining two years.

### 5.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 5.5.1, above. Following the findings of the *Condition Survey Report*, monitoring consists of groundwater readings from 3no. piezometers (L1, L3 and L5) and 2 no. inclinometers (L4 and L6) located within the grounds of The Holms and 2 no. inclinometers (L11 and L12) located atop the cliffs above The Holms.

Additional installations comprising 3 no. inclinometers (BH11, BH3I and 4I) and 4 no. piezometers (BH1P to 4P) located on slopes above The Oasis Café, Scarborough North Bay were included in the monitoring regime in August 2009. The monitoring regime at this site was enhanced with the inclusion of the replacement monitoring equipment, monitored from February 2011 onwards, which was installed at The Holms in late 2010. The additional installations consist of 2 no. piezometers (BH8 and 9) and 2 no. inclinometers (BH10A and 11). Monitoring data from this event is presented within the relevant sections of this chapter and the Appendices to this report.

Inclinometers L4 and L6 at The Holms were located by SBC staff, following vegetation clearance, between 13<sup>th</sup> and 18<sup>th</sup> October 2009. The inclinometer tubes of these instruments were initially dipped with a dip meter and tested for internal integrity by lowering a test inclinometer probe through the length of each casing. The base of these instruments was proved to shallower depths than the original installed depths, thus indicating that these instruments were damaged (sheared) due to ground movements. These instruments have been monitored for groundwater levels only and no further inclinometer monitoring has been undertaken.

### 5.5.3 Ongoing Monitoring Results

#### *Inclinometer Readings*

Inclinometers L4, L6, L11 and L12 and slip indicator in N2 were proved to be blocked at various depths and hence, readings have not been retrieved from these instruments. Inclinometers (BH1I, BH3I and 4I) above The Oasis Café continue to be monitored within the regime of North Bay. Replacement inclinometers were installed at The Holms, inclinometer data is presented in Appendix C and D.

The replacement inclinometer graphs for BH10A and 11 consist of up to eleven readings taken by the contractor during site works from 8<sup>th</sup> September to 22<sup>nd</sup> October 2010 and separately, baseline readings recorded by Mouchel on 4<sup>th</sup> February 2011 and follow up readings of June and December 2011.

#### *Groundwater Readings*

Groundwater levels have been recorded from the Initial Full Suite Survey (15<sup>th</sup> July 2009) to the Sixth Full Suite Survey in December 2011. Groundwater levels recorded between June and December 2011 show little fluctuation except for boreholes L11 and L12 which showed decreases of 460 and 1010 mm, respectively. Variations of 40 mm and 120 mm in L1 (a & b) are attributed to changes in tidal levels. Piezometers installed above the Oasis Café indicate a static groundwater level at 8.05 m (BH2P) although an increase was recorded in a piezometer located higher up the coastal slope in BH3P and a decrease in BH4P of 110mm and -560 mm, respectively over the same period. Boreholes BH8 and 9 have been installed within the mid-slopes of The Holms. The instruments recorded groundwater increases in BH8a & b, BH9b and a reduction was recorded in BH9a.

Groundwater readings are presented in Appendix E and F.

## 5.6 Conclusions

The wide fluctuation of groundwater levels within L11 and L12 is likely to be the result of groundwater run-off which has infiltrated the installations and affected water level readings. Groundwater levels within borehole L1 would appear to be affected by tidal influences and the remaining instruments are either sheared or blocked at depth negating their use as reliable monitoring instruments. Groundwater levels within BH8 and BH9 do not seem show any consist pattern from which to derive a meaningful regime. Therefore, no meaningful conclusions can be reached regarding the groundwater regime at this site at the present time.

Cumulative inclinometer data for inclinometer BH4I (from the Oasis Café) appears to indicate ground movements of up to 5 mm whereas incremental inclinometer data for BH4I illustrates that no movements have occurred. This 'apparent' movement is due to inaccuracies arising from the use of two different probes (different calibration values) for the separate monitoring events. BH1I has not been monitored since December 2009 due to construction works and BH3I indicates no ground movements have occurred. Previous readings of December 2009 from BH3I showed 4 mm of movement have taken place at 3.5 m to 2.5 m depth. However, successive readings from this borehole show no movement and thus it is concluded that the readings of December 2009 were affected by temperature or operator error and do not indicate that any significant movement has taken place in the vicinity of this instrument since December 2009.

The results of inclinometer monitoring indicate that the slopes above the Oasis Café are presently in a stable condition within the vicinity of the inclinometer instruments, although there is evidence of limited shallow ground movements within the slopes.

Piezometers installed above the Oasis Café indicate elevated groundwater levels present within the slopes with water level increases of 440 mm (BH2P) to 3560 mm (BH3P). Groundwater readings from BH8 indicated water levels have increased by over 11.0 metres, while those from BH9 showed a decrease in ground water levels of 570 mm and 1930 mm in comparison with those of December 2011. Evidently these instruments are giving erratic readings and it is recommended that these instruments are flushed out with clean water.

Replacement boreholes BH10A and 11 were installed with inclinometers at The Holms area of Scarborough North Bay. To date no ground movement has been indicated by BH10A. However BH11 (installed above The Holms) shows that readings taken in June 2011 indicate 4 mm of movement had occurred between 13 and 10 metres depth since December 2010. The latest readings of June 2012 show that this movement has now increased to 18 mm, 14 mm since June 2011.

Groundwater data graphs for the two replacement instrumentation is yet to provide definite information on groundwater regimes around The Holms area. Due to the some what erratic groundwater observations recorded from BH8 and BH9a and b, it is recommended that these piezometers are flushed with clean water as they may be blocked to some degree with silt or other debris.

## 6 Scarborough South Cliff

### 6.1 Site Location and Description

Scarborough is a popular sea-side resort located on the north east coast of England. The South Cliff occupies the southern bay of Scarborough town with a gently sweeping coastline from the northern promontory of Castle Hill to the Black Rocks some 2km southwards, see Figure 6. The South Cliff site comprises a variety of landscaped gardens stretching from north to south in the following order: Spa Chalet Cliff, Spa Cliff, Prince of Wales Cliff, South Cliff Gardens, Rose Gardens, South Bay Pool Cliff, Holbeck Gardens, Holbeck Cliff and Wheatcroft Cliff. The cliff top is a gently undulating plateau surface with a road, Esplanade Crescent, running parallel to the cliff line. Large houses and hotels line the landward side of the road, set-back generally 30metres, but up to 100metres in places, from the cliff edge.

Figure 6 Site Location – Scarborough South Cliff



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### 6.1.1 *Historic Review of Problems*

The cliffs of Scarborough South Cliff are formed from glacial till slopes of varying thickness, underlain by Jurassic sandstones and siltstones, which are prone to landsliding. All of the cliffs along this section have toe protection provided by seawall / coastal defences, but localised landslide activity on the slopes and head scarps is common. At the Spa Cliffs, South Cliff Gardens and South Bay Pool the cliffs comprise steep rear scarps, forming arcuate embayments up to 200 metres in width, with gentle sloping stepped slopes at the base. Geomorphological features such as the steep rear scarps and mid-slope benches, present at these gardens, possibly display the remnants of historic deep-seated retrogressive rotational failures within the glacial tills. At Holbeck Cliff, the 1993 landslide involved a complex series of retrogressive displacements which overwhelmed the seawall and extended 150 metres across the foreshore.

The remaining sites present between those mentioned above consist of Spa Chalet Cliff, Prince of Wales Cliff, Rose Gardens, Holbeck Gardens and Wheatcroft Cliff. These sites represent intact coastal slopes which are subjected to localised small-scale shallow slope failures within the glacial tills due in part to increases in porewater pressures which lead to softening of and a decrease in shear strength of the tills. Such failures result in disrupted footpaths and minor damage to other structures and could be expected to occur on a yearly basis.

### 6.1.2 *Site Walk-over*

A site walkover was conducted by a geotechnical engineer from Mouchel on 27<sup>th</sup> November 2008 and again in early June 2009 as part of the Condition Survey. The Condition Survey (Mouchel Report No. 721229/001/CSR/02/FINAL, July 2009) was conducted in order to provide factual information on the existence, condition and functionality of the inclinometer installations. The instruments were recorded as being in good working order and as such, they were deemed to be of use in providing useful ongoing data for recording ground movements where this phenomenon is occurring.

### 6.1.3 *Topography and Geomorphology*

Late Devensian age glacial tills have been emplaced across much of the underlying landscape composed of Jurassic sedimentary rocks (predominantly sandstones and siltstones). These tills include stiff silty sandy clays, sands and gravels and, laminated silty clays. At Scarborough South Cliff, the till has completely in-filled a pre-glacial valley and now the whole cliff profile has developed in this glacial till attaining a height of between 50 m and 65 m. The glacial till slopes have been subjected to coastal protection measures, landscaping and drainage improvements since becoming the property of SBC in the late 19<sup>th</sup> century.

The South Cliff is occupied by a series of terraced gardens developed into glacial till slopes of varying height underlain by Jurassic sandstones and siltstones. At the Spa Cliffs, South Cliff Gardens and South Bay Pool the cliffs comprise steep rear scarps, forming arcuate embayments up to 200metres in width, with gentle sloping stepped slopes at the base. In other areas of the garden complex the landscaped slopes attain angles of up to 40 degrees becoming steeper at the base and are criss-crossed by a network of footpaths, bench-cut into the slopes and supported by small walls and revetments. A concrete seawall with a promenade has been built along the base of the cliff line from Spa Chalet Cliff to Holbeck Cliff where in the absence of a seawall, a rock armour revetment was constructed to replace the seawall destroyed in 1993 by a landslide. A variety of buildings occupy sites within South Cliff from the Spa Complex and Ocean Ballroom constructed at the base of Prince of Wales Cliff, a cliff railway operating from cliff top down slope to the Spa complex and a swimming pool and a series of chalets at South Bay Pool Cliff.

#### 6.1.4 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL, pp80-81. Additional reports were presented by SBC for further consultation for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 6.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheet 54 Solid & Drift, Scarborough indicates that the site is underlain by superficial deposits of Quaternary glacial till comprising stony clay, underlain by Oxford Clay of up to 36-76 metres in thickness. This overlies Osgodby Formation which consists of calcareous sandstones above undifferentiated strata of the Cayton Clay Formation and Cornbrash Formation consisting of limestones and mudstones. An unconformity separates this stratum from the underlying mudstones and sandstones of the Scalby Formation. The Scalby Formation is underlain by the Scarborough Formation limestones and mudstones, which outcrop as the Black Rocks of the South Bay foreshore.

## 6.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Minor Aquifer, overlain by class HU soils.

Due to the less reliable nature of data collected in urban areas, the worst case scenario is assumed and soils are classified as having a high leaching potential.

Minor Aquifers are variably permeable rocks, usually fractured rocks with a low primary permeability or unconsolidated deposits. They rarely produce large quantities of water for abstraction but often provide important base flow supplies to rivers. Major Aquifers may occur beneath Minor Aquifers.

## 6.4 Instrumentation

### 6.4.1 *Definition of Existing Problems*

Existing problems of slope failure along Scarborough South Cliffs include both first-time shallow slip failures within the intact slopes and the reactivation of existing deep-seated rotational failures related to increased ground water pressures.

### 6.4.2 *History of Monitoring*

Within the various garden areas of Scarborough South Cliffs, 12 no. inclinometers and 22 no. piezometers have been installed as part of eight ground investigations carried out between January 1996 and January 1998.

Monitoring data for inclinometer instruments has been provided from the instrument installation date until late September 2006. A single set of readings ('baseline') are available for 24-25 July 2006 and November 2008.

Piezometer data recording groundwater levels across the site has been recorded from the date of instrument installation up to August 2008.

Groundwater levels are available for 5 no. piezometer instruments installed around the Spa Ocean Room area. Monitoring data has been recorded from 16 January 2003 until 5 August 2008. However, no further details of ground investigation works, installation details, etc at this location have been made available for analysis.

Crack monitoring was undertaken at several locations at the Prince of Wales Cliff gardens from installed survey pins (C21A, B and C) covering the period 21 June 2000 to 17 January 2006.

A photographic record of the individual areas covering Scarborough South Cliffs has been undertaken on a periodic basis since June 2001 onwards. The photographs record damage caused by slope instability encompassing slip failures, back scars, cracking in paths, pavements and structural damage to footsteps and retaining walls.

## 6.5 Monitoring Regime

### 6.5.1 Recommended Monitoring Regime

As a consequence of the analysis and interpretation of monitoring data and reports made available by SBC, a regime of future monitoring was formulated. These recommendations have been reported in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL.

The recommendations for Scarborough South Cliff were that a regular monitoring and inspection regime should be undertaken at monthly intervals for a period of six months and then every two months until month twelve. If no significant movement was revealed during this twelve month period then monitoring should revert to six monthly intervals (bi-annually) for a further two years.

Monitoring was to be carried out over a period of three years to retrieve long term data for analysis in order to determine any seasonal patterns of rainfall, ground water levels and ground movements. The monitoring encompasses readings of inclination in two directions (A0 and A180) within each inclinometer tube and also monitoring of groundwater levels.

### 6.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 6.5.1, above. Following on from the findings of the *Condition Survey Report*, monitoring consists of taking measurements from five inclinometers, fourteen piezometers and three lines of survey pins (associated with boreholes H4, E3 and BH2) located within the gardens of Scarborough South Cliff, see Appendix A, Drawings 6 to 8. The inclinometers were monitored using a Vertical Digital Bluetooth Inclinometer system (MkII) with a TDS Recon 200 PDA and piezometers were monitored using a dip meter.

The monitoring regime at this site was enhanced with the inclusion of the replacement monitoring equipment, monitored from February 2011 onwards, which was installed at this site in late 2010 (See Appendix B, Drawings 3 to 5). The addition installations consist of 3 no. piezometers with slip indicators (BH15, 18 and 19) and 7 no. inclinometers (BH12–14, 16A, 17, 20 and 21). Monitoring data from this event is presented within the relevant sections of this chapter and Appendices to this report.

### 6.5.3 Ongoing Monitoring Results

The monitoring regime, based upon the findings of the *Condition Survey Report*, detailed five inclinometers and fourteen piezometers to be in a serviceable condition and have been included in the monitoring regime. This has been increased with the inclusion of replacement instrumentation detailed in Section 6.5.2.

#### *Inclinometer Readings*

Monitoring of inclinometers has been undertaken in accordance with the procedures detailed in Section 1.2 of this report and results are presented in Appendix C and D. In addition to this, the replacement inclinometer graphs consist of up to seven readings taken by the contractor during site works from 8<sup>th</sup> September to 22<sup>nd</sup> October 2010 and separately, baseline readings recorded by Mouchel on 2<sup>nd</sup> - 3<sup>rd</sup> February with follow up readings in June 2011, December 2011 and June 2012.

#### *Groundwater Readings*

Groundwater levels have been recorded from the Initial Full Suite Survey (15<sup>th</sup> July 2009) up to the Seventh Full Suite monitoring of June 2012. A comparison of the readings show a wide variation in depth changes, illustrating variations in tidal levels and the groundwater regimes that are active across the sites of Scarborough South Cliff.

Groundwater readings are presented in Appendix E and F.

#### *Survey Point Readings*

Three lines of survey pins were set out from the crest extending down slope to boreholes H4 and E3 and, from BH2 extending down slope in order to supplement the monitoring of slope movements at these locations. A comparison of survey data from July 2009 to June 2012 shows that a maximum ground movement of +20 mm occurred over this period at borehole BH2. Along the other two survey sections, +9 mm was recorded at H4 and +8 mm difference was recorded at E3.

Survey Point readings are presented in Appendix G and photographs of the survey points are presented in Appendix H.

## 6.6 Conclusions

Monitoring data from the Seventh Full Suite for inclinometers and survey pins have generally shown that there are slight ground movements, restricted to shallow disturbance, around AA10 (F2) and AA08 (D3).

Within inclinometer AA10 ground movements of up to 20 mm are apparent from 3.5 metres depth to ground level. This movement has occurred in made ground and is probably due to surface creep. The plotted graphs for AA08 indicate slight movements at 6.5 m depth occurring in a layer of slightly clayey silty SAND. No ground movements are indicated from plotted graphs for AA04, AA07 and AA11. Due to the limited coverage of the site offered by the reduced number of inclinometers, there had previously been the possibility of undetected ground movements occurring elsewhere particularly along the promenade where the majority of inclinometer instruments have been reported as having failed. Along the promenade are a number of replacement boreholes with inclinometer installations notably BH12, 13, 14, 16A and 17; elsewhere BH20 and 21 have been installed at mid-slopes further south.

Inclinometer data graphs for the majority of the replacement instrumentation shows that ground movements have occurred since monitoring began from late 2010 to June 2012 and, is summarized below.

BH12 – Development of a slip plane with 54 mm movement indicated from 39 to 31 m depth in strata described as Sand, gravel, cobbles and boulders. Displacement has increased by 4 mm since December 2011.

BH13 – A maximum of 13 mm movement is indicated from 61 m depth to 45 m in Clays and Sands, increasing to 60 mm from 45 m depth to GL in Glacial Till. No change since December 2011.

BH14 – A maximum of 10 mm movement is indicated from 56 m to 32 m depth in sandstone, clays and clayey sands and 5 mm from 32 m to GL in Glacial Till. No change since December 2011.

BH16A – 10 mm movement indicated from 30 m depth to GL in Glacial Till. No change since December 2011.

BH17 – No movement identified.

BH20 – No movement identified.

BH21 – No movement identified.

Inclinometers BH12, BH13, BH14 and BH16A are located at the top of the South Cliffs and show that ground movements, which lead to the malfunctioning of previously installed inclinometers along the promenade, continue to occur at depth which may lead to slope failures in the future. It is recommended that the monitoring frequency of these instruments should be increased as they continue to display ground movements and the development of slip planes at the stated depths. The monitoring frequency of six-monthly intervals should be increased, in view of the continued ground movements, to a frequency of two-monthly intervals for six months leading up to December 2012. This frequency of monitoring should also be reviewed following each monitoring event and interpretation of data.

Piezometer instruments located immediately behind The Spa (G3, H5 and Piezometers SPA1 to 5) have generally shown an increase in water levels ranging from no change (Spa5) to 6030 mm (Spa4), although other boreholes located above The Spa (1A & B SPA, G1a & b and H2a & b,) have displayed a decrease in water levels between 2920 mm (H2b) and 20 mm (1B SPA) along with piezometers installed in the Spa Chalet Cliff area (I2 and I2A). Elsewhere along South Cliff gardens, particularly the southern section, piezometric levels have shown a pattern of raised groundwater levels within the deeper instruments of BH3b and BH4a with ground water increases of 430 mm and 880 mm observed, respectively. BH3b was installed to a depth of 45.40 m BGL in sandy mudstone. These instruments are more than likely reacting to the water regime within a deeper watertable that is unaffected by short-term rainfall patterns. Elsewhere, the shallower instruments have recorded decreases in ground water levels of between 50 mm (BH4b) and 1930 mm (BH1a). In general the groundwater monitoring results collated to-date reflect fluctuations in the prevailing groundwater regime within the various soil horizons in which piezometers have been installed.

Groundwater levels recorded in piezometers across the site do not reflect the higher than average monthly rainfall experienced during the Autumn and early Winter of 2011. Groundwater levels recorded within water well installations behind The Spa continue to be erratic.. The differing water level readings may be due to the wells being blocked with silt, giving erratic readings, and may need cleaning or flushing out.

Survey data gathered from measurements taken from the survey pins installed in line with boreholes H4, E3 and BH2 emphasise the lack of ground movement within the vicinity of these instruments. A comparison of survey data from July 2009 to December 2011 shows that a maximum ground movement of +22 mm occurred over this period at borehole H4. Along the other two survey sections, +18 mm was recorded at BH2 and +12 mm difference was recorded at E3.

## 7 Knipe Point

### 7.1 Site Location and Description

Knipe Point is a promontory located at the north of Cayton Bay, 3.5 km south of Scarborough and 7 km north of Filey, on the north east coast of England. Set back beyond the promontory the main coastal route (A165) between Scarborough and Filey follows an almost parallel course to the coastline (see Figure 7). From the A165, north of Tenants' Cliff, to Knipe Point a series of holiday homes occupies the crest and the southern side of the promontory. The land north of the crest and the holiday homes complex is given over to agriculture. Osgodby Village is located immediately west of the A165.

Figure 7: Site Location



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#### 7.1.1 Historic Review of Problems

The landslide complex at Knipe Point abuts the steep sided ridge to the north and Tenants' Cliff landslide complex to the south. The landslide complex comprises a series of retrogressive rotational slides developed primarily in the glacial till deposits, with a deep-seated basal shear surface within the Oxford Clay, and in the toe area,

the Kellaway Rocks. A combination of groundwater seepages from granular horizons within the tills and toe erosion by wave action at the base of the cliffs represents the main mechanisms of cliff instability. The landslide complex is active with tension cracks and ground displacements evident over much of the area. Ground movements are degradational and appear to be mostly contained within the existing boundaries of the landslide complex.

### 7.1.2 Site Walk-over

A site walkover was conducted by a geotechnical engineer from Mouchel accompanied by a member of SBC staff on 4<sup>th</sup> March 2010 in order to determine the extent and range of monitoring required by the client.

### 7.1.3 Topography and Geomorphology

The relatively erosion-resistant rock outcrops of the promontory Osgodby (Knipe) Point forms the northern most limit of Cayton Bay. The site is bounded by the steep-sided ridge of Knipe Point to the north and Tenants' Cliff to the south. The crest of the promontory trends south west rising in elevation up to the old coast road (A165) and the village of Osgodby. The crest and southern side of this physical feature are occupied by holiday homes which have been present on this site in some form or other since the 1930's. Immediately south of the holiday village the slopes of Cayton Cliffs are present and are continuously encroaching upon this development at an unpredictable rate. The Cayton Cliff landslide complex is developed in glacial tills, up to 30 metres thick, overlying the Oxford Clay and Kellaway Rocks. The area is densely wooded with areas of denudation the results of mudslides and ground movements and, ponded water, springs and other features of poor drainage are also present over the slopes. A combination of groundwater seepages from granular horizons within the tills and toe erosion by wave action at the base of the cliffs represents the main mechanisms of cliff instability.

### 7.1.4 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data*" 721228/001/GR/01/02/FINAL, pp89-96 and supplemented by further reports from SBC. Additional reports have been provided by SBC for further consultation by Mouchel for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 7.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheet 54 Solid & Drift, Scarborough indicates that the site is underlain by superficial deposits of glacial till (Quaternary), underlain by Oxford Clay of up to 36-76 m in thickness. This overlies 3 to 13 m of Osgodby Formation calcareous sandstone above a thin (1.5 to 3 m) layer of

undifferentiated Cayton Clay Formation and Cornbrash Formation consisting of limestones and mudstones. An unconformity is encountered, beneath which there is 60 metres of the Scalby Formation mudstones and sandstones. Outcrops of strata generally young in a southerly direction, trending north west to south east. A fault trending NNW-SSE dissects the point, truncating the aforementioned strata. The tip of the point comprises the Gristhorpe and Lebberston Members (limestones and mudstones) of the Cloughton Formation.

## 7.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Minor Aquifer, overlain by soils of Intermediate Class 1. Minor Aquifers are variably permeable rocks, usually fractured rocks with a low primary permeability or unconsolidated deposits. They rarely produce large quantities of water for abstraction but often provide important base flow supplies to rivers. Major Aquifers may occur beneath Minor Aquifers.

## 7.4 Instrumentation

### 7.4.1 *Definition of Existing Problems*

The landslide complex comprises a series of retrogressive rotational slides developed in the glacial till deposits, with a deep-seated basal shear surface within the Oxford Clay, and in the toe area, the Kellaway Rocks. A combination of groundwater seepages from granular horizons within the tills and toe erosion by wave action at the base of the cliffs represents the main mechanisms of cliff instability. The landslide is active, with tension cracks and displaced ground evident over much of the area. These movements are degradational and appear to be restricted to the existing boundaries of the landslip complex, with only minimal failure of the sides and rear scarp.

### 7.4.2 *History of Monitoring*

A previous ground investigation was carried out in 1975, as referenced in Report No. 198. This ground investigation comprised four boreholes to various depths across Knipe Point site. The factual report has not been made available, though details of sub-surface geology and hydrogeology were inferred from a MSc. project (Mills, 1981) which included details of this ground investigation.

Mills (1981) carried out a geotechnical investigation at Cayton Cliff which identified three distinct soil units within the glacial tills. These soils comprised sandy coarse units interbedded with laminated and sandy clay tills. These till units are considered to control the nature and mechanism of landsliding as they are likely to be brittle and prone to progressive failure.

A series of fixed ground marker pins forming part of the National Trust (NT) Monitoring network were installed on 18 April 2008. The survey pins were observed to cover the whole area of instability of Knipe Point and Tenants' Cliff. Survey data from this network has not been made available to Mouchel. Cliff recession survey pins, installed along the Cornelian Bay, Knipe Point and A165 head scarp, have been monitored since installation at monthly intervals and this information along with groundwater monitoring data has been made available to Mouchel. Since installation, some of these markers have been lost to ground movements particularly at Cornelian Bay where only two of the original eight markers remain in place. The remaining markers were supplemented by a single marker point which is measured in two directions.

A photographic record of the site covering Knipe Point has been undertaken on a periodic basis since June 2001 onwards. The photographs record damage caused by slope instability including slip failures, back scars, tension cracks, cracking in paths, pavements and structural damage to footsteps, buildings and retaining walls, see Appendix J.

Scarborough Borough Council commissioned a ground investigation, in late 2008, involving the drilling of boreholes and installation of piezometer and slip-indicator instrumentation.

## 7.5 Monitoring Regime

### 7.5.1 *Recommended Monitoring Regime*

During early 2008 the main landslide complex at Knipe Point became reactivated resulting in the retreat of the south facing (Knipe Point Headland) headscarp up to existing property boundaries. The increased development of the head scarp eventually led to the demolition of three properties (No.s 21, 23 and 24) and the distinct possibility that more properties could be similarly affected. A detailed ground investigation including the installation of 6 no. piezometers and slip indicators was commissioned over this site in late 2008 (see Drawing 9, Appendix A). These instruments along with weather station monitoring and cliff recession points along the Former A165, Knipe Point Headland and Cornelian Bay Headland became part of the Coastal monitoring regime from March 2010. The site was monitored at monthly intervals from March to August 2010, in October and, from December 2010 and will be monitored at six monthly intervals up to June 2012.

### 7.5.2 *Ongoing Monitoring Regime*

The monitoring regime includes groundwater levels from the existing boreholes except BH02 and BH03 which are blocked due to ground movements at depth and, BH04 which gradually collapsed at ground level in late February 2010 possibly the result of a heavy period of rainfall on or around 26<sup>th</sup> February 2010.

### 7.5.3 Ongoing Monitoring Results

Mouchel began monitoring the site of Knipe Point under a new instruction from SBC, from March 2010 onwards. Monitoring data and a photographic record are ongoing exercises carried out in a similar manner to that previously undertaken by a third party on behalf of The National Trust (NT) along with surveying cliff top marker pins and retrieving data from the automatic weather station.

#### *Groundwater Readings*

Groundwater levels within boreholes have been restricted to readings from BH01, BH05 and BH06 due to ground movements and collapse of the remaining boreholes. Groundwater readings are presented in Appendix E.

#### *Survey Point Readings*

Monitoring of the recession survey points is undertaken at regular intervals as described in section 7.5.1 above. On-going monitoring results are compared to and commented on in relation to 'Baseline' readings taken in February 2010 which were supplied by SBC. The results are presented in Appendix G.

#### *Weather Records*

Continuous rainfall, air and ground temperatures are recorded on site by an automatic weather station located within the residential area of the site. A photograph of this equipment is presented in Plate 21, Appendix J.

## 7.6 Conclusions

Knipe Point was introduced into the coastal monitoring programme in March 2010 under a new instruction. A comparison of previously recorded data, collected on behalf of SBC, from December 2010 with that of June 2011 indicates that the landward retreat of the Cornelian Bay headscarp has rapidly increased with between 2 and 5 metres of land lost and the total loss of previously repositioned monitoring points and the fence posts of properties No. 5 and 6. Recent reports and monitoring data on recession rates, available from the National Trust, have also detailed the rates of landward degradation of the headscarps of Cornelian Bay and Knipe Point.

A photographic record of the site, presented in Appendix J, shows the degradation of the headscarps under observation particularly that of Cornelian Bay headland. Recession at survey point C08 had previously been noted to continue in a northerly direction and eastwards, recession rates had significantly accelerated since June 2010 with approximately 2.0 metres of land being lost to cliff recession (see Plates 1 to 6, Appendix J). This rapid rate of recession has continued with more than 5

metres of the headland being lost to recession since December 2010. Plates 1 to 6 clearly show the extent of this land loss, particularly since December 2011. From the most recent photographs (June 2012) a manhole, previously seen *in situ* in the glacial till cliffs, can be viewed partly down slope of it's original position and, the fencing and garden borders of properties 5 and 6 have almost entirely collapsed and disappeared down slope.

Variations in ground water levels between boreholes reflect the installation depths of piezometers in key strata of contrasting hydrogeological character. Ground water data has indicated that potentially significant ground water pressures exist landward of the headscarp which are likely to contribute to ground movements and potential failure of Knipe Point headlands. However, since June 2011 groundwater levels have increased by 10 mm in piezometers at the base of the cliffs complex (BH5 and 6) and reduced by 970 mm in BH01 located at the top of the cliffs of Knipe Point Headland.

Knipe Point headscarp has previously been the most active in terms of cliff recession rates which lead to the demolition of three properties in 2008 as the cliff edge receded landward. However, since the start of monitoring in March 2010, this section of cliff headscarp has shown a cessation in cliff recession rates along the most active section which is covered by monitoring points H04 to H10b. Total recession rates (from December 2010 to June 2011) measured from these monitoring points has been recorded in the order of 30 mm to 2200 mm. Since December 2011 up to June 2012 this section of cliff has displayed further cliff recession of magnitudes of 30 mm to 40 mm. Road pins have been emplaced in order to mark the shear edge, although in places the cliff is actually heavily undercut to >500 mm. This section of the headland has previously displayed surface tension cracking with potential block detachment which was reported in National Trust (Halcrow) Report No. 10, (SBC records, issued 18<sup>th</sup> December 2009). Surface tension cracks continue to develop with the increased potential of headland loss and block detachment. The greater loss of land at H06 relates to a section of the headland affected by a mid-slope landslide. While at present there are no longer any structures threatened by cliff recession, the unstable and unpredictable condition of these cliffs still poses a danger to the residents of this community.

During a survey carried out in April 2010 a 'fresh' mudslide with failure run-out and rafted trees was observed on the slopes of Knipe Point immediately below monitoring point H06. During the site monitoring of December 2010, this mudslide was observed to have developed further and was approximately 10 metres below cliff crest level and extending further down the slopes. Ground water seepages were observed to be active (free flowing ground water was observed) from this point in the slope and continue to be coincident with the mudslide. Immediately above the mudslide on the slope crest, an area of increasing instability continues to develop which may be unconnected to the mudslide phenomenon. Tension cracks visible at the surface are developing parallel to garden fencing and properties around the promontory at H06 (first detailed above in Halcrow report No. 10). The continued

development and extension of these cracks will eventually lead to block detachment and localised cliff recession. It is considered that this immediate area is unstable and unsafe to walk near. Despite the presence of road pins and warning tape, the cliff edge is heavily undermined in places. We would therefore recommend that the existing road pins and red & white bunting tape be moved inland a further metre from their current position and replaced with a more robust barrier with warning signs, along the cliff edge between survey pins H06 and H11.

No further cliff recession has been observed along the A165 headscarp. Comparisons of measurement data from several monitoring points taken in February, March and that of April 2010 are not entirely consistent as they have been recorded by different engineers. Some changes in the methods and manner of data collection are inevitable which can lead to the resulting anomalies.

A small landslide which developed in mid-February 2010, along the A165, has not been investigated as this area lies outside of Mouchel's remit of the Knipe Point site. Since the closure of this road, any such failures at this location do not pose an immediate, pending danger to the public or to near-by assets. The headscarp along this section is currently separated from the public and the thoroughfare by a thick blackthorn hedge.



## 8 Filey Town

### 8.1 Site Location and Description

The site is located to the south and east of Filey town centre, a popular holiday resort, on the north east coast of England, see Figure 8.

Martin's Ravine is a steep sided valley to the south of Filey, through which a footpath leads, sloping downwards from a car park to the southern end of Royal Parade and the sea. Royal Parade is a flat esplanade along the sea front extending from the south at the base of Martin's Ravine, northwards to where The Crescent approaches from above, and continues north towards Filey town centre and Church Ravine. To the rear of Royal Parade is a line of small chalets behind which is a steep slope rising up to a level grassed area (Glen Gardens). The northern edge of this area is bounded by Crescent Hill which leads off The Crescent, from the top of the recreation grounds, and winds down to join Royal Parade. A number of footpaths criss-cross the slopes allowing pedestrian access from the cliff top to the beaches below.

Figure 8 Site Location – Filey Town



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### 8.1.1 *Historic Review of Problems*

The severe adverse impacts of an intense period of prolonged and extremely heavy rainfall, in July 2007, resulted in considerable and widespread flooding to parts of Filey. The resulting rainwater run-off caused slope failure and scour damage to riffles and bridge abutments within Martin's Ravine. Existing drain runs were damaged due to excessive rainwater around Glen Gardens and this also caused drainage to collapse leading to slope instability behind Royal Parade chalets and Crescent Hill.

### 8.1.2 *Site Walk-over*

A site walkover was conducted by a geotechnical engineer from Mouchel on 27<sup>th</sup> November 2008 and in early June 2009 as part of the Condition Survey. The Condition Survey (Mouchel Report No. 721229/001/CSR/02/FINAL, July 2009) was conducted in order to provide factual information on the existence, condition and functionality of the four inclinometer installations. The instruments were recorded as being in good working order and as such, they were deemed to be of use in providing useful ongoing data for recording ground movements where this phenomenon is occurring.

### 8.1.3 *Topography and Geomorphology*

During the last glacial period (Devensian), ice sheets spread south and east across this area to the North Sea. As these ice sheets retreated glacial till was emplaced over the landscape, formed of Jurassic rocks, completely infilling pre-glacial valleys and embayments. Filey is part of a long stretch of exposed cliffs running north-south forming protected, soft, glacial till cliffs between Church Ravine and Martin's Ravine. Further south towards Reighton the coastline is formed of unprotected, soft, glacial till cliffs. The slopes attain a height of up to 30 metres at slope angles of 25 to 35 degrees. The faces of the slopes are criss-crossed by pedestrian footpaths which give public access from the top of the cliffs to the beach below. Other features present over the slopes are benched, viewing points and relict slip failure scars with thin and bare patches of vegetation. At the base of the slopes is a sea wall with a broadwalk, forming a sea defence, with a wide sandy beach foreshore.

Martin's Ravine is bounded by steeply sided sloping edges (1v:1.5h to the north and 1v:1h to the south) and slopes downwards from a car park in the west to the sea front in the east. The side slopes measure about 12 m in height at their highest point. Towards the base of the ravine the slopes have been remediated with a combination of gabion baskets and soil nailing in order to stabilise the slopes. At other sections of the ravine the stream is partly constricted by a culvert.

The eastern most edge of Glen Gardens slopes steeply (>1v:2h) down to the back of chalets along Royal Parade; the slope is 15 to 18 m high with upper slope angles steeper than at the toe. The steep slope separating Glen Gardens and Crescent Hill has an estimated height of 14 metres and both are crossed by stepped footpaths

ascending the slopes. The road at Crescent Hill slopes gently down to the sea front. In 2009 parts of these slopes were remediated following partial slope failures over the north facing slopes and slopes behind the chalets. The failed materials were dug out and replaced with granular fill and, the slope drainage and footpaths were repaired.

#### 8.1.4 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL, pp107-108. Additional reports were presented by SBC for further consultation for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 8.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheet 54 Solid & Drift, Scarborough indicates that the site is underlain by superficial deposits of glacial till (Boulder Clay) composed of stony clays. The solid succession at depth in the area is indicated as strata of the Kimmeridge Clay Formation of Upper Jurassic age. This typically comprises bituminous clays.

## 8.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Non-Aquifer because of their negligible permeability. These formations are generally regarded as containing insignificant quantities of groundwater. However, groundwater flow through such soils, although imperceptible, does take place and needs to be considered in assessing the risk associated. Some Non-Aquifers can yield water in sufficient quantities for domestic use. Major and Minor Aquifers may occur beneath Non-Aquifers.

## 8.4 Instrumentation

### 8.4.1 Definition of Existing Problems

The prevailing problems at Filey would seem to originate from the inadequacy of the existing drainage systems to cope with heavy and / or prolonged periods of rainfall. Surface water is constricted to the west of the site by a railway embankment trending north-south. East of the embankment, surface water flows towards the coast where it is channelled and concentrated within the ravine. The erosive potential of the

waters is increased by flowing down the steep gradients of the ravine resulting in undercutting of the bed of the streams and slopes and the eventual collapse of the slopes. This is coupled with surface water run-off flowing down over the slopes from the plateaux north and south of the ravine.

#### 8.4.2 *History of Monitoring*

Standpipe piezometers were installed in BH01 at 14.00 m and BH04 at 9.00 m in cohesive glacial till, in BH02 at 2.00 m in non cohesive glacial till and in BH05B at 6.45 m in made ground. Groundwater readings were taken during and after the completion of site works, up to early October 2008. Inclometers installed in BH03 and BH06 to depths of 29.70 m and 30.00 m, respectively have been similarly monitored.

A photographic record covering Filey Town and The Brigg has been undertaken by SBC on a periodic basis since June 2001 onwards. The photographs record damage caused by slope instability encompassing slip failures, back scars, cracking in paths, pavements and structural damage to footsteps and retaining walls.

## 8.5 **Monitoring Regime**

#### 8.5.1 *Recommended Monitoring Regime*

It was recommended that a regime of regular monitoring and inspection of Filey should be undertaken at six monthly intervals (bi-annually). This was to be carried out over a period of three years to retrieve long term data for analysis in order to determine any seasonal patterns of rainfall, ground water levels and ground movements. The frequency of walkover surveys and instrument monitoring was recommended to be increased following periods of heavy and / or prolonged rainfall.

#### 8.5.2 *Ongoing Monitoring Regime*

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 8.5.1, above. Following on from the findings of the *Condition Survey Report*, instrumentation consists of a single inclinometer (BH06) and a piezometer (BH04) located within Glen Gardens above the coastal slopes of Royal Parade (see Appendix A, Drawing 10). Piezometer instruments were located south of and at the base of Martin's Ravine and on Royal Parade below Glen Gardens (BH01, BH02 and BH05B).

The reduced monitoring regime is based upon the findings of the *Condition Survey Report*. This detailed inclinometer (BH06) and piezometer (BH04) as not being located due to dense vegetation and hence not available for monitoring. Following vegetation clearance and remedial works around this vicinity, these instruments were located and introduced into the monitoring regime at a later date.

### 8.5.3 Ongoing Monitoring Results

#### *Inclinometer Readings*

Monitoring of inclinometers BH03 and BH06 has been undertaken in accordance with the procedures detailed in Section 1.2 of this report and results are presented in Appendix C. While undertaking the monitoring of the site (10<sup>th</sup> December 2009), the base of BH03 was found to be dipping at a reduced depth of 18.35 mBGL. Further investigation carried out on 11<sup>th</sup> December 2009 revealed a blockage within the tube at this same depth. A stainless steel mandrill was used in an attempt to clear the tube although this proved unsuccessful. The tube remains blocked at 8.80 mBGL and has not been monitored since December 2009.

#### *Groundwater Readings*

Groundwater levels have been recorded since the Initial Full Suite Monitoring (8<sup>th</sup> July 2009) up to the June 2012. A comparison of readings taken in December 2011 and the latest recorded in June 2012 has been undertaken. Groundwater levels within BH05B and 06 have increased by 49 mm and 560 mm respectively. A rise in water levels of 152 mm was recorded in BH01 which seems to reflect the prevailing water level within the stream flowing through Martin's Ravine.

There is limited data available for BH04 although this instrument continues to record some what erratic data and this may be due to the piezometer tip being silted up. It is therefore recommended that this piezometer is flushed out with clean water in order to make it functional.

Groundwater readings are presented in Appendix E.

## 8.6 Conclusions

The results of monitoring inclinometer BH06 so far seem to indicate that the previously noted ground movements (<5 mm between 12.0 m and 7.00 m depth) initially recorded in December 2009 have not developed further. The inclinometer data show that slopes at this location would seem to be in a stable condition. Inclinometer readings for BH03 only consist of initial 'Baseline' readings. The inclinometer graphs are presented in Appendix C.

Groundwater levels at this site have increased since December 2011 with a maximum rise of 560 mm indicated in BH4. Readings from BH05B (+49 mm) reflect the tidal fluctuations affecting water levels in this borehole. Ground water readings from BH01 would seem to reflect the water level within the stream flowing through Martin's Ravine.

There is limited data available for BH04 although this instrument continues to record some what erratic data and this may be due to the piezometer tip being silted up. It is therefore recommended that this piezometer is flushed out with clean water in order to make it functional.

## 9 Filey Flat Cliffs

### 9.1 Site Location and Description

Filey Flat Cliffs is situated near Primrose Valley Holiday Park, 2 km south of Filey town centre on the north east coast of England, see Figure 9. The site comprises steep unprotected coastal slopes of glacial till on which holiday homes and static caravans have been constructed with narrow tarmac access roads. The site is bounded to the north, west and south by the holiday park and to the east by the cliffs.

Figure 9 Site Location – Filey Flat Cliffs



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#### 9.1.1 Historic Review of Problems

At Filey Flat Cliffs there is evidence of active slope erosion, cliff-top recession and slope instability. Slope instability is particularly apparent at this site where an active landslide (rotational failures forming a benched slope profile) now threatens to breach the only vehicle access route into the area.

### 9.1.2 Topography and Geomorphology

The coastal cliffs are entirely composed of glacial till with solid rock formations dipping below sea level. The glacial till deposits comprise a highly variable mixture of clays, silts and, sands and gravels. They are easily eroded by wave action and are susceptible to groundwater effects and mass movements. Complex landslides are present at Filey Flat Cliffs; large-scale, deep-seated failure of the glacial till cliffs has occurred. At the north end of Filey Flat Cliffs, the surface morphology indicates rotational failure of the glacial till has occurred. At Filey Flat Cliffs (south), large undercliffs have formed which appear from the surface morphology to be formed by translational failure of the glacial till slopes, possibly founded upon or within weathered bedrock at depth.

### 9.1.3 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL, p117. Additional reports were presented by SBC for further consultation for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 9.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheet 54 Solid & Drift, Scarborough indicates that the site is underlain by superficial deposits of glacial till (Quaternary), overlying the Speeton Clay Formation. This formation overlies the Kimmeridge Clay Formation.

## 9.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Non-Aquifer because of their negligible permeability. These formations are generally regarded as containing insignificant quantities of groundwater. However, groundwater flow through such soils, although imperceptible, does take place and needs to be considered in assessing the risk. Some Non-Aquifers can yield water in sufficient quantities for domestic use. Major and Minor Aquifers may occur beneath Non-Aquifers.

## 9.4 Instrumentation

### 9.4.1 Definition of Existing Problems

The presence of confined granular strata within the glacial till slopes may result in excess groundwater pressures developing resulting in the collapse of the head scarp and recession of the cliff crest.

## 9.5 Monitoring Regime

### 9.5.1 Recommended Monitoring Regime

As a consequence of the analysis and interpretation of monitoring data and reports made available by SBC, a regime of future monitoring was formulated. These recommendations have been reported in Mouchel Report “*Analysis and Interpretation of Coastal Monitoring Data*” 721228/001/GR/01/02/FINAL. The recommendations for Filey Flat Cliffs were that a regular monitoring and inspection regime should be undertaken at monthly intervals for a period of six months and then every two months until month twelve. If no significant movement was revealed during this twelve month period then monitoring should revert to six monthly intervals (bi-annually) for a further two years.

### 9.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 9.5.1, above. Following on from the findings of the *Condition Survey Report*, monitoring consists of a single inclinometer BB02 (A2) located on the landside of the main access road down through Filey Flat Cliffs and 3 no. piezometers (A3, B1 and D1), one located within Filey Flat Cliffs and the remainder located above the village beyond the cliff crest, see Appendix A, Drawing 11.

The reduced monitoring regime is based upon the findings of the *Condition Survey Report* which detailed inclinometer BB01 (D2) as being blocked at 14.20 m, possibly due to ground movements, 8 metres short of the installed depth. Hence, due to the discrepancy between the two depths this instrument was not monitored other than for water levels and has been recommended for replacement.

### 9.5.3 Ongoing Monitoring Results

#### *Inclinometer Readings*

Inclinometer readings for BB02 (A2) have been recorded in accordance with the procedures detailed in Section 1.2 of this report and are presented in Appendix C.

### *Groundwater Readings*

Groundwater levels have not been recorded from D1 and A3 as these piezometers have now been fitted with data logging devices. As such it has not been possible to read the instruments with a dip meter and record water levels. A groundwater reading from B1 revealed a reduction in water levels of 520 mm in comparison with readings of December 2011. Groundwater readings up to May 2012 are presented in Appendix E.

## **9.6 Conclusions**

Previous monitoring data, up to December 2011, from the inclinometer BB02 (A2) has illustrated very little ground movement occurring within the vicinity of this borehole. A deviation of 15mm was indicated at near surface from a comparison of readings between December 2010 and June 2011. This had increased by 5 mm to 20 mm by comparing inclinometer readings of June with those of December 2011. These readings are probably more likely to be due to temperature variations and the use of two different probes for recording the sets readings rather than an indication of ground movements. Up to December 2011 the monitoring data has indicated that no ground movements have taken place within the location of inclinometer BB02. Future readings from BB02 and the repaired inclinometer in BB01 may provide further data on ground movements at this site.

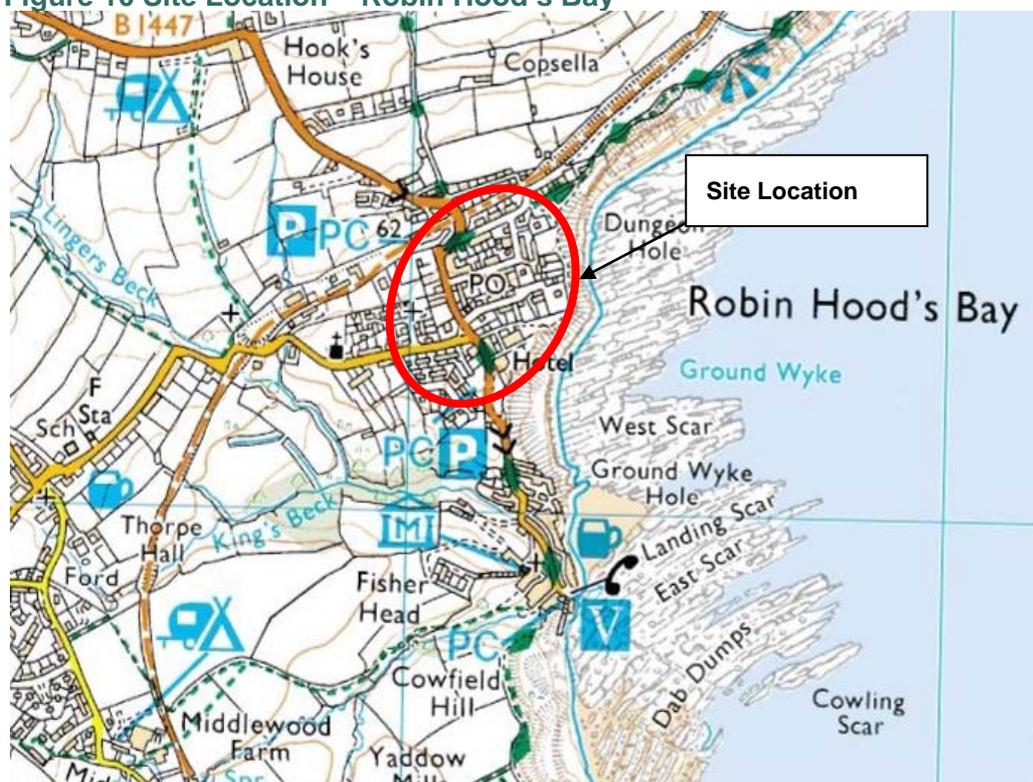
The single inclinometer offers very limited coverage at Filey Flat Cliffs and there is the distinct possibility of undetected ground movements occurring elsewhere at this site. Previous interpretative reports (provided by SBC) have drawn attention to the fact that there is a lack of valid geotechnical data retrieved from this area with which to build a meaningful geotechnical model and to also carry out slope stability analyses. It is understood from SBC that additional instrumentation has been installed at this site and also the inclinometer BB01 has been repaired and upgraded to provide readings remotely.

## 10 Robin Hood's Bay

### 10.1 Site Location and Description

Robin Hood's Bay is located approximately 5 miles south of Whitby along the North Yorkshire coast, see Figure 10. This area has a long history of coastal slope instability with a number of properties being lost to cliff top recession. The area of Robin Hood's Bay identified for this study is the upper town, to the north and east of the Victoria Hotel which has been previously identified as being at risk of slope instability and coastal erosion. The instability is affecting the coastal slope with shallow slips evident and movement continuing to occur.

Figure 10 Site Location – Robin Hood's Bay



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#### 10.1.1 Historic Review of Problems

At Robin Hood's Bay there is evidence of active slope erosion, cliff-top recession and slope instability. Movement within the clay slopes above the sea cliffs is dependent on recession of the lower reaches of the sea cliffs. As the cliffs retreat landslides on the mid-slope bench lose toe support and reactivation of landslips may occur with the till slopes degrading to a more stable slope angle.

Attempts have been made to assess the rate of regression of the top of the clay slope using the historic OS maps and aerial photographs but these have proved inconclusive. The movement affects localised areas of the slope with obvious loss of land at the top of the slope as witnessed by realignment of the coastal cliff path. This movement tends to occur as a 'one-off' slip rather than being a continuous, gradual process.

### 10.1.2 Topography and Geomorphology

The site is located in the upper part of the village of Robin Hood's Bay, focusing on the coastline to the north and east of the Victoria Hotel at Mount Pleasant. Here, the land forms a steep till slope down towards the sea, with an almost vertical rock sea cliff below. No coastal defences exist in this area and regression of the sea cliffs and till terraces, due to coastal erosion and landslide, will eventually result in the loss of a few properties. Movement within the clay slopes above the sea cliffs is dependent on recession of the sea cliffs. As the cliffs retreat landslides on the mid-slope bench lose toe support and reactivation of landslips may occur with the till slopes degrading to a more stable slope angle. This movement tends to occur as a 'one-off' slip rather than being a continuous but gradual process. During winter 2009 and spring of 2010, after prolonged wet weather, movement of the clay slope below the Rocket House near BH2 (see Drawing No. 12, Appendix A) was noted. This appeared to comprise shallow spalling and slumping of the clay face.

The outcrop pattern of the rocks on both the geological map and on the aerial photographs shows the presence of an anticline, with the younger rocks forming an arc around the older Redcar mudstone. The Redcar mudstone forms the centre of Robin Hood's Bay, outcropping largely as wave cut platform, from Old Peak in the south to Ness Point immediately north of the village. The arc immediately surrounding the mudstone is composed of Staithes sandstone, which forms the steep cliffs at the northern edge of the bay. A band of Cleveland ironstone forms an arc around the sandstone and occurs north of the site. The strata dip at angles of 2-3° away from the bay in each direction. Three minor faults are evident on the geological map, cutting through the lower portion of the village, south of the site, in a northwest-southeast direction. In each case the south western side has been downthrown.

### 10.1.3 Existing Information

A number of reports were provided by SBC for consultation, these are detailed in Mouchel Report "*Robin Hood's Bay Coastal Strategy Study*" *Ground Investigation Report, 1022894/GEO/R/01/02/FINAL*, August 2010.

Additional reports were presented by SBC for further consultation for the Ongoing Analysis. This data has been placed on an Arcview GIS layer for ease of use and availability.

## 10.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheet 35 & 44, Whitby and Scalby, 1998 indicates that the site is underlain by superficial deposits of glacial till (Quaternary), overlying the Lias Group (Lower Jurassic). Quaternary drift deposits of glacial till cap the Lower Jurassic Lias rock cliffs, with exposed mudstones forming a wave cut platform.

## 10.3 Groundwater Regime

### Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of north east Yorkshire has classified the area partly as a minor aquifer and partly as a non-aquifer. A region of non-aquifer stretches from the southern part of the village, south to Old Peak. This is ringed by an arc of minor aquifer and an outer ring of non-aquifer. Minor aquifers are classed as variably permeable due to their low primary and variable secondary permeability. However, groundwater flow through such rocks, although imperceptible, does take place and needs to be considered in assessing the risk to stability. They seldom produce large quantities of water for abstraction but are important for local supplies and for base flow. Major aquifers may underlie minor aquifers.

## 10.4 Instrumentation

### 10.4.1 Definition of Existing Problems

The main geotechnical risks identified at the site of Robin Hood's Bay are considered to be:

- Layers of sand / gravel within the glacial till
- Soft material within 5-6m of the ground surface within glacial till
- Layers of laminated clay
- Water pressure within the granular layers / lenses and at rock head
- Highly fractured and weathered material at rock head

It is noted that some movement at depth has been recorded and it has been recommended that inclinometers installed as part of a ground investigation in February 2010 continue to be monitored beyond the site works period.

## 10.5 Monitoring Regime

### 10.5.1 Recommended Monitoring Regime

Within Mouchel report (*“Robin Hood’s Bay Coastal Strategy Study” Ground Investigation Report, 1022894/GEO/R/01/02/FINAL*, August 2010) recommendations for future monitoring at Robin Hood’s Bay were that following the completion of site works in February 2010, a regular monitoring and inspection regime should be undertaken at monthly intervals for a period of six months and then every two months until month twelve. If no significant movement was revealed during this twelve month period then monitoring should revert to six monthly intervals (bi-annually) for a further two years. In February 2010 SBC instructed Mouchel to begin monitoring the instruments at this site from June 2011 onwards. The monitoring regime is to follow the existing frequency for the coastal monitoring scheme in that three visits are to be undertaken in June and December 2011 and, June 2012.

### 10.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in June 2011 and follows that detailed in Section 10.5.1, above. The monitoring regime consists of two piezometers (BH1 and 3) installed to a maximum depth of 50.50 m and two inclinometers (BH2 and 4) also installed to a maximum depth of 50.50 m (see Drawing No. 12, Appendix A).

### 10.5.3 Ongoing Monitoring Results

#### *Inclinometer Readings*

Inclinometer readings for BH2 and BH4 have been recorded in accordance with the procedures detailed in Section 1.2 of this report and are presented in Appendix C. Since installation in late February 2010, BH2 inclinometer has displayed ground movements of up to 35 mm at a depth of between 26 and 29 metres bgl. This movement was recorded by SBC staff during monitoring events following the completion of site works (in February 2010) from March to August 2010. This period was noted as being ‘unseasonally dry’ in comparison to previous years whereby the recorded monthly rainfall for March, April, May, July and August 2010 was lower than the average monthly rainfall recorded from the previous fifteen years.

#### *Groundwater Readings*

A comparison of the latest groundwater readings with those recorded in December 2011 shows groundwater levels within BH3A had fallen by 40 mm and in BH3B recorded a rise of 1.27 m. BH1A indicated a reduction in groundwater of 2.55 m, the deeper piezometer in BH1A has been continuously reported as dry.

Groundwater readings are presented in Appendix E.

## 10.6 Conclusions

BH2 inclinometer had previously displayed ground movements of up to 35 mm at a depth of between 26 and 29 metres bgl. This movement was recorded by SBC staff during monitoring events following the completion of site works (in February 2010) from March to August 2010. Although this amount of recorded movement is not considered to be “catastrophic”, continued monitoring on a monthly basis, and after prolonged periods of rainfall was strongly recommended to determine whether the movement is accelerating or reaching a critical point. The inclinometer installed in BH4 has so far indicated no ground movements.

During the monitoring event of June 2011 BH 2 inclinometer tube could only be read to 21.5 metres depth (inclinometer installed to 41.0 m) as the probe would not travel further down the inclinometer tubing. This would indicate that ground movements continue to occur, in a similar manner to that reported above, at an indeterminable rate as the data previously recorded by the contractor, following field works, cannot be combined with later data as the depths of the instrument do not match. However, the readings of this instrument recorded from the reduced depth of 21.5 metres do indicate continued ground movements around the area of this inclinometer.

In view of the previously recorded ground movements indicated from previous monitoring data, it is recommended that the monitoring frequency at this site is increased from six monthly intervals to three monthly intervals (over a 12 month period) in order to record the rate of ground movement occurring and provide a basis for predicting further ground movement particularly if such movement could have a detrimental effect upon life and/or property.



## 11 References

Anderton R, et al (1979) A Dynamic Stratigraphy of the British Isles, Chapter 17. George Allen & Unwin.

British Geological Survey (BGS) 1:50,000 Scale, Solid and Drift (Sheet 34, Guisborough)

British Geological Survey (BGS) 1:50,000 Scale, Solid and Drift (Sheet 35 & 44, Whitby and Scalby).

British Geological Survey (BGS) 1:50,000 Scale, Solid and Drift (Sheet 54, Scarborough)

BS 1377: (1990) Soils for Civil Engineering Purposes. British Standards Institution.

BS 5930: (1999) + A2:2010 Code of Practice for Site Investigations. British Standards Institution.

BS 6031: (2009) Code of Practice for Earthworks. British Standards Institution.

BS 8002: (1994) Code of Practice for Earth Retaining Structures. British Standards Institution.

CIRIA Special Publication 149 (1998): A Guide to British Stratigraphic Nomenclature.

Environment Agency, 2006: Underground, Under Threat, Groundwater Protection: Policy and Practice.

Environmental Agency website, "What's in my Backyard"?  
[http://www://216.31.193.171/asp/1\\_introduction.asp](http://www://216.31.193.171/asp/1_introduction.asp)

Geotechnics Ltd "*Ground Investigation at Robin Hood's Bay, Whitby*". *Factual Report PC093976*, April 2010.

Lee, E.M. & Jones, D.K.C. (2004) *Landslide Risk Assessment* – Thomas Telford Ltd.

Mills. (1981) Site investigation report Knipe Point, Cayton Bay, North East Yorkshire, MSc Thesis.

Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data*" 721228/001/GR/01/02/FINAL, March 2009.

Mouchel Report "*Ongoing Analysis and Interpretation of Coastal Monitoring Data. Condition Survey Report*" 721229/001/CSR/02/FINAL, July 2009.

Mouchel Report “*Feasibility Study into the Replacement of Damaged Monitoring Equipment*” 721229/017/GIR/002/FINAL, October 2009.

Mouchel Report “*Definition of Heavy / Prolonged Rainfall Events*” Geotechnical Interpretative Report, 721229/004/GIR/001/Final, January 2010

Mouchel Report “*Robin Hood’s Bay Coastal Strategy Study*” Ground Investigation Report, 1022894/GEO/R/01/02/FINAL, August 2010.

Scarborough Borough Council Records.

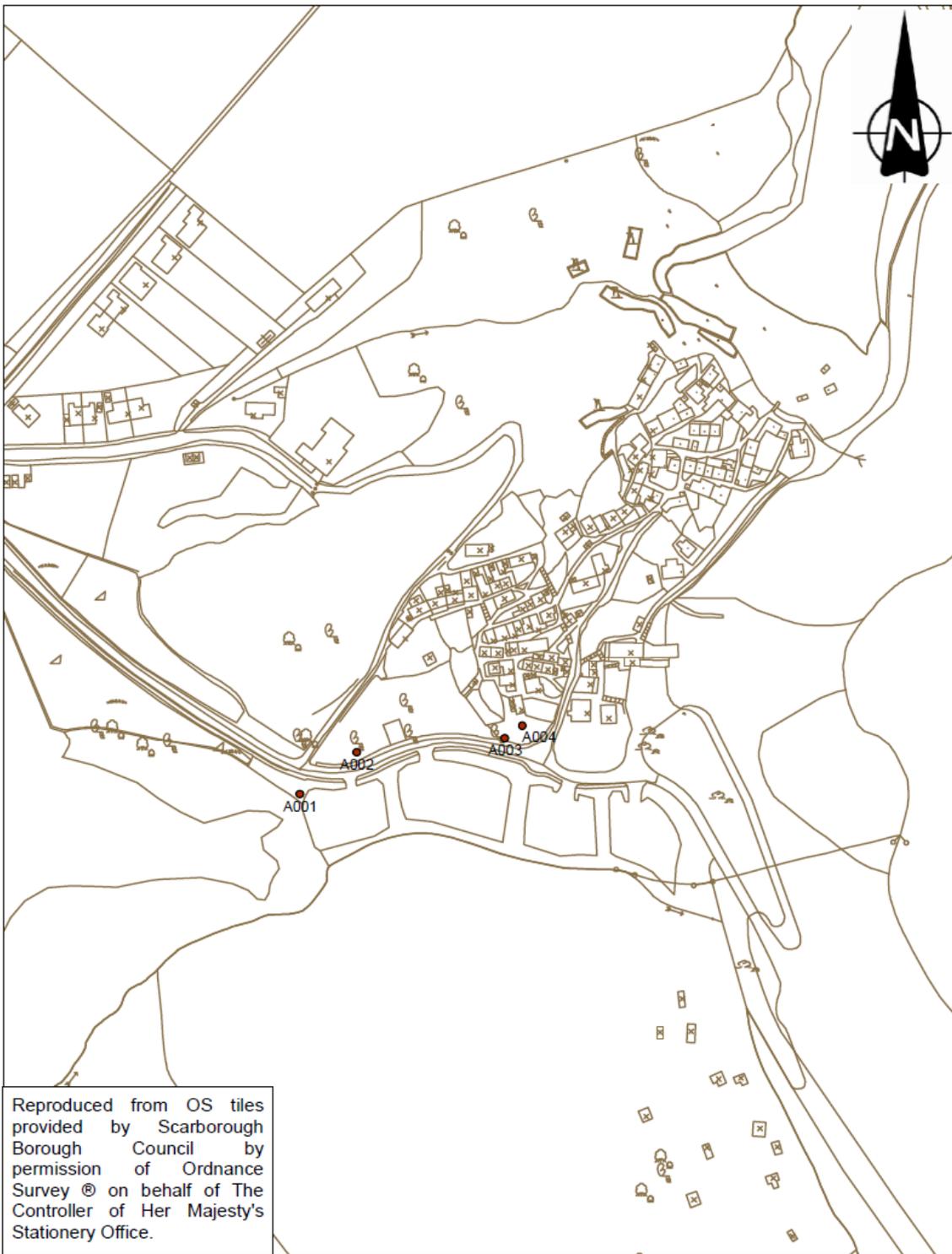
Spark, B W (1981) Geomorphology - 2<sup>nd</sup> Edition. Longman.

Tomlinson, M. J. (2001) Foundation Design and Construction - 7<sup>th</sup> Edition. Longman Ltd

Trenter, N. A., Earthworks: a guide (2001)

# **Appendix A   Exploratory Holes Location Plans**

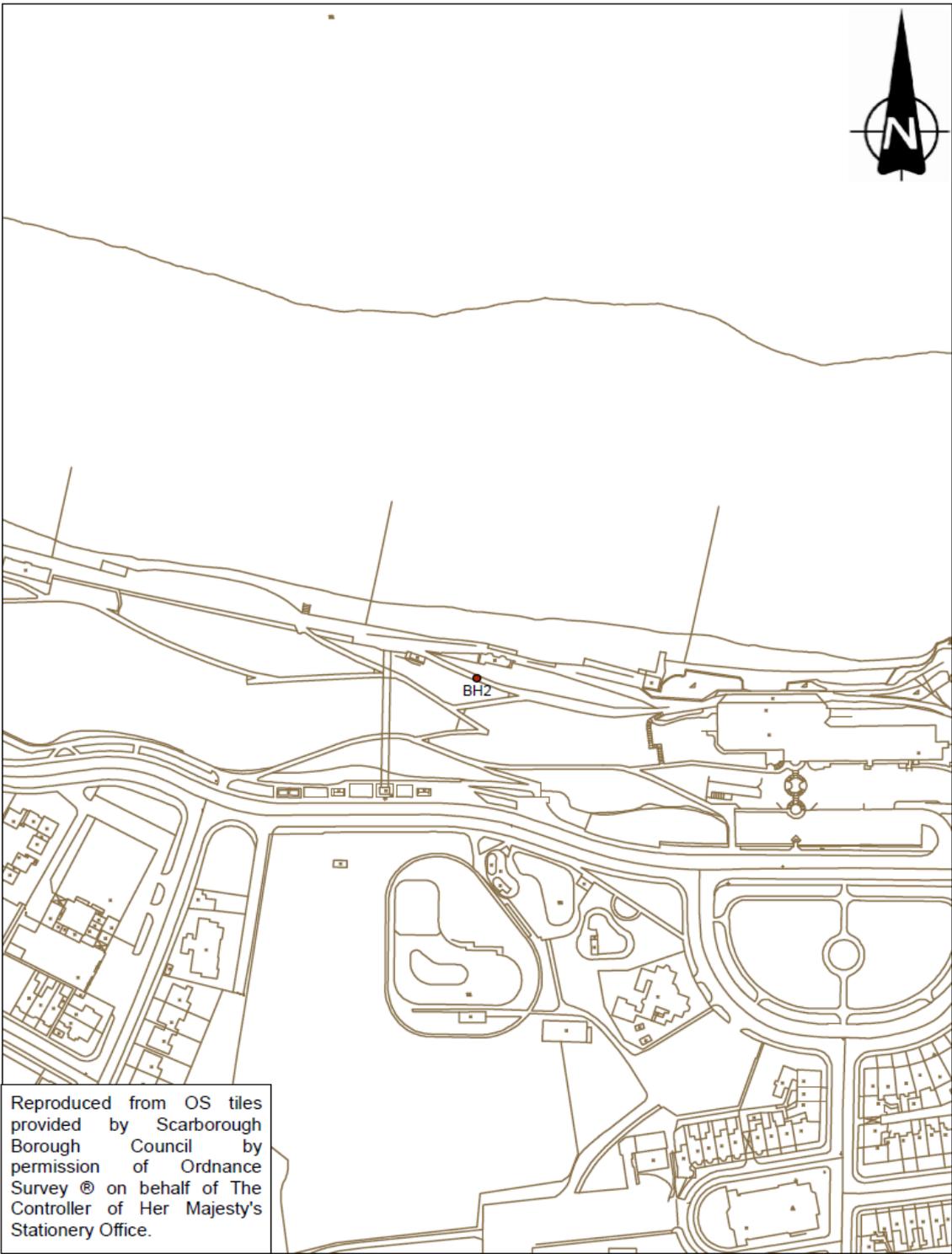




Reproduced from OS tiles provided by Scarborough Borough Council by permission of Ordnance Survey © on behalf of The Controller of Her Majesty's Stationery Office.

Runswick Bay Inclinometer Location Plan	Scale: 1:2,500	
Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data		 <i>A great place to live, work &amp; play</i>

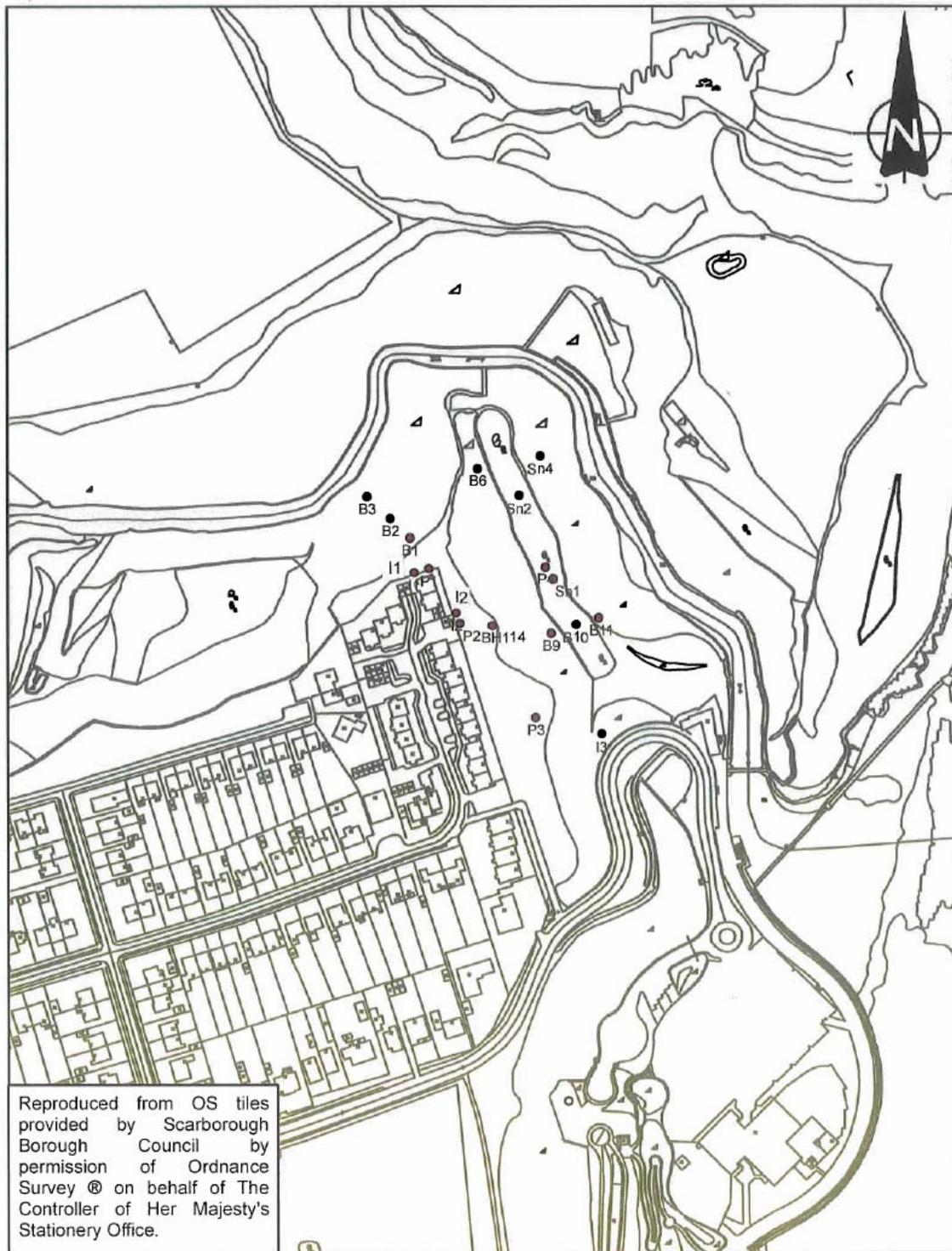
Drawing No. 1 Location Plan of Runswick Bay



Reproduced from OS tiles provided by Scarborough Borough Council by permission of Ordnance Survey © on behalf of The Controller of Her Majesty's Stationery Office.

Whitby West Cliff Inclinometer Location Plan	Scale: 1:2,500	
Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data		 <i>A great place to live, work &amp; play</i>

Drawing No. 2 Location Plan of Whitby West Cliff



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Scalby Ness Exploratory Holes Location Plan	Scale: 1:2,500	mouchel 
Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data		 <i>A great place to live, work &amp; play</i>

Drawing No. 3 Location Plan of Scalby Ness



Reproduced from OS tiles provided by Scarborough Borough Council by permission of Ordnance Survey © on behalf of The Controller of Her Majesty's Stationery Office.

<p>Scarborough North Bay Exploratory Holes Location Plan</p>	<p>Scale: 1:2,500</p>	
<p>Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data</p>		 <p><i>A great place to live, work &amp; play</i></p>

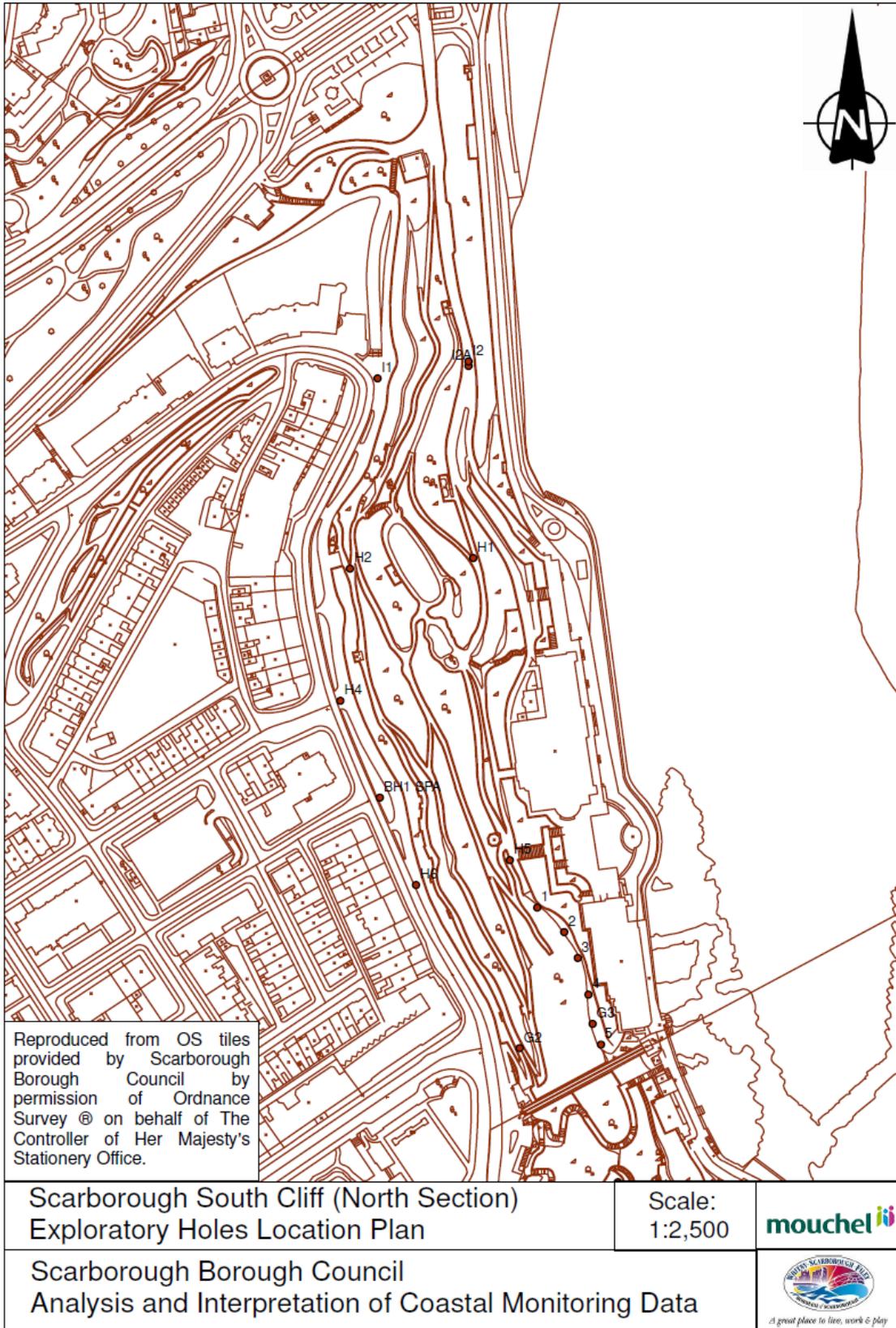
Drawing No. 4 Location Plan of Scarborough North Bay (Oasis Cafe)



Reproduced from OS tiles provided by Scarborough Borough Council by permission of Ordnance Survey © on behalf of The Controller of Her Majesty's Stationery Office.

<p>Scarborough North Bay (East Section) Exploratory Holes Location Plan</p>	<p>Scale: 1:2,500</p>	
<p>Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data</p>		 <i>A great place to live, work &amp; play</i>

Drawing No. 5 Location Plan of Scarborough North Bay (East)



Drawing No. 6 Location Plan of Scarborough South Cliff (North)



Reproduced from OS tiles provided by Scarborough Borough Council by permission of Ordnance Survey © on behalf of The Controller of Her Majesty's Stationery Office.

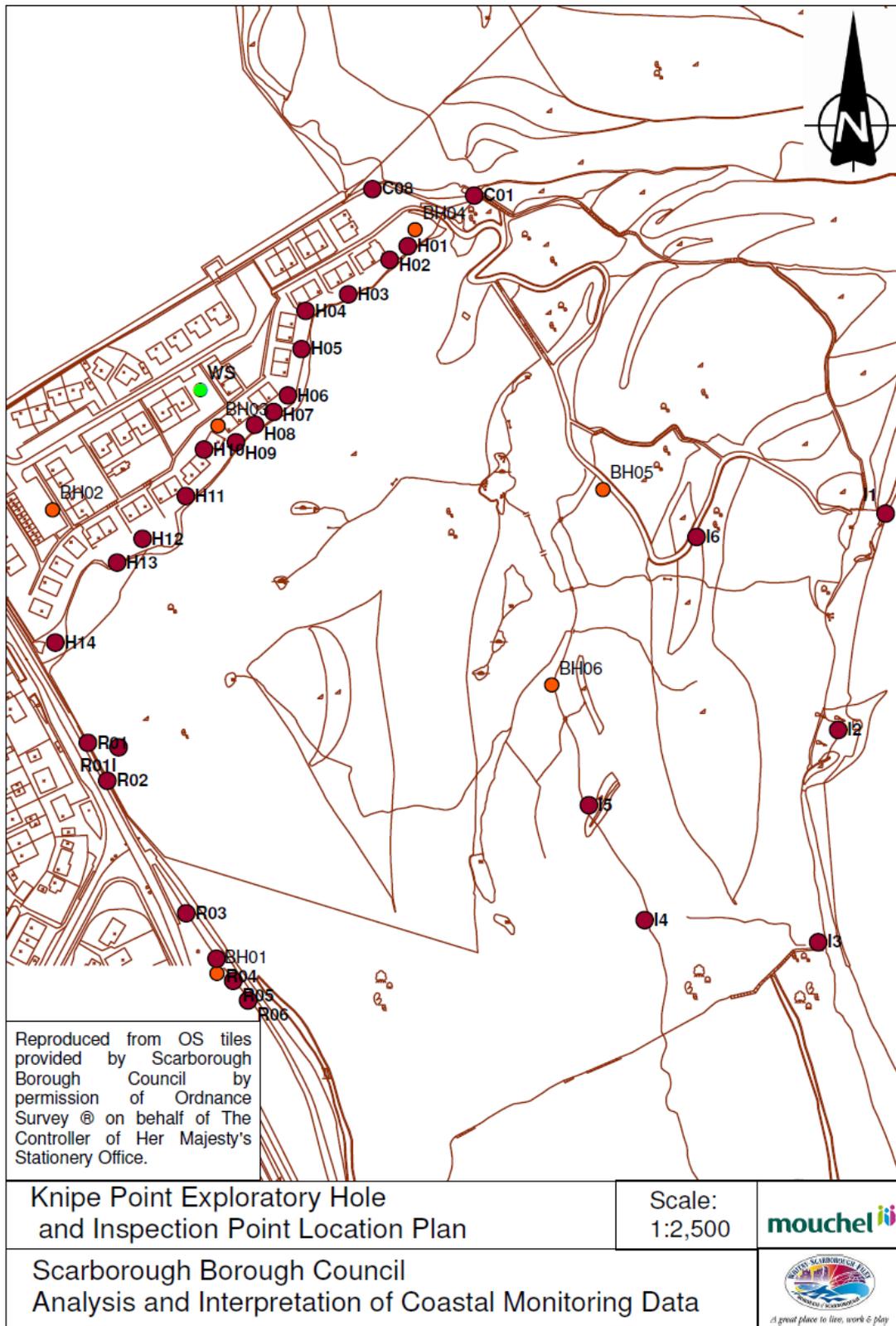
<p>Scarborough South Cliff (Central Section) Exploratory Holes Location Plan</p>	<p>Scale: 1:2,500</p>	
<p>Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data</p>		 <i>A great place to live, work &amp; play</i>

Drawing No. 7 Location Plan of Scarborough South Cliff (Central)

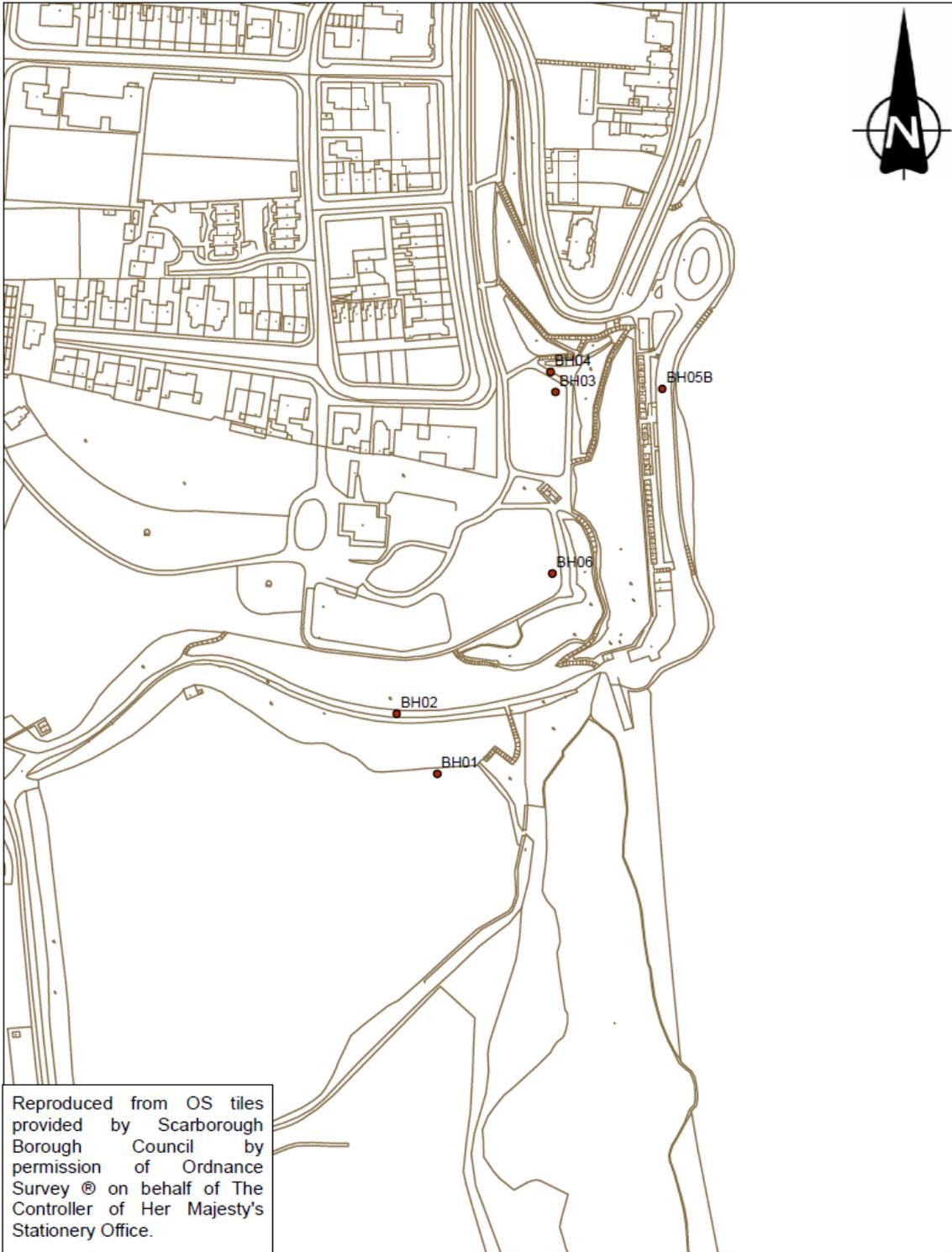


<p>Scarborough South Cliff (South Section) Exploratory Holes Location Plan</p>	<p>Scale: 1:2,500</p>	
<p>Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data</p>		 <i>A great place to live, work &amp; play</i>

Drawing No. 8 Location Plan of Scarborough South Cliff (South)



Drawing No. 9 Location Plan of Knipe Point



<p>Filey Exploratory Holes Location Plan</p>	<p>Scale: 1:2,500</p>	
<p>Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data</p>		 <p><i>A great place to live, work &amp; play</i></p>

Drawing No. 10 Location Plan of Filey Town



<p>Filey Flat Cliffs Exploratory Holes Location Plan</p>	<p>Scale: 1:2,500</p>	
<p>Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data</p>		 <i>A great place to live, work &amp; play</i>

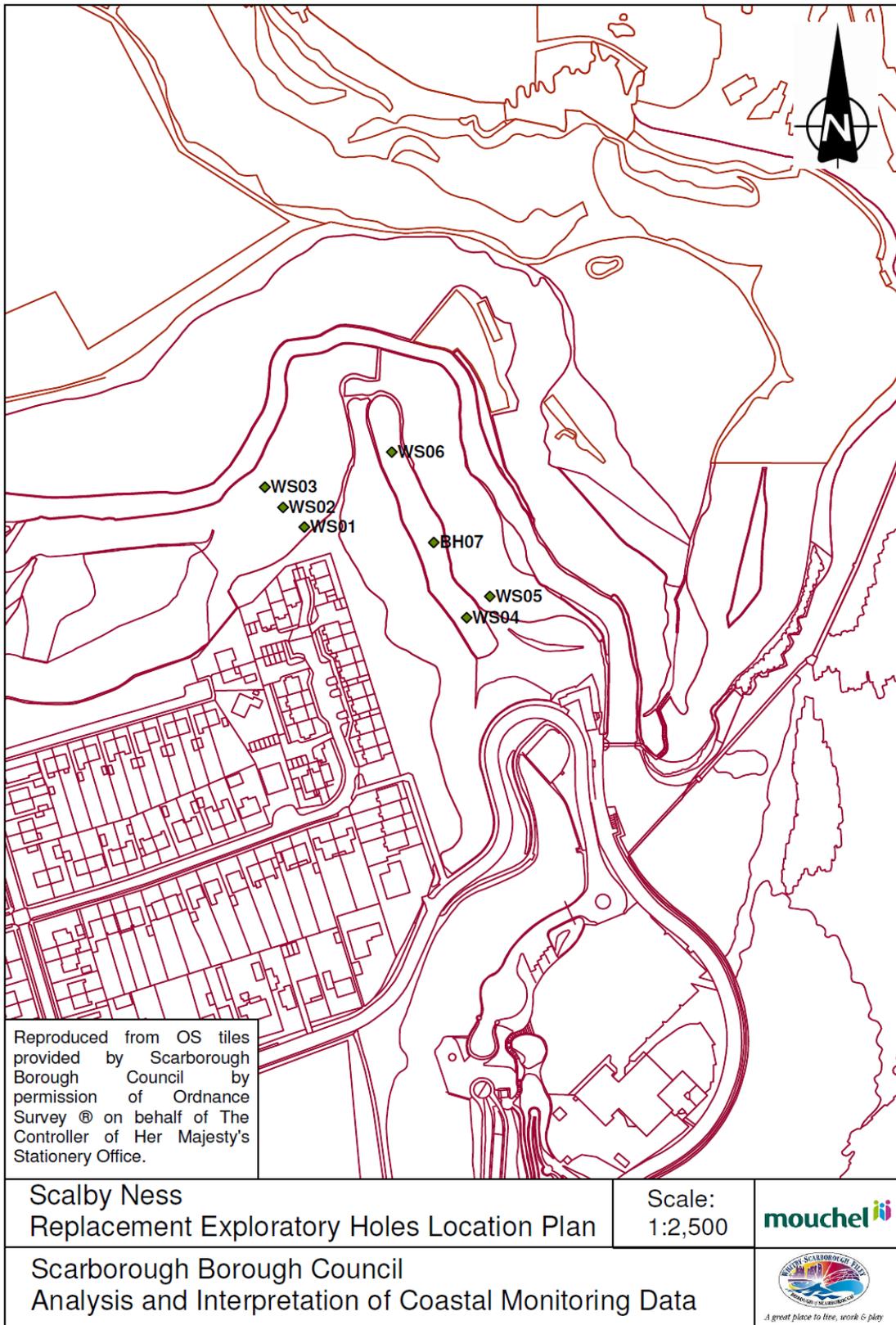
Drawing No. 11 Location Plan of Filey Flat Cliffs



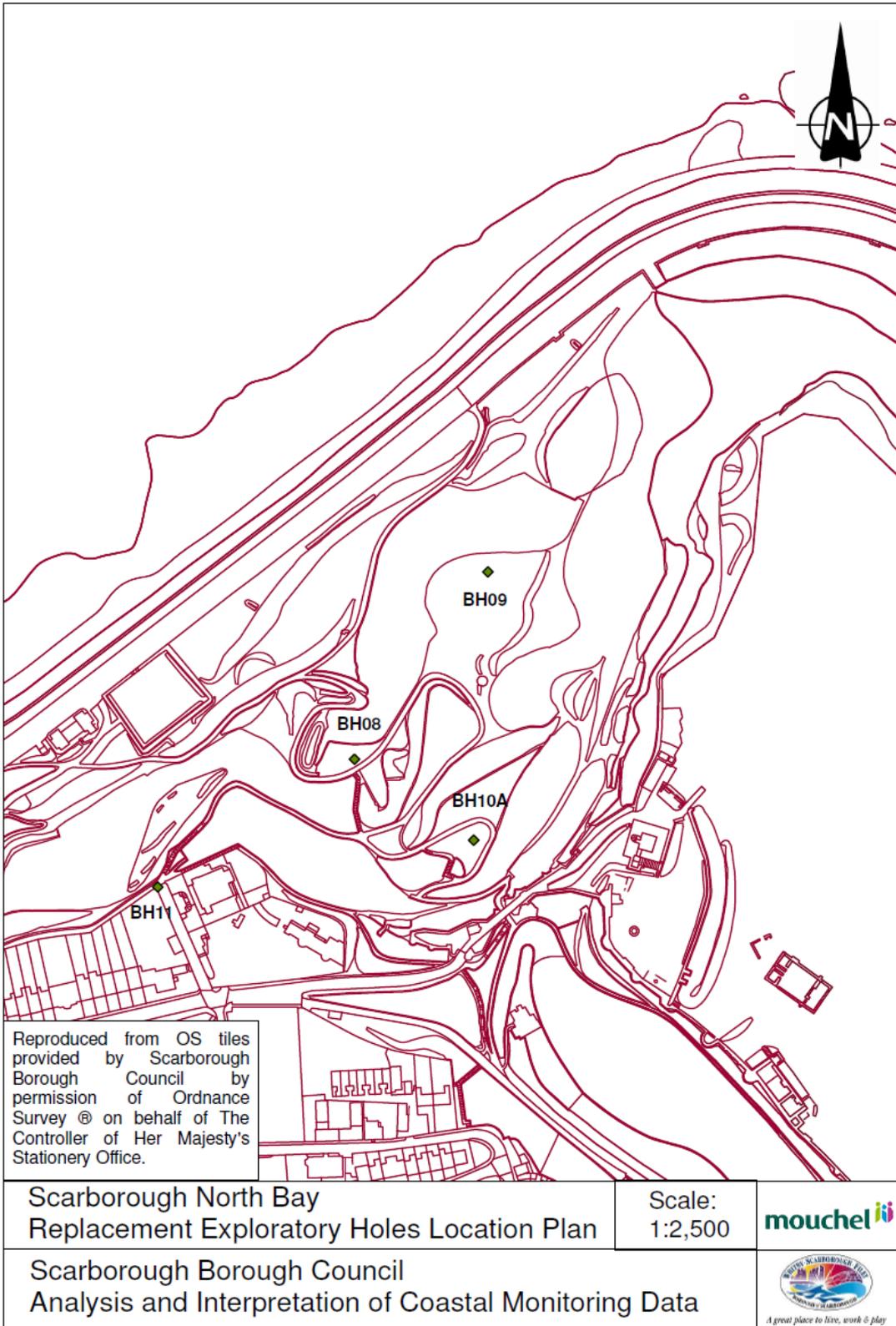
Drawing No. 12 Location Plan of Robin Hood's Bay

# **Appendix B Replacement Installation Location Plans**

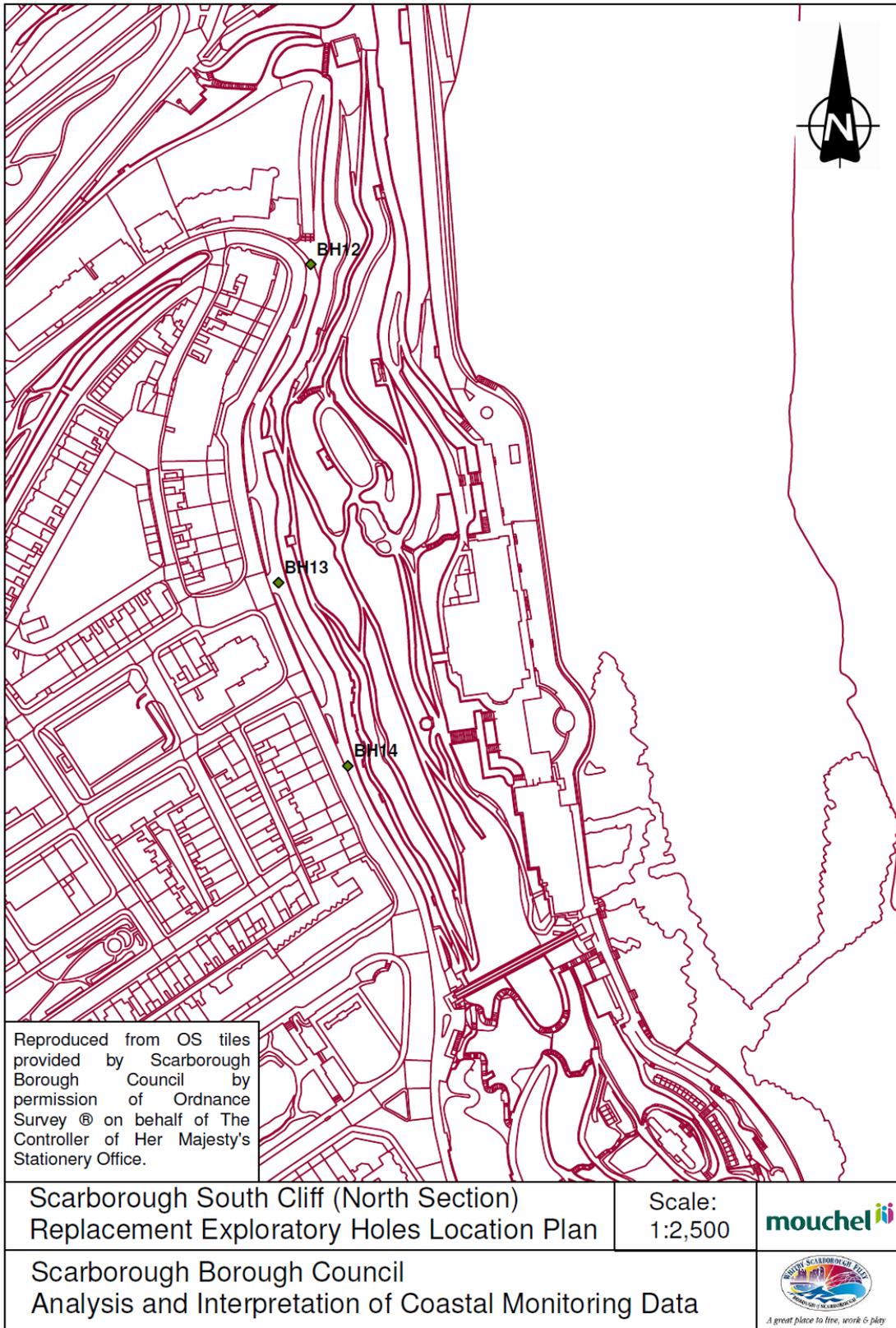




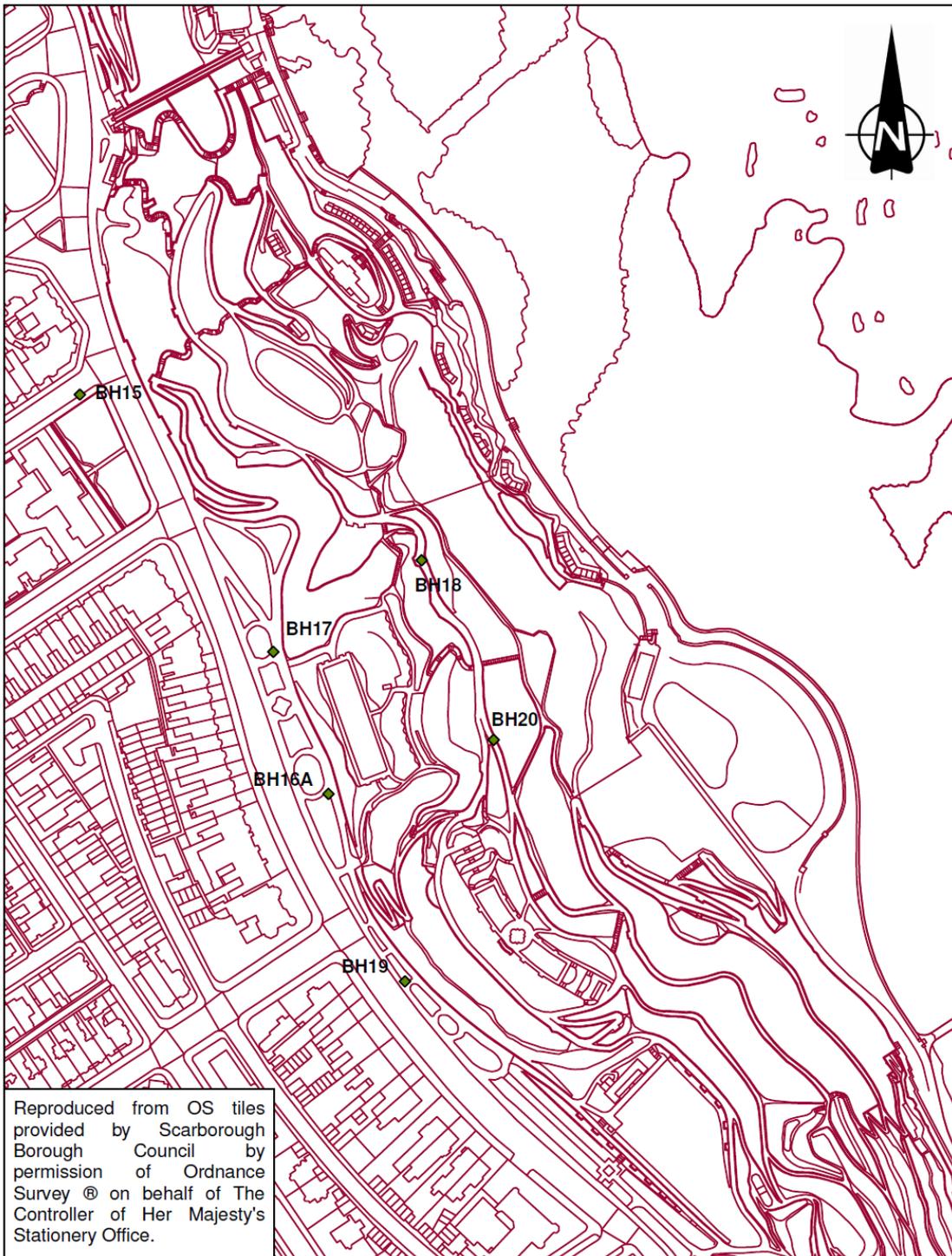
Drawing No. 1 Location Plan of Scalby Ness



Drawing No. 2 Location Plan of The Holms, Scarborough North Bay

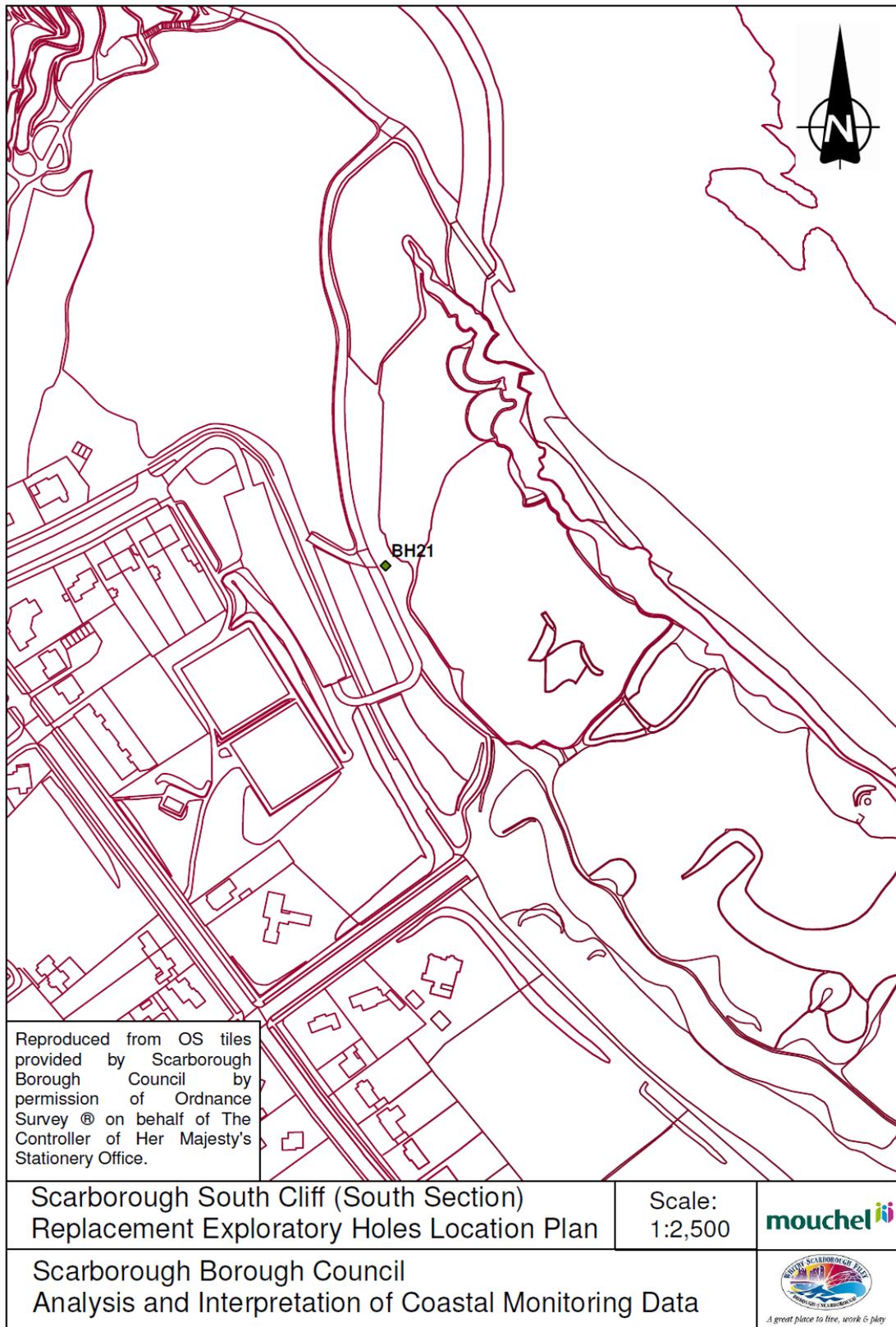


Drawing No. 3 Location Plan of Scarborough South Cliff (North Section)



Scarborough South Cliff (Central Section) Replacement Exploratory Holes Location Plan	Scale: 1:2,500	
Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data		 <i>A great place to live, work &amp; play</i>

Drawing No. 4 Location Plan of Scarborough South Cliff (Central Section)



Drawing No. 5 Location Plan of Scarborough South Cliff (South Section)

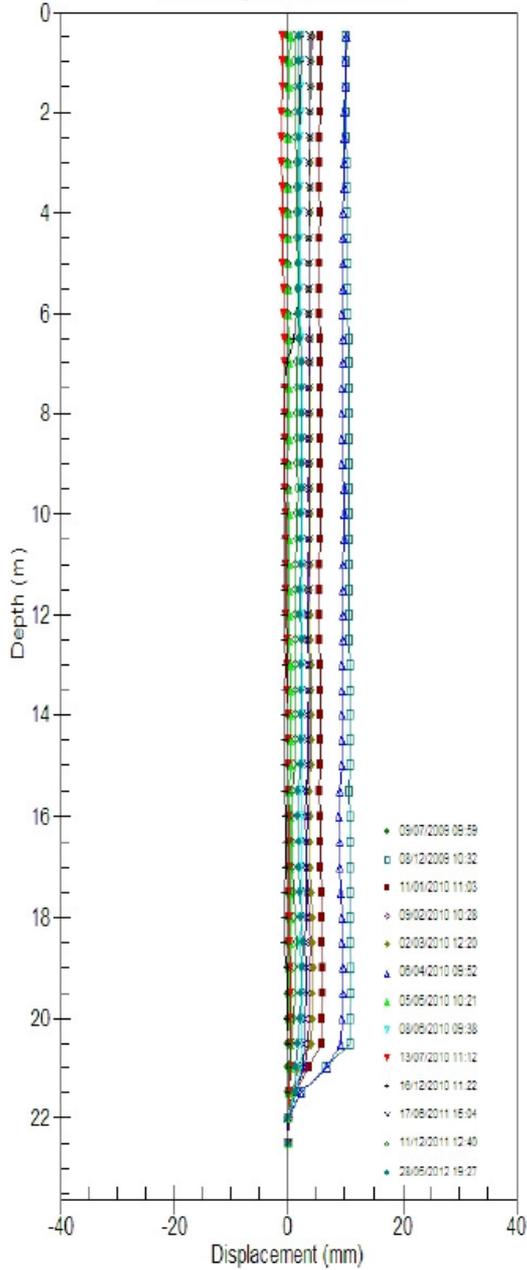


## **Appendix C    Inclinometer Graphs**



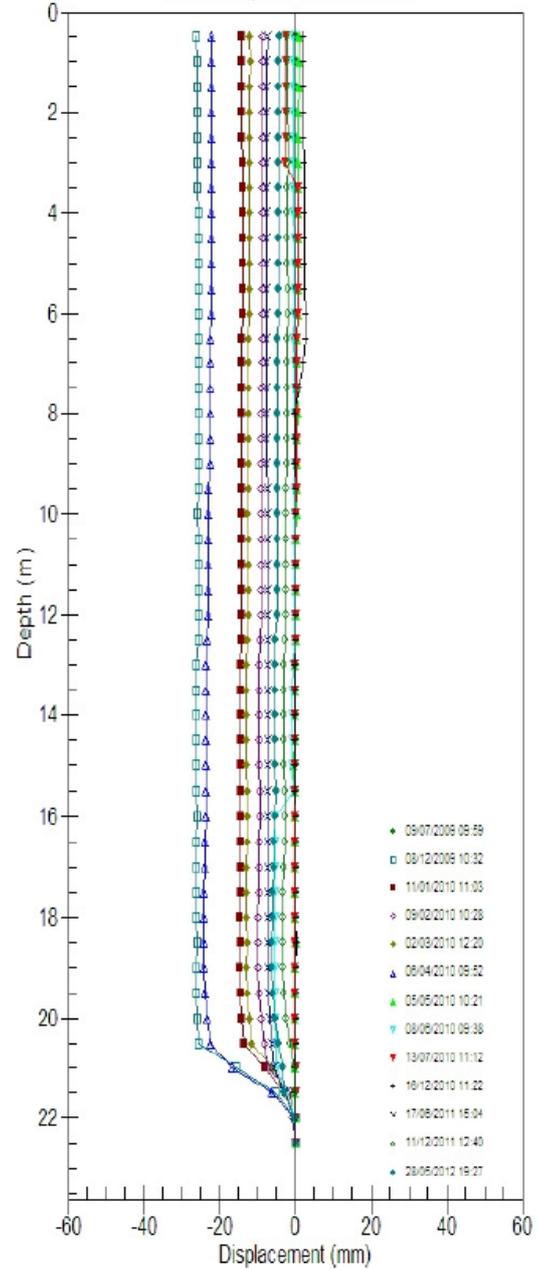
### RB:A001 - A Axis Cumulative

Initial survey: 09/07/2009 09:59



### RB:A001 - B Axis Cumulative

Initial survey: 09/07/2009 09:59



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Runswick Bay

INSTALLATION: A001

COMPANY: Mouchel Ltd

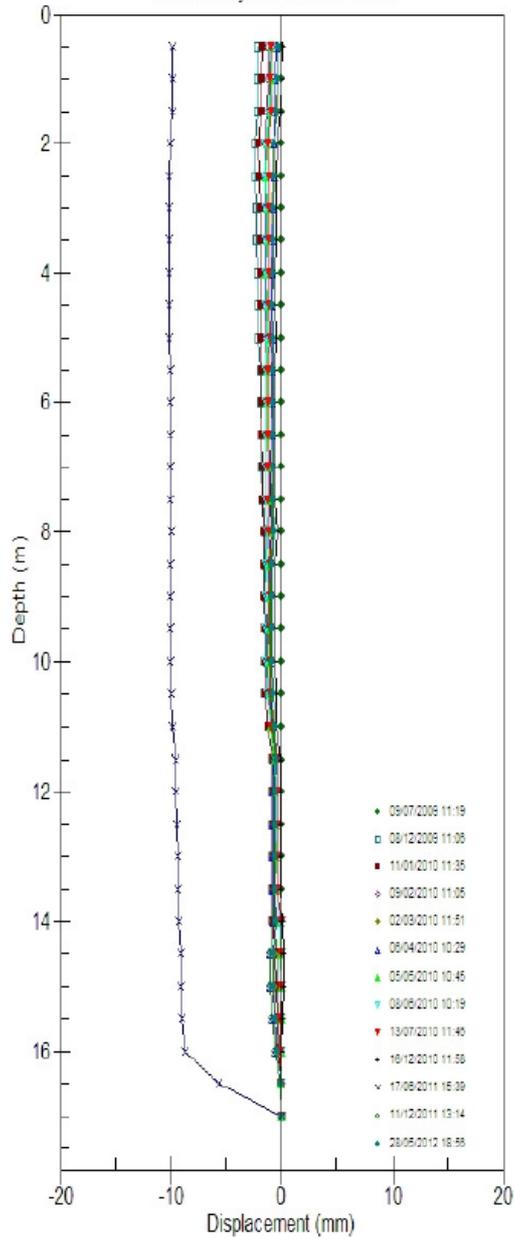
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East



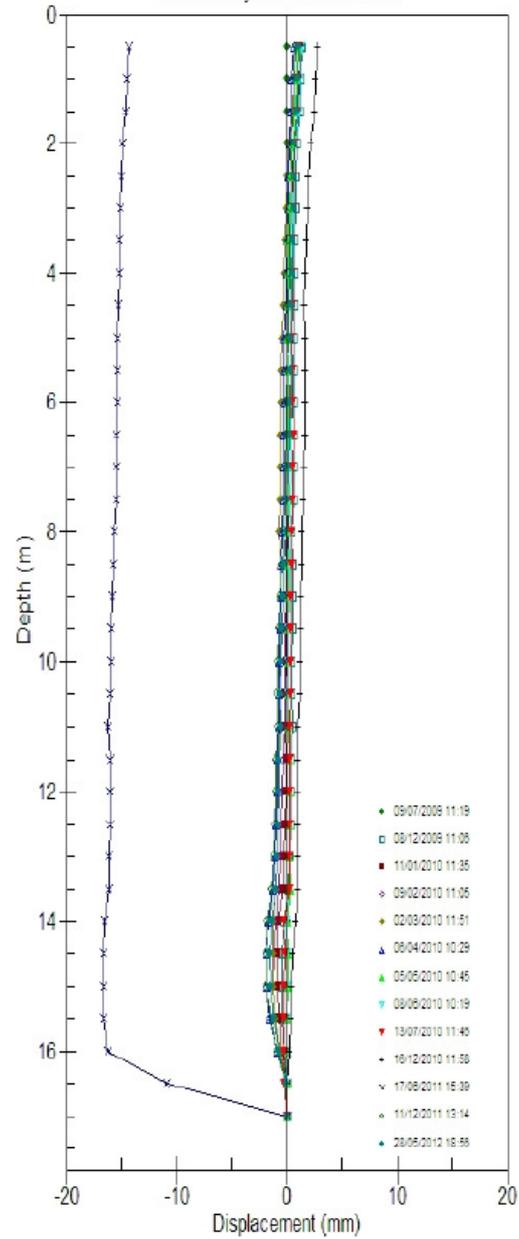
### RB:A002 - A Axis Cumulative

Initial survey: 09/07/2009 11:19



### RB:A002 - B Axis Cumulative

Initial survey: 09/07/2009 11:19



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Runswick Bay

INSTALLATION: A002

COMPANY: Mouchel Ltd

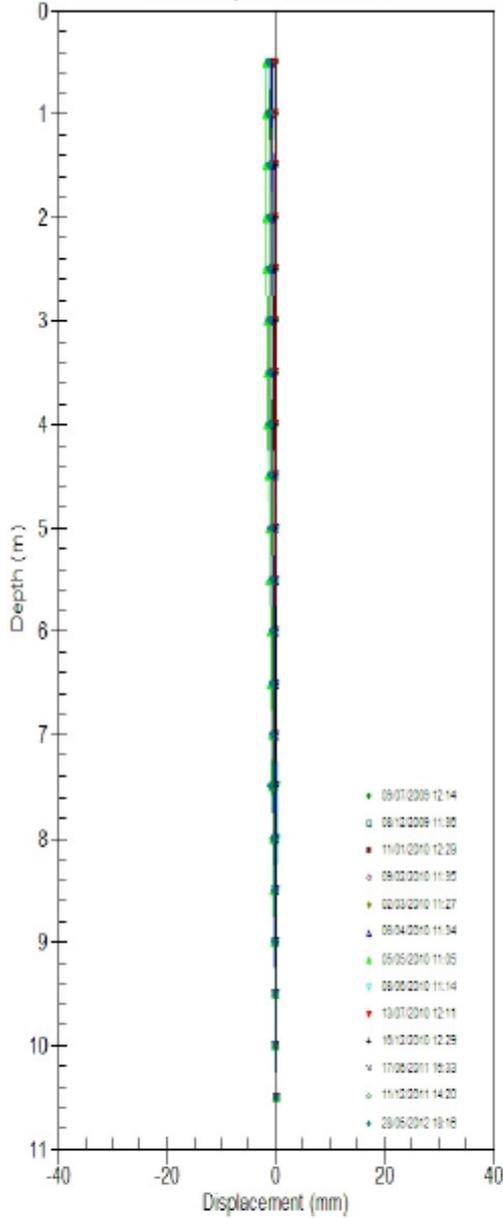
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East



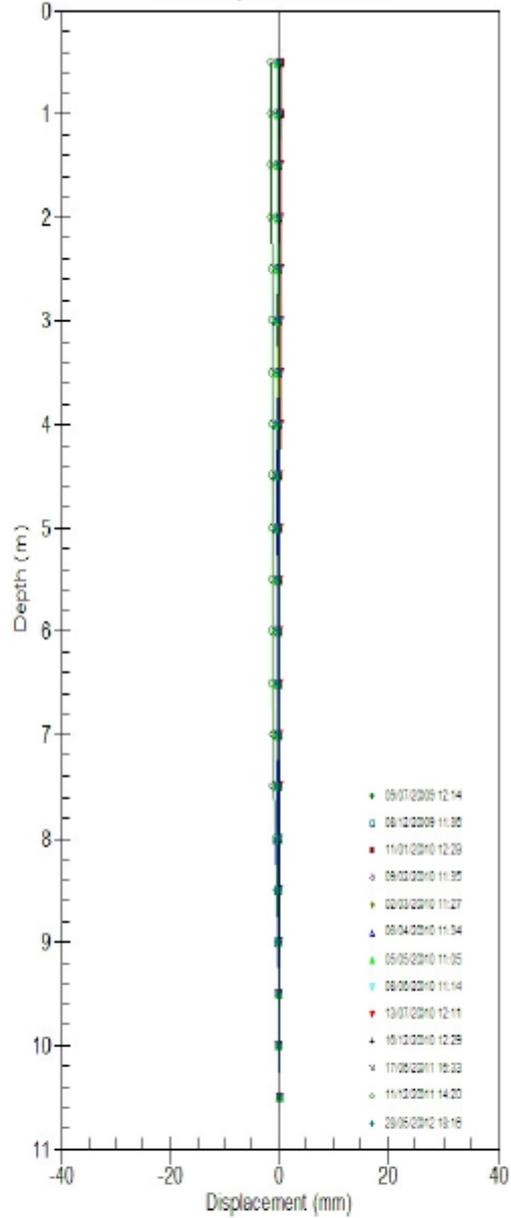
### RB:A003 - A Axis Cumulative

Initial survey: 09/07/2009 12:14



### RB:A003 - B Axis Cumulative

Initial survey: 09/07/2009 12:14



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Runswick Bay

INSTALLATION: A003

COMPANY: Mouchel Ltd

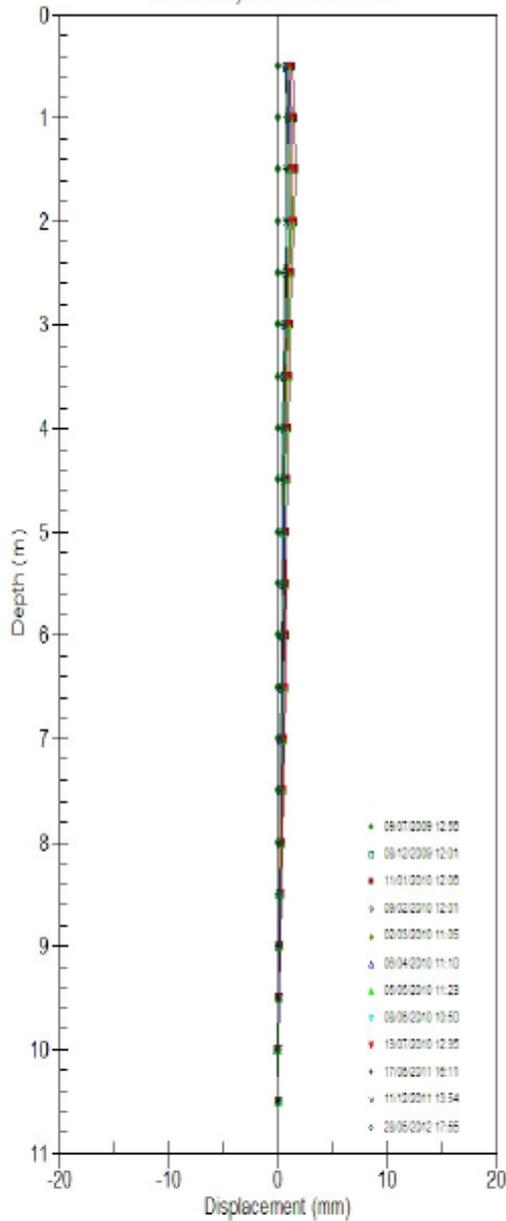
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = South East

mouchel 

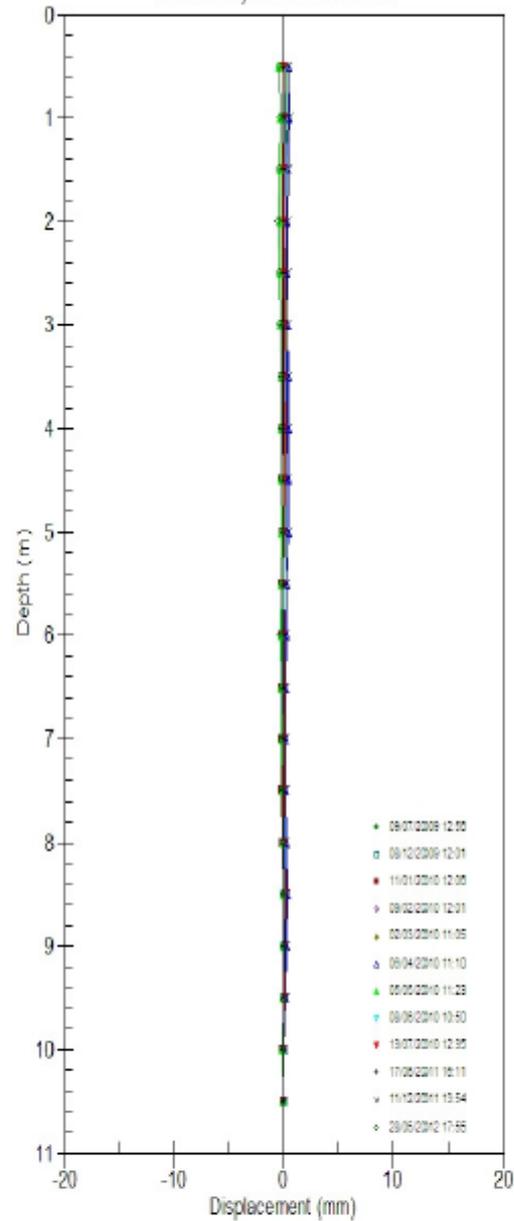
### RB:A004 - A Axis Cumulative

Initial survey: 09/07/2009 12:56



### RB:A004 - B Axis Cumulative

Initial survey: 09/07/2009 12:56



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Runswick Bay

INSTALLATION: A004

COMPANY: Mouchel Ltd

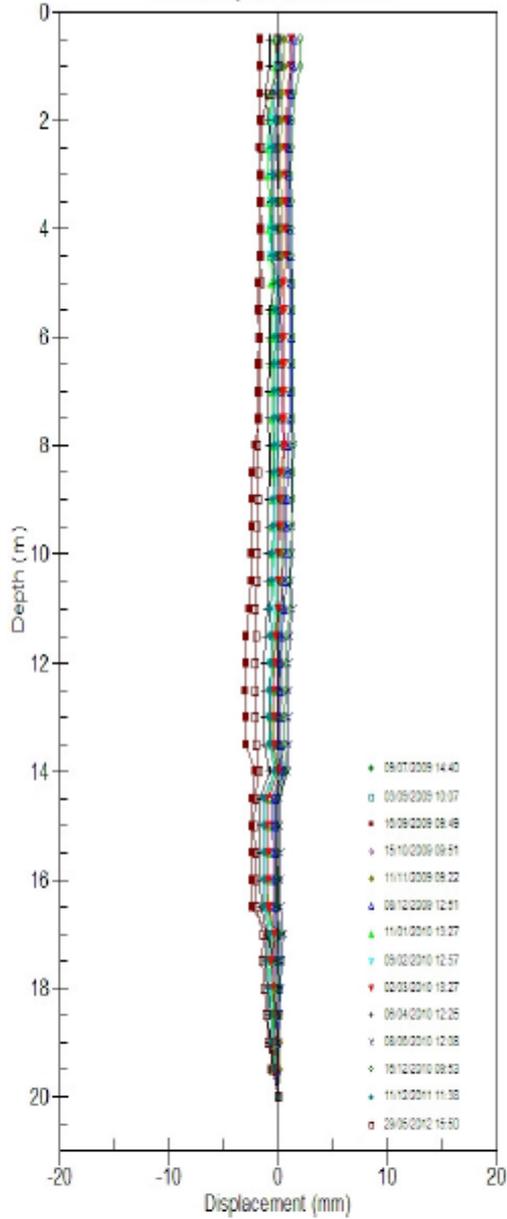
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = South East



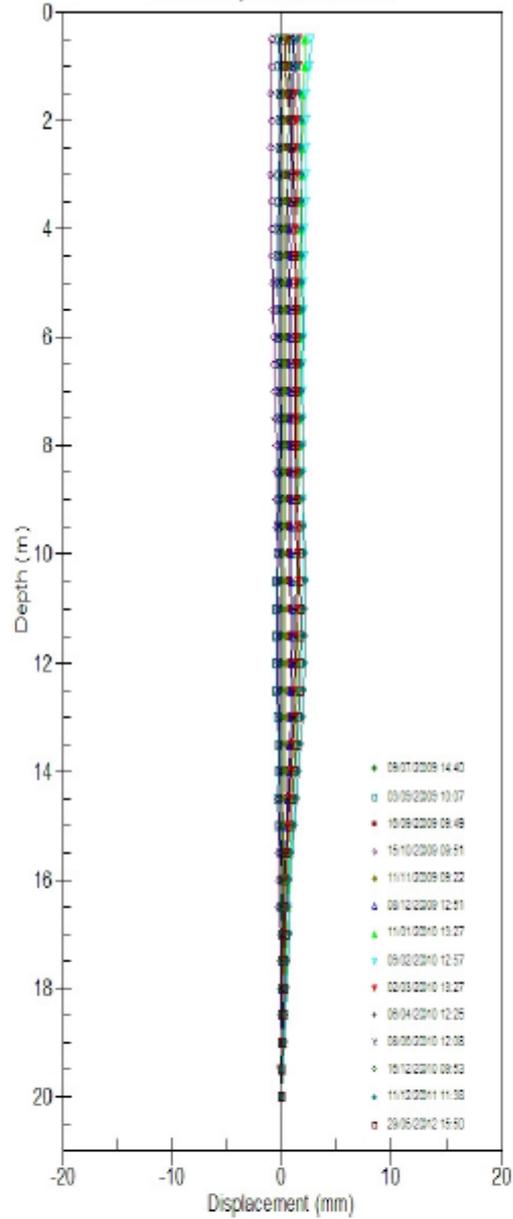
### WWC:BH2 - A Axis Cumulative

Initial survey: 09/07/2009 14:40



### WWC:BH2 - B Axis Cumulative

Initial survey: 09/07/2009 14:40

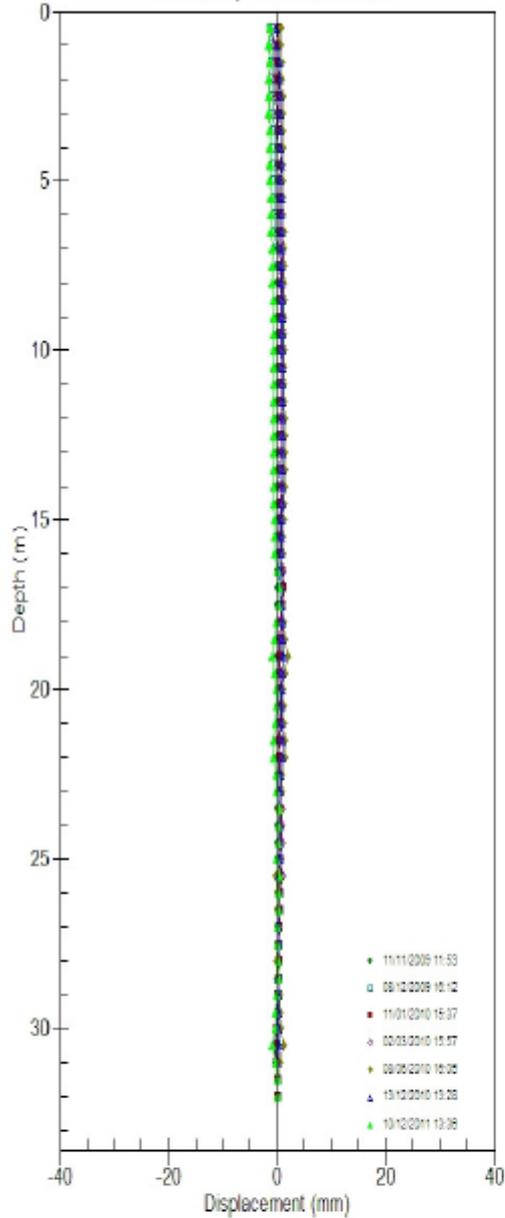


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
SITE: Whitby West Cliff  
INSTALLATION: BH2  
COMPANY: Mouchel Ltd  
CLIENT: Scarborough Borough Council  
NOTE: A0 Direction = North



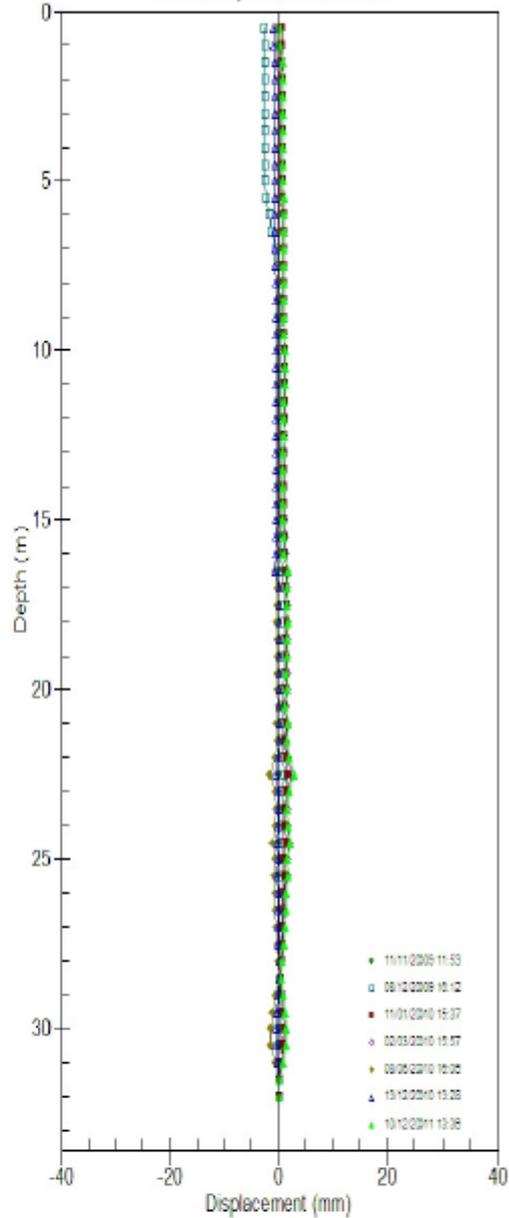
### SN:I1 - A Axis Cumulative

Initial survey: 11/11/2009 11:53



### SN:I1 - B Axis Cumulative

Initial survey: 11/11/2009 11:53



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scalby Ness

INSTALLATION: I1

COMPANY: Mouchel Ltd

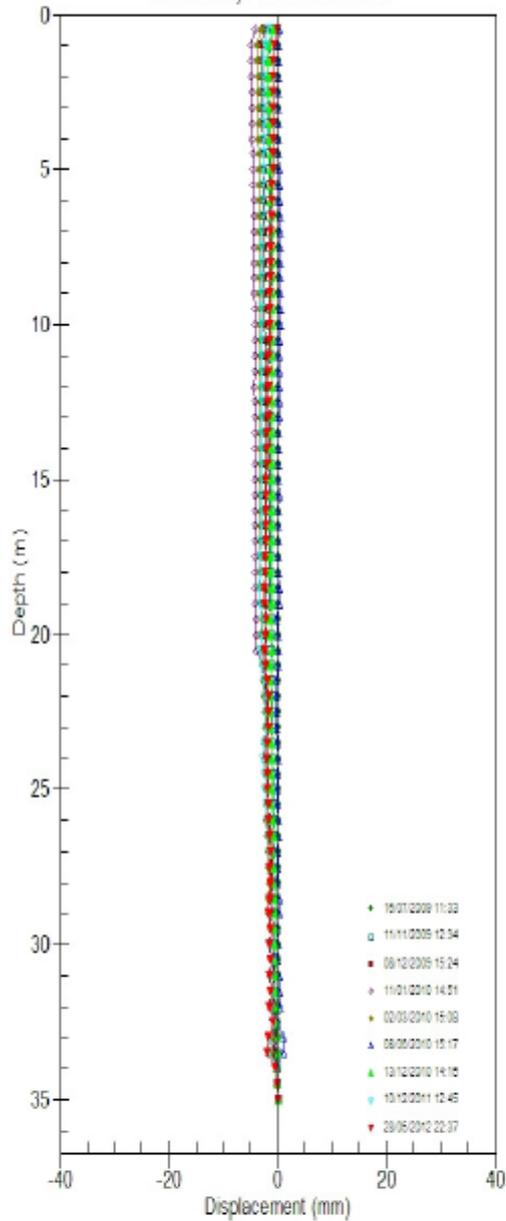
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North



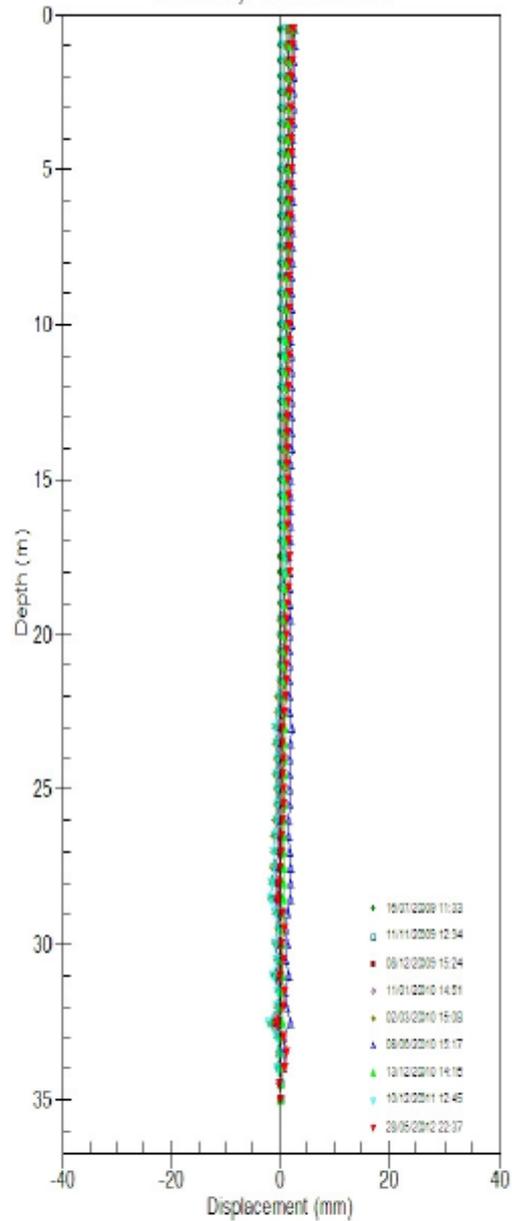
### SN:I2 - A Axis Cumulative

Initial survey: 16/07/2009 11:33



### SN:I2 - B Axis Cumulative

Initial survey: 16/07/2009 11:33



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scalby Ness

INSTALLATION: I2

COMPANY: Mouchel Ltd

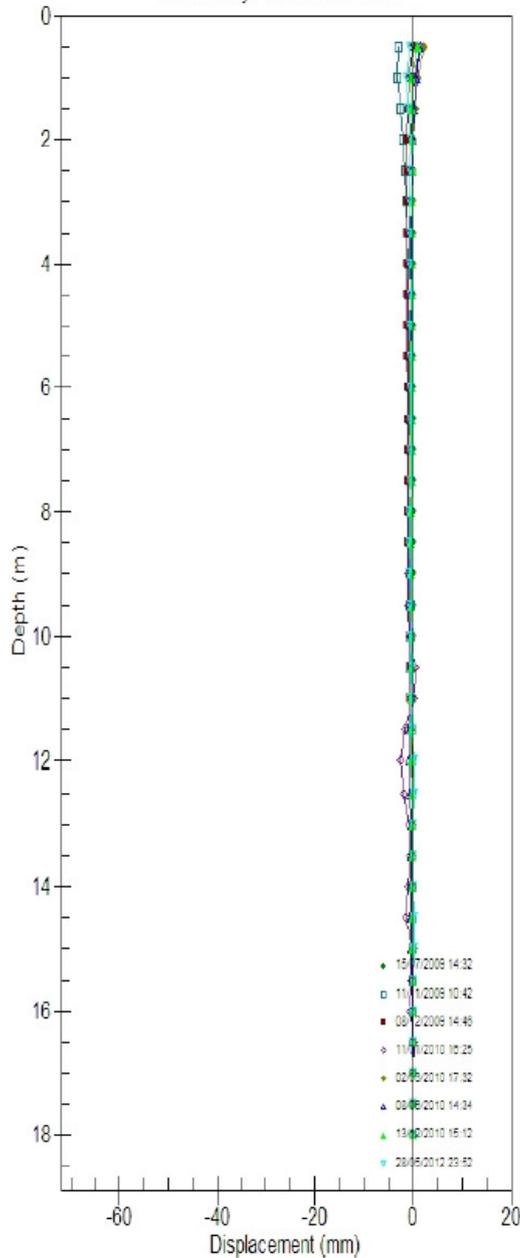
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North East

mouchel 

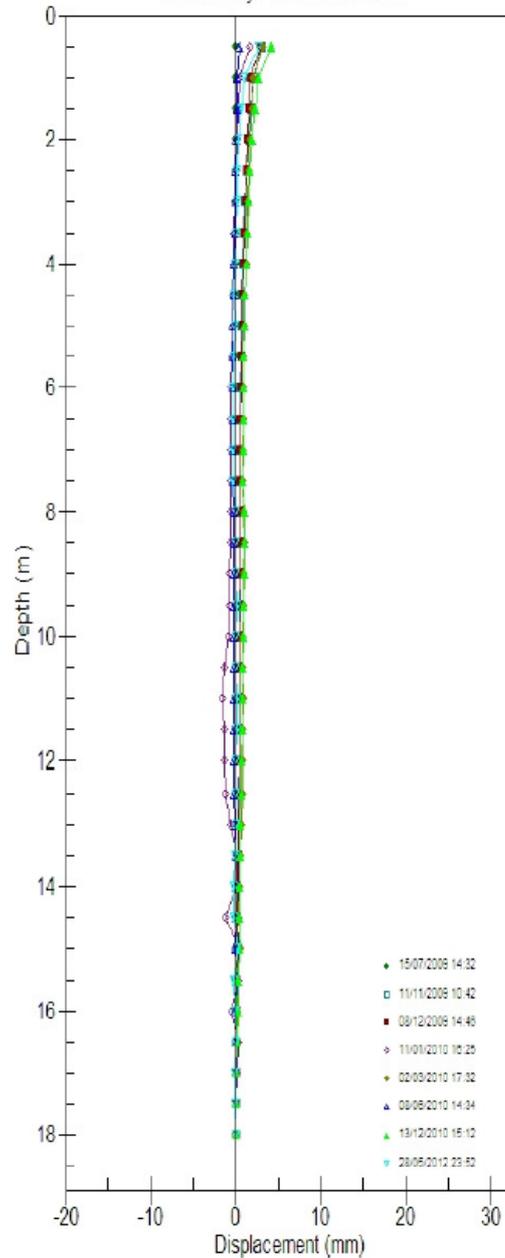
### SN:I3 - A Axis Cumulative

Initial survey: 15/07/2009 14:32



### SN:I3 - B Axis Cumulative

Initial survey: 15/07/2009 14:32



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scalby Ness

INSTALLATION: I3

COMPANY: Mouchel Ltd

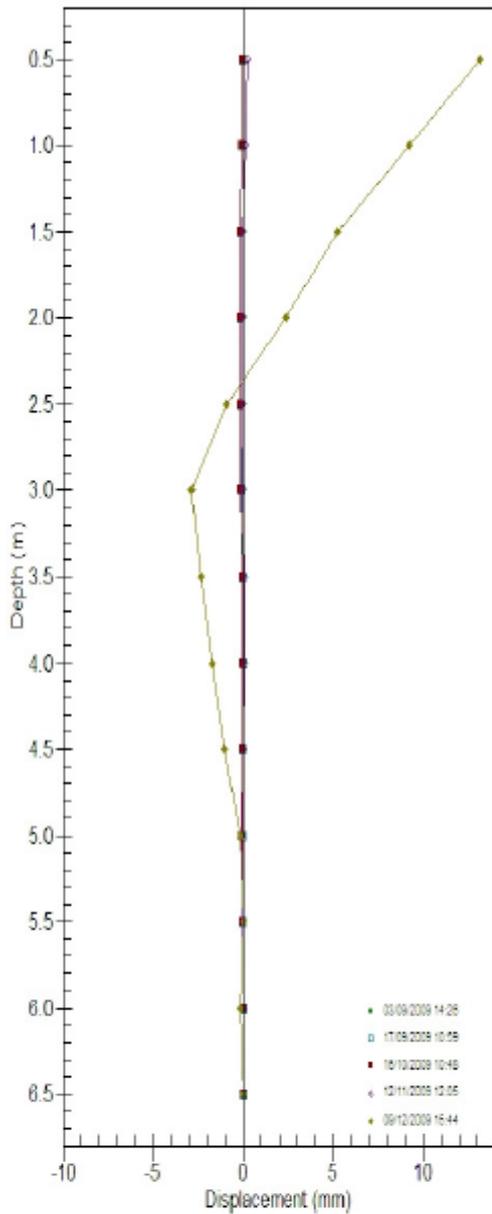
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East

mouchel 

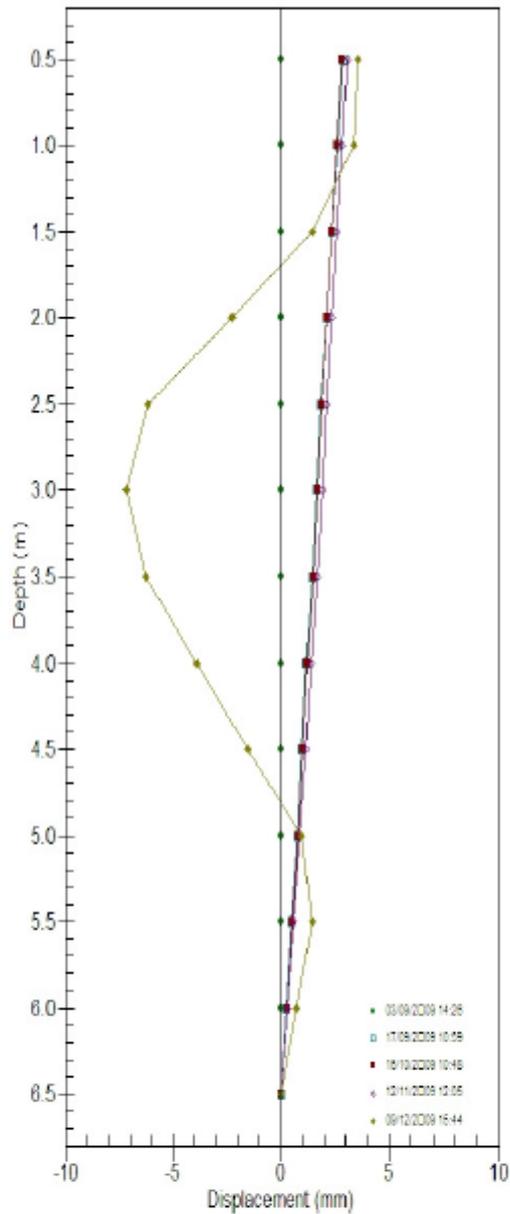
### OASIS:BH1 - A Axis Cumulative

Initial survey: 03/09/2009 14:26



### OASIS:BH1 - B Axis Cumulative

Initial survey: 03/09/2009 14:26

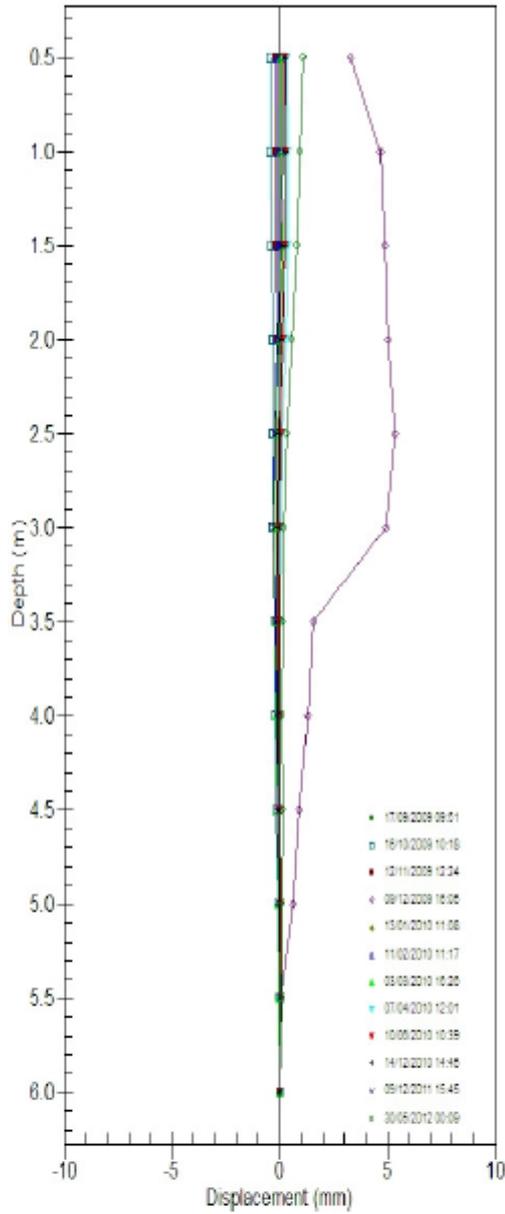


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
SITE: OASIS CAFE  
INSTALLATION: BH1  
COMPANY: Mouchel Ltd  
CLIENT: Scarborough Borough Council  
NOTE: A0 Direction = East



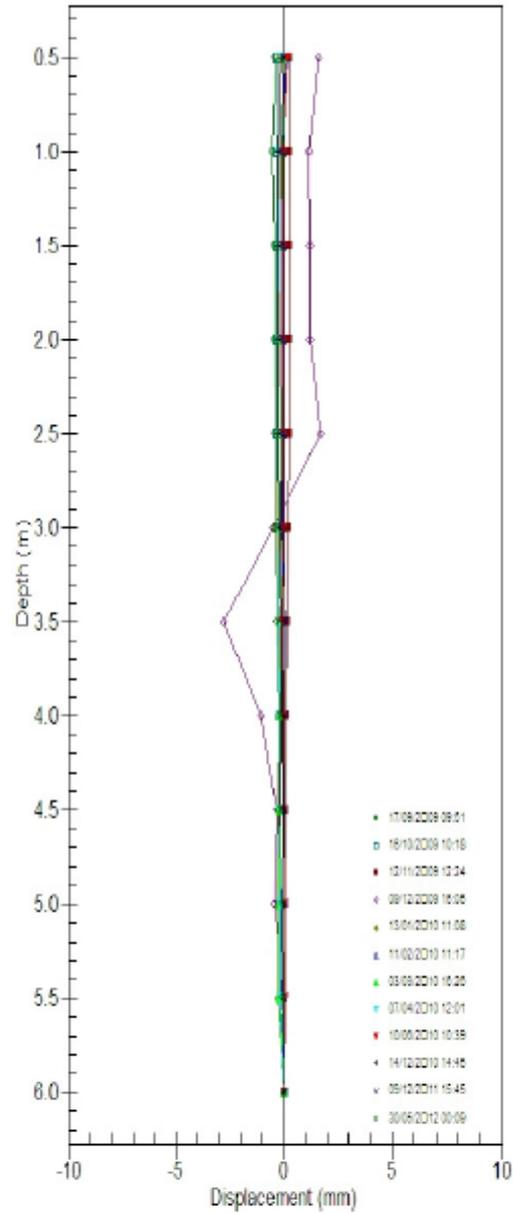
### OASIS:BH3 - A Axis Cumulative

Initial survey: 17/09/2009 09:51



### OASIS:BH3 - B Axis Cumulative

Initial survey: 17/09/2009 09:51



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: OASIS CAFE

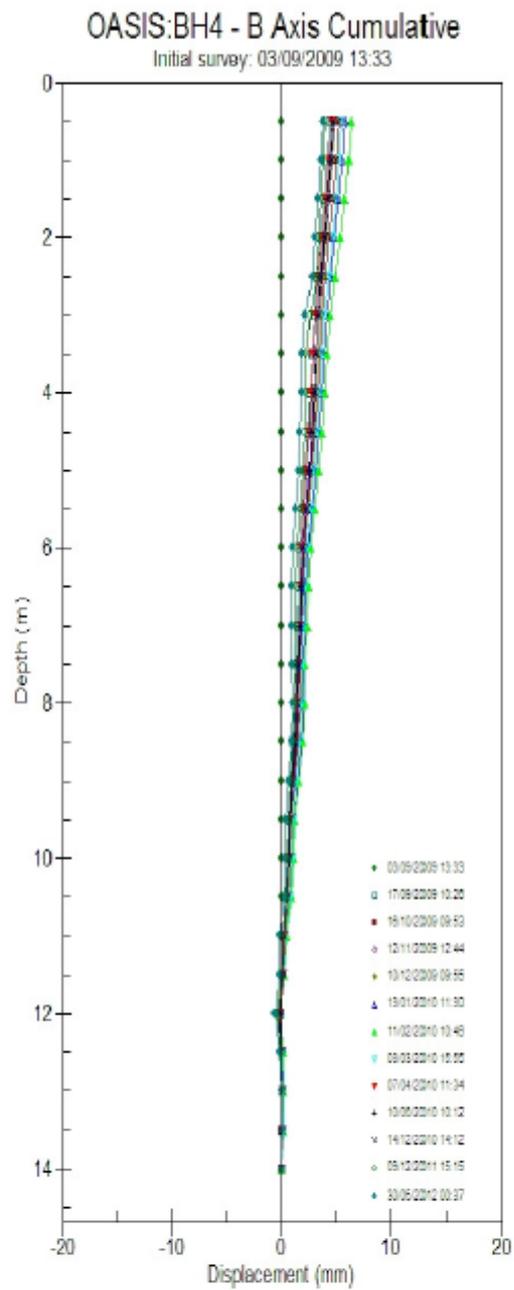
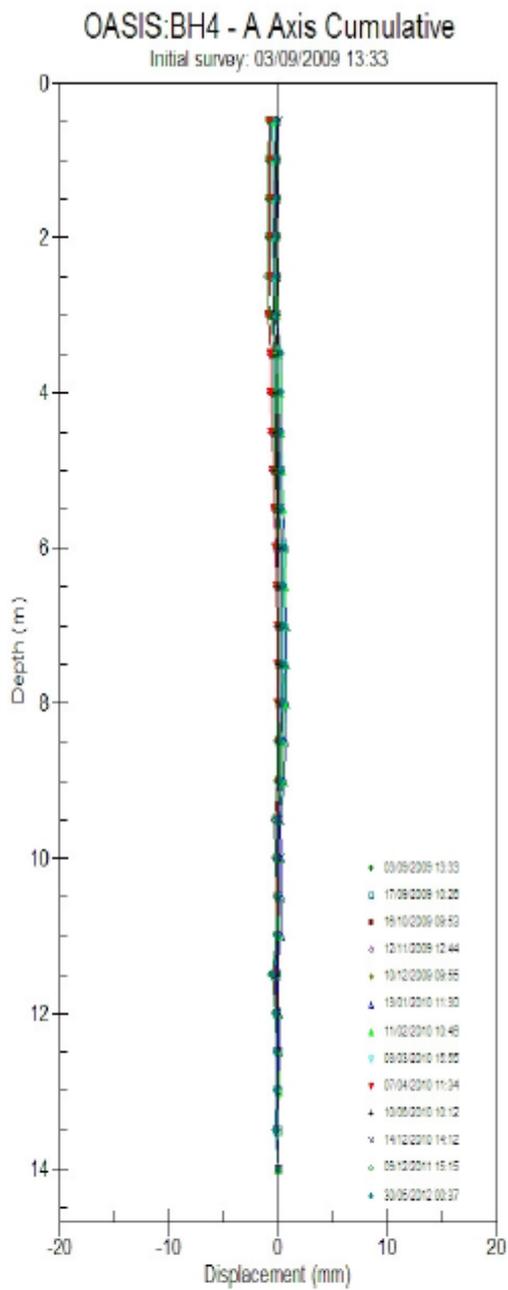
INSTALLATION: BH3

COMPANY: Mouchel Ltd

CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East

mouchel 

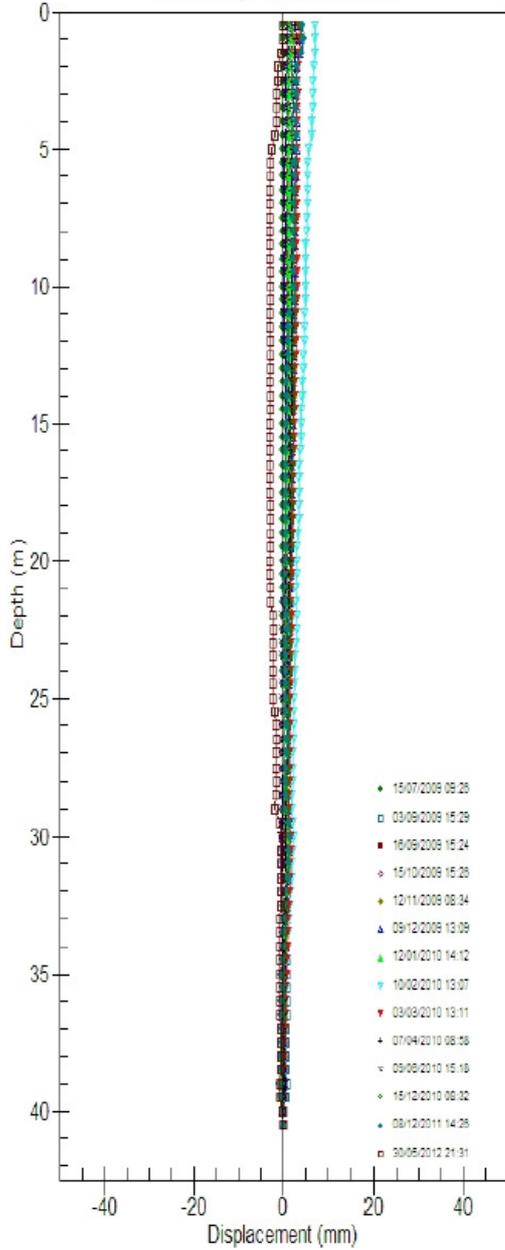


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
 SITE: OASIS CAFE  
 INSTALLATION: BH4  
 COMPANY: Mouchel Ltd  
 CLIENT: Scarborough Borough Council  
 NOTE: A0 Direction = East



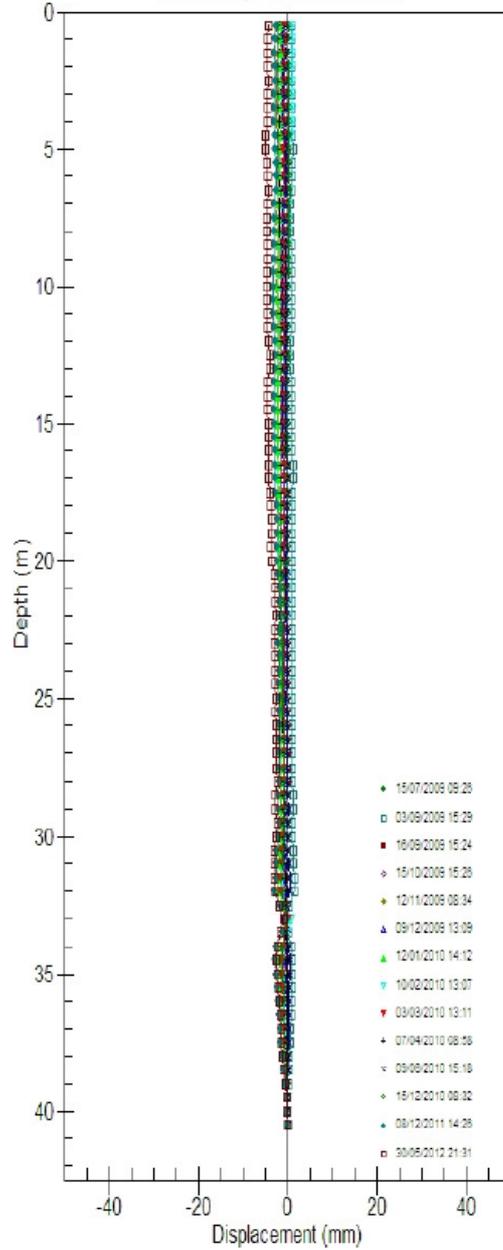
### SSC:AA04 - A Axis Cumulative

Initial survey: 15/07/2009 09:26



### SSC:AA04 - B Axis Cumulative

Initial survey: 15/07/2009 09:26



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough South Cliffs

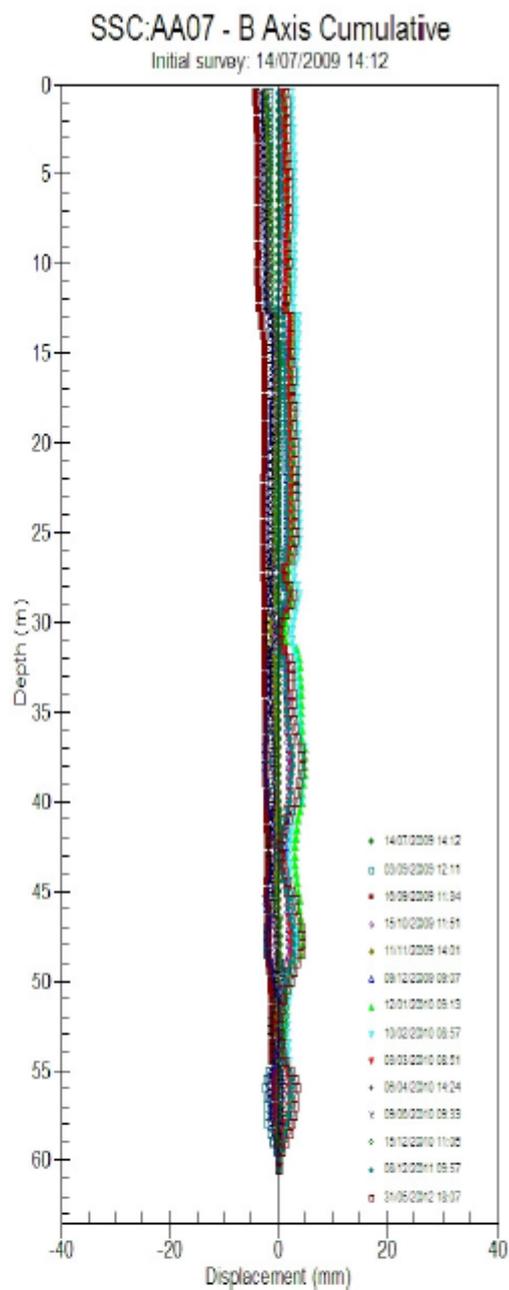
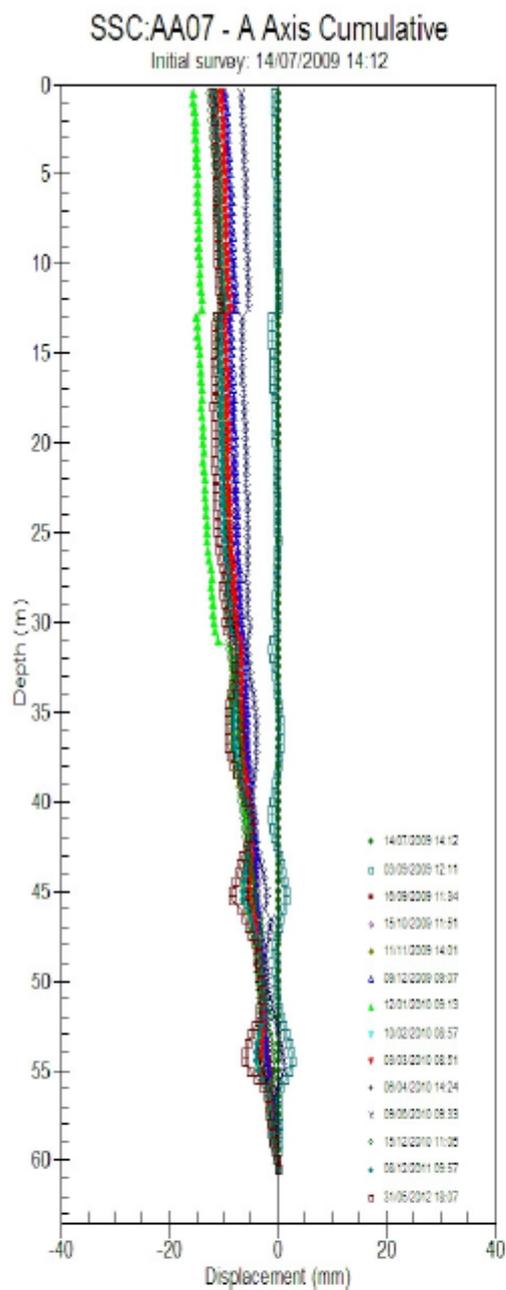
INSTALLATION: AA04

COMPANY: Mouchel Ltd

CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North East



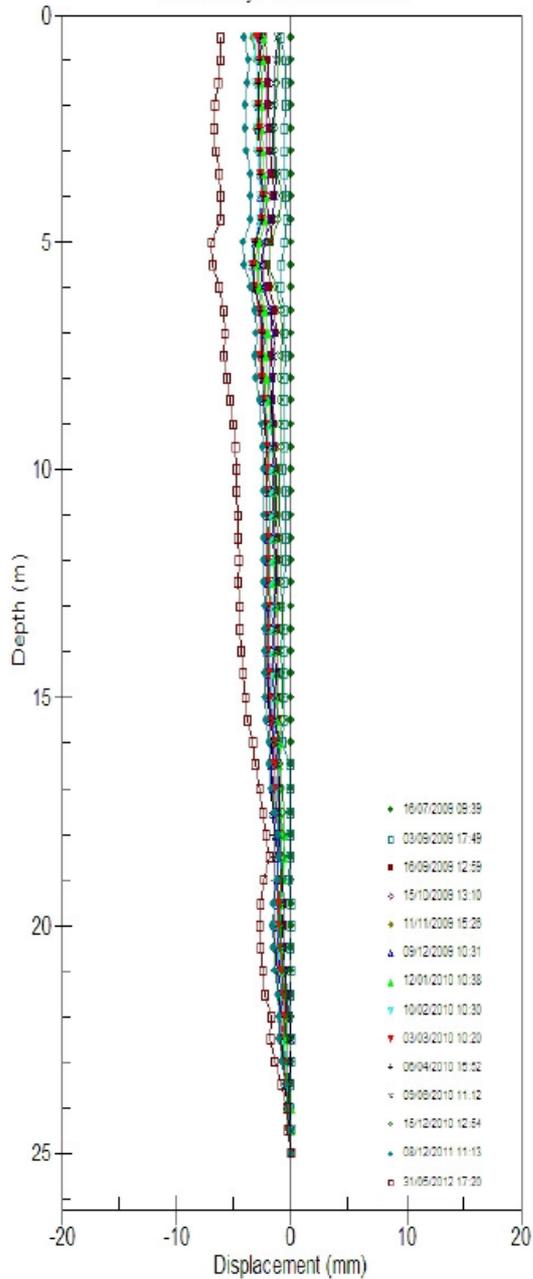


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
 SITE: Scarborough South Cliffs  
 INSTALLATION: AA07 (BH2)  
 COMPANY: Mouchel Ltd  
 CLIENT: Scarborough Borough Council  
 NOTE: A0 Direction = North East



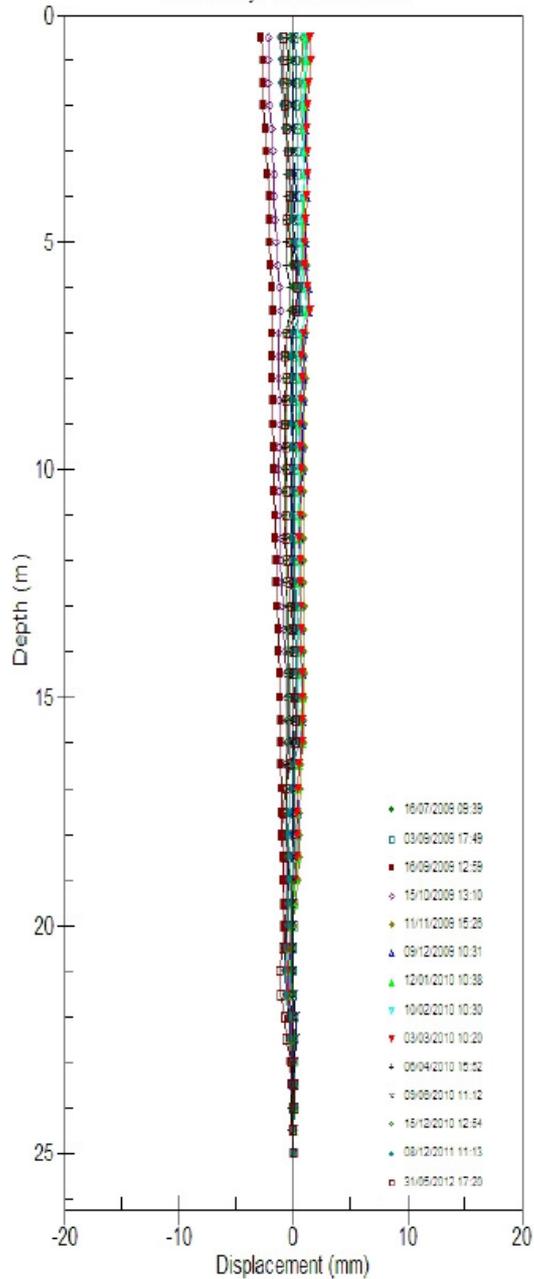
### SSC:AA08 - A Axis Cumulative

Initial survey: 16/07/2009 09:39



### SSC:AA08 - B Axis Cumulative

Initial survey: 16/07/2009 09:39



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough South Cliffs

INSTALLATION: AA08

COMPANY: Mouchel Ltd

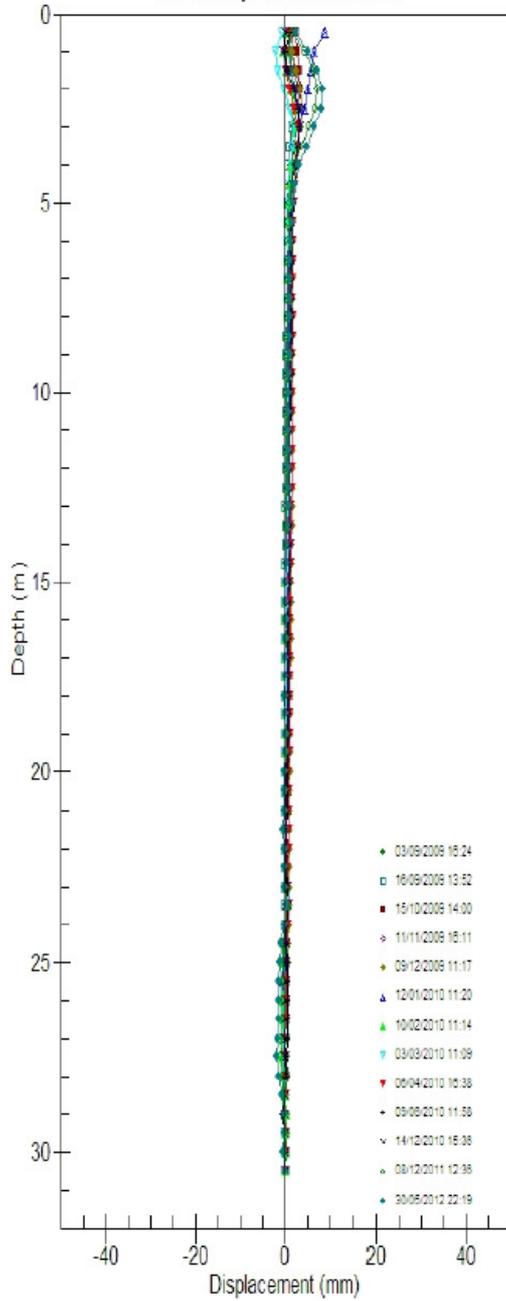
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East



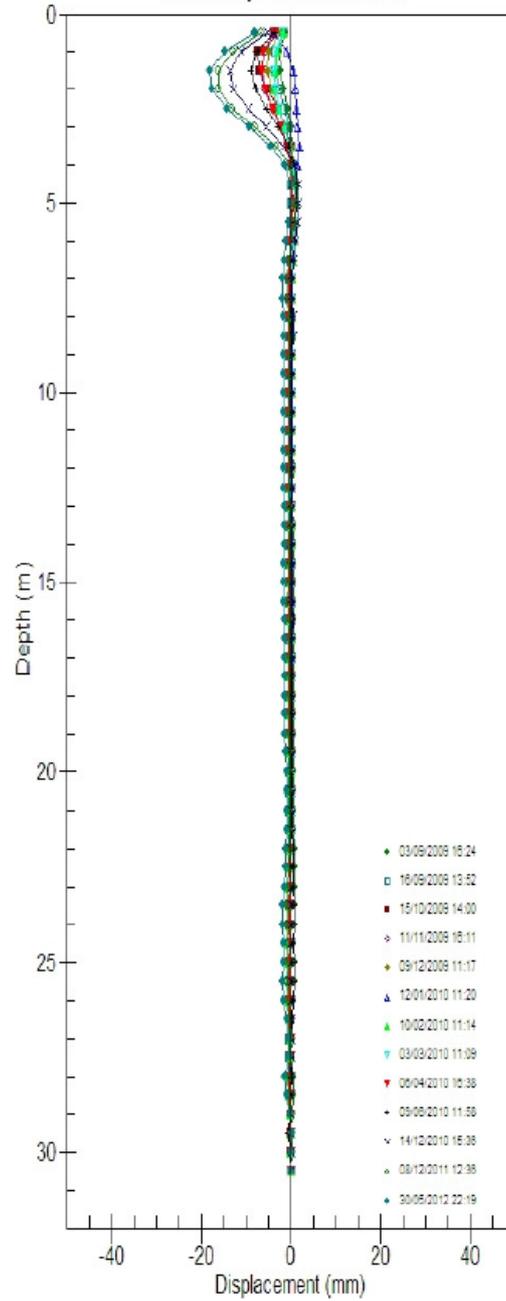
### SSC:AA10 - A Axis Cumulative

Initial survey: 15/07/2009 11:20



### SSC:AA10 - B Axis Cumulative

Initial survey: 15/07/2009 11:20



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough South Cliffs

INSTALLATION: AA10

COMPANY: Mouchel Ltd

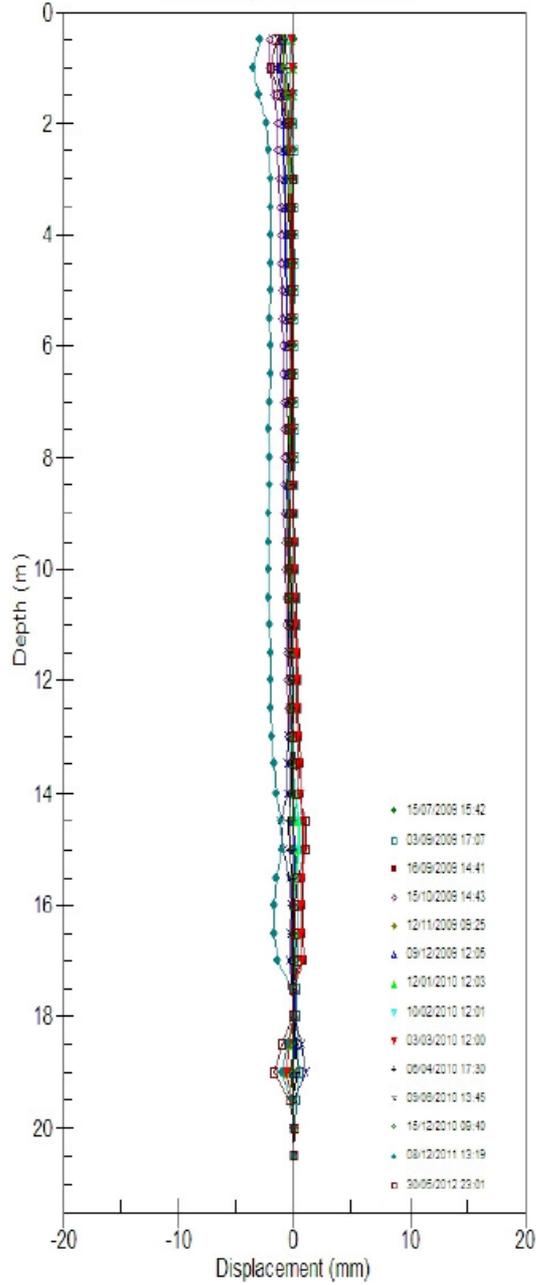
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North East

mouchel 

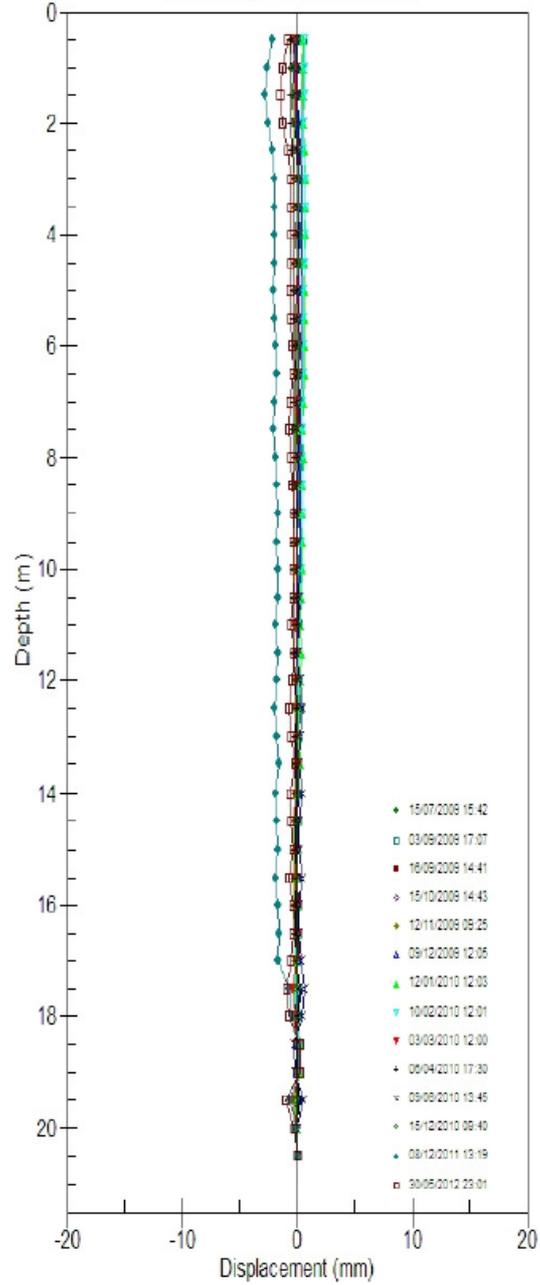
### SSC:AA11 - A Axis Cumulative

Initial survey: 15/07/2009 15:42



### SSC:AA11 - B Axis Cumulative

Initial survey: 15/07/2009 15:42



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough South Cliffs

INSTALLATION: AA11 (F4)

COMPANY: Mouchel Ltd

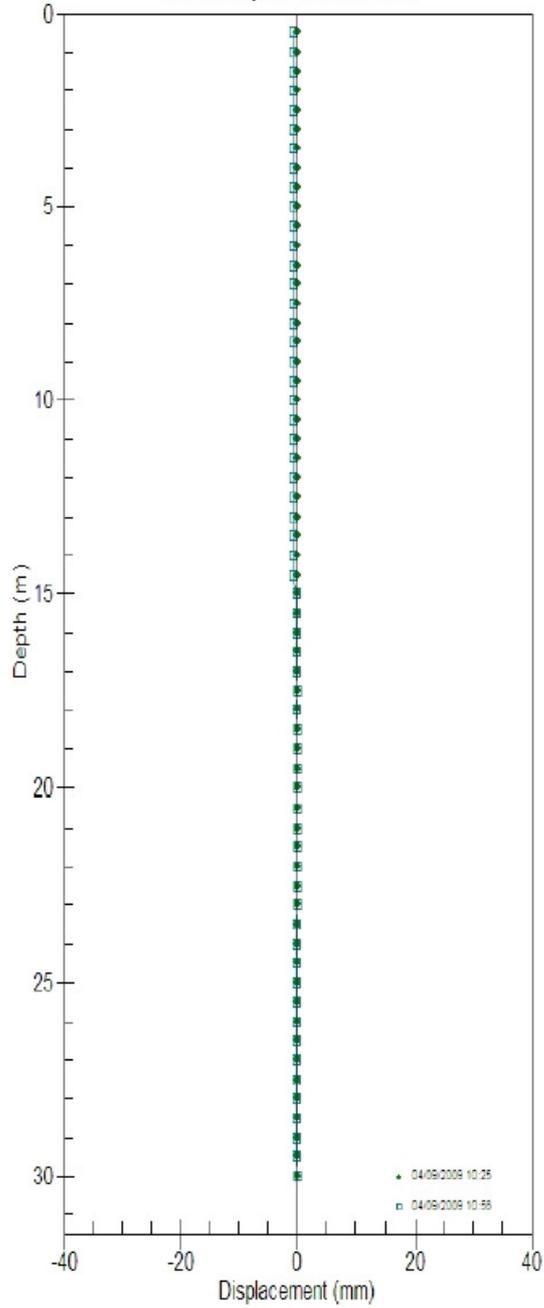
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North East



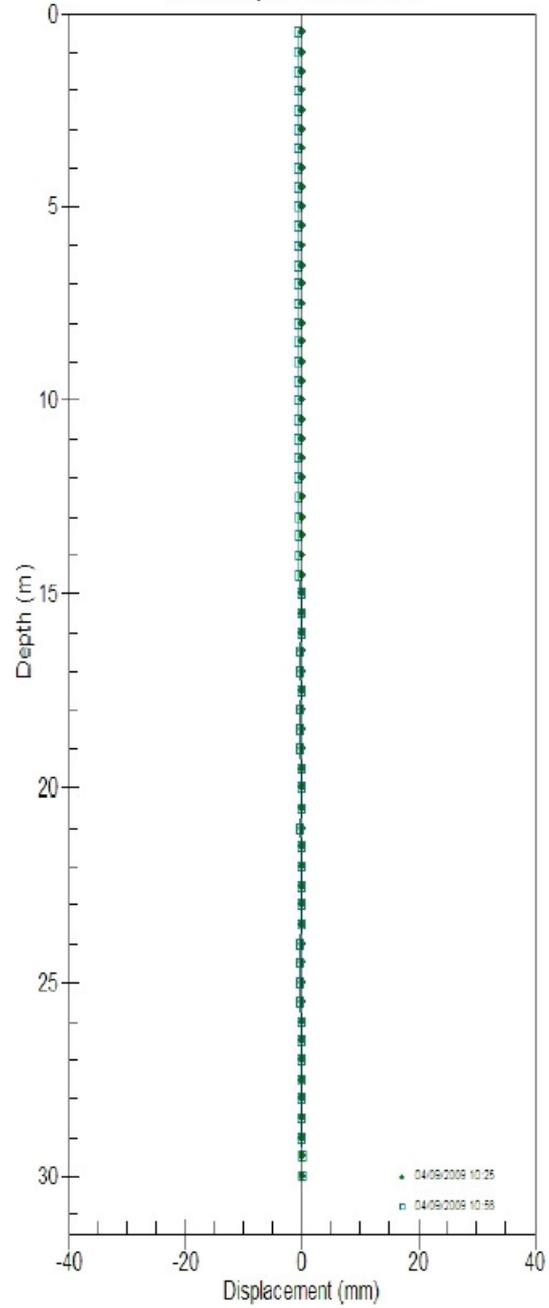
### FILEY: BH3 - A Axis Cumulative

Initial survey: 04/09/2009 10:25



### FILEY: BH3 - B Axis Cumulative

Initial survey: 04/09/2009 10:25



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: FILEY

INSTALLATION: BH3

COMPANY: Mouchel Ltd

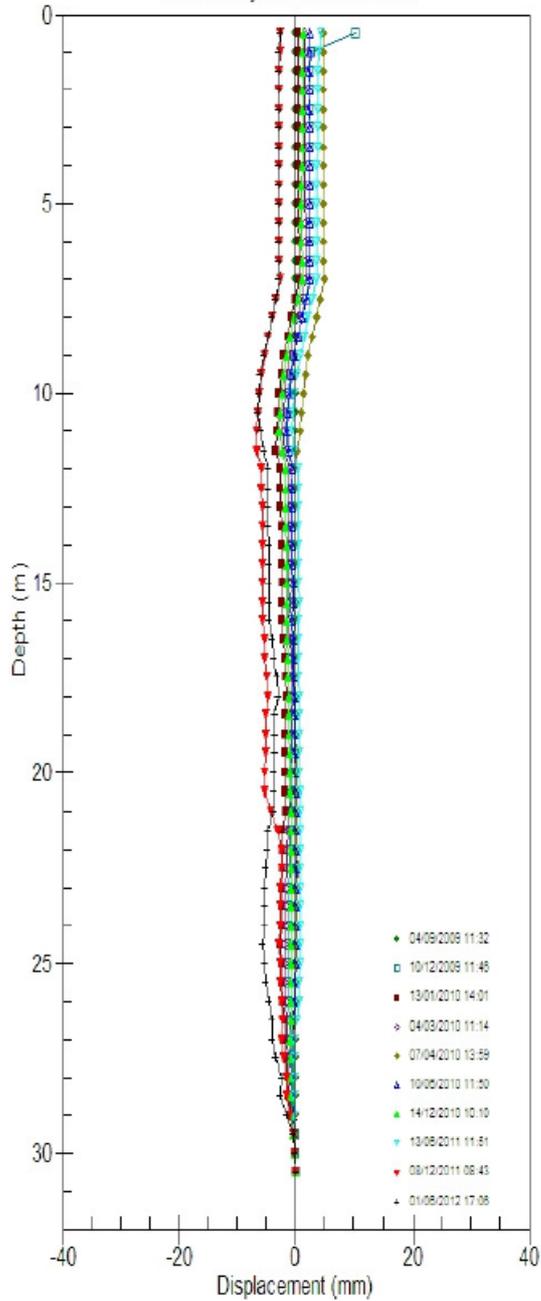
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North East



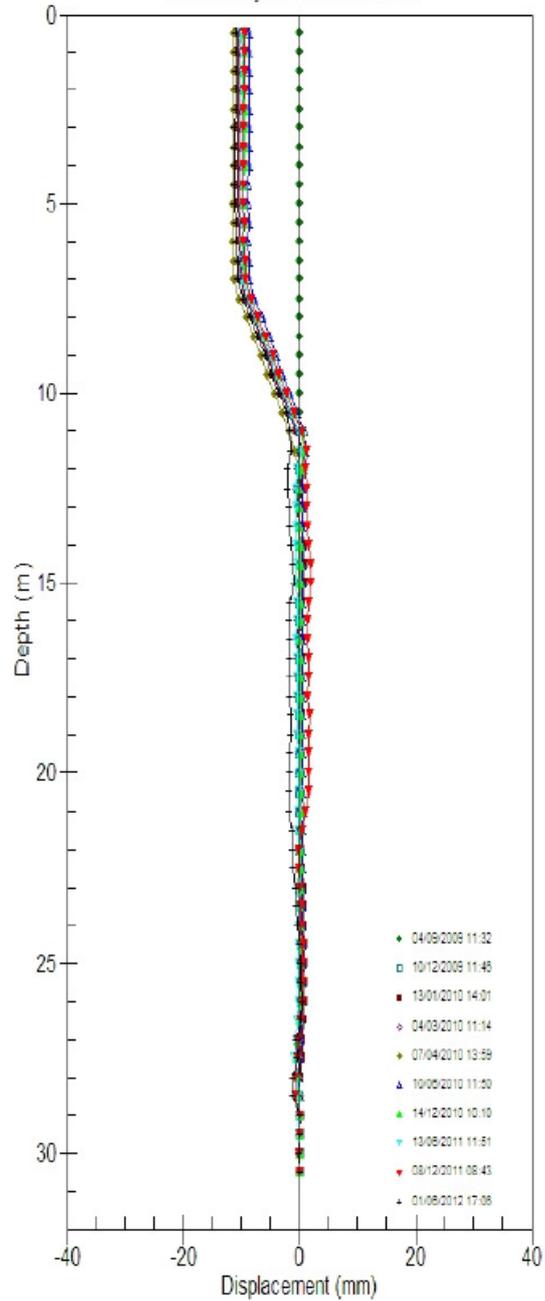
### FILEY: BH6 - A Axis Cumulative

Initial survey: 04/09/2009 11:32



### FILEY: BH6 - B Axis Cumulative

Initial survey: 04/09/2009 11:32



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: FILEY

INSTALLATION: BH6

COMPANY: Mouchel Ltd

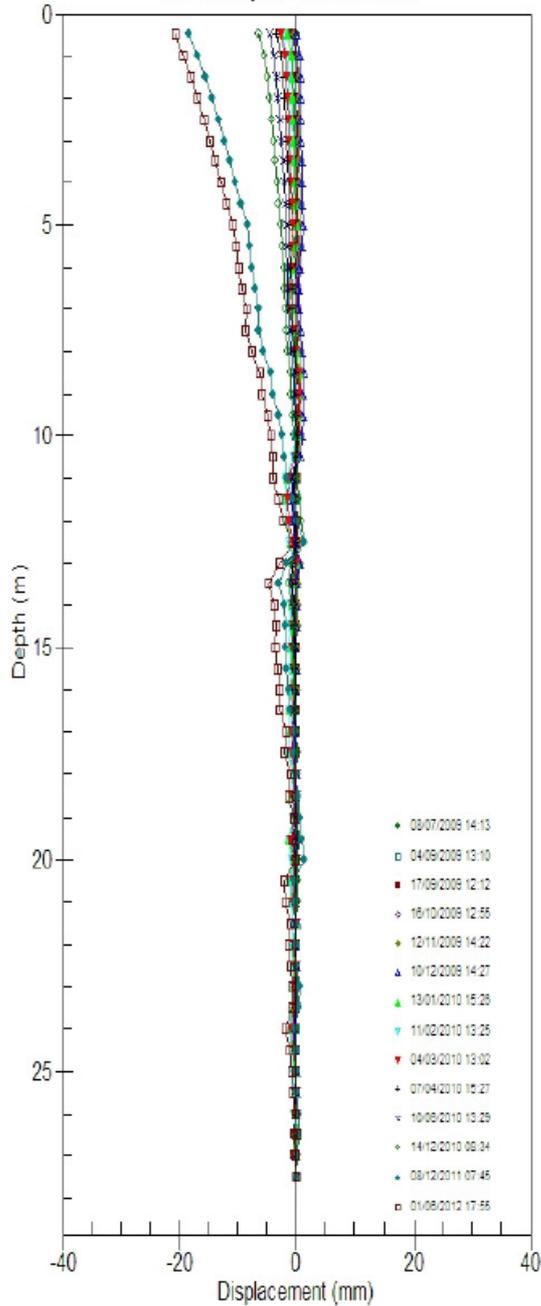
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North East

mouchel 

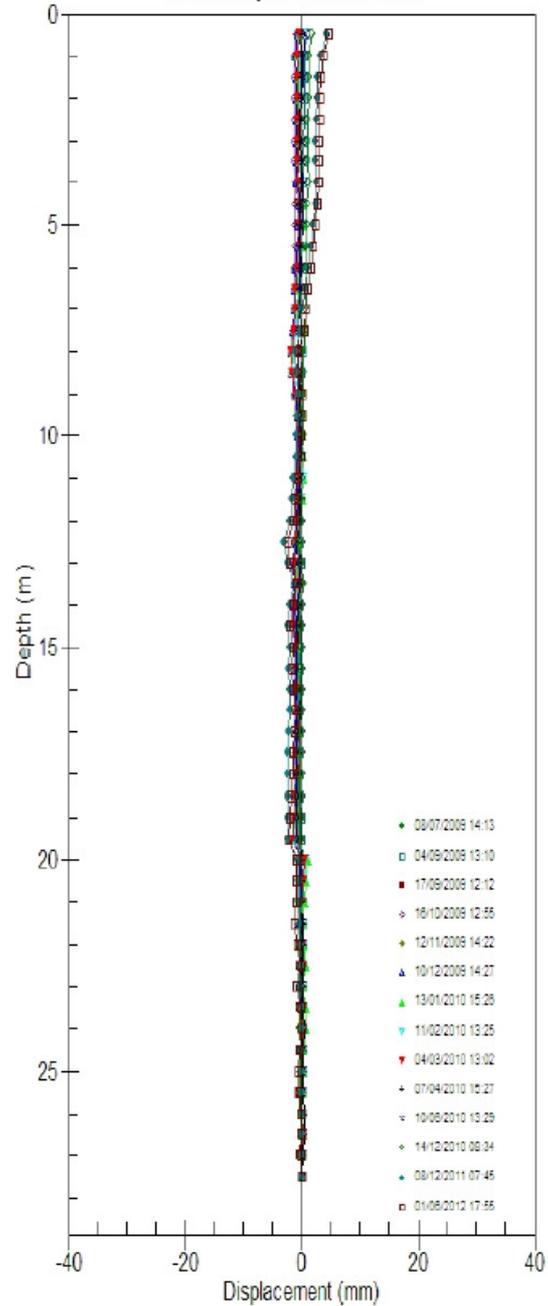
### FFC:BB02 - A Axis Cumulative

Initial survey: 08/07/2009 14:13



### FFC:BB02 - B Axis Cumulative

Initial survey: 08/07/2009 14:13



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Filey Flat Cliffs

INSTALLATION: BB02

COMPANY: Mouchel Ltd

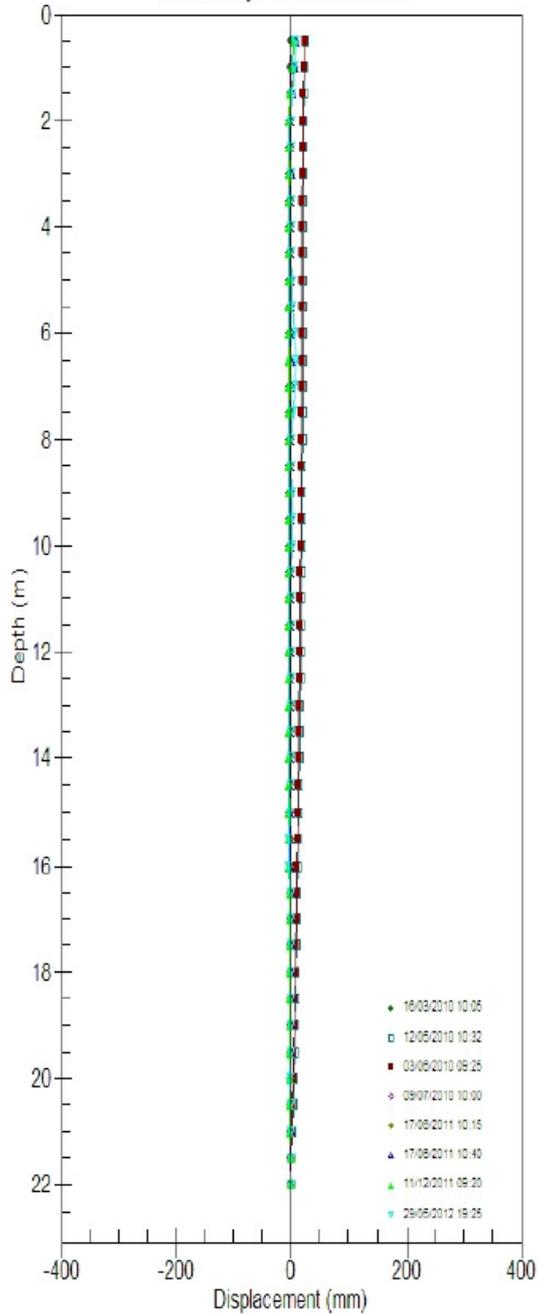
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East



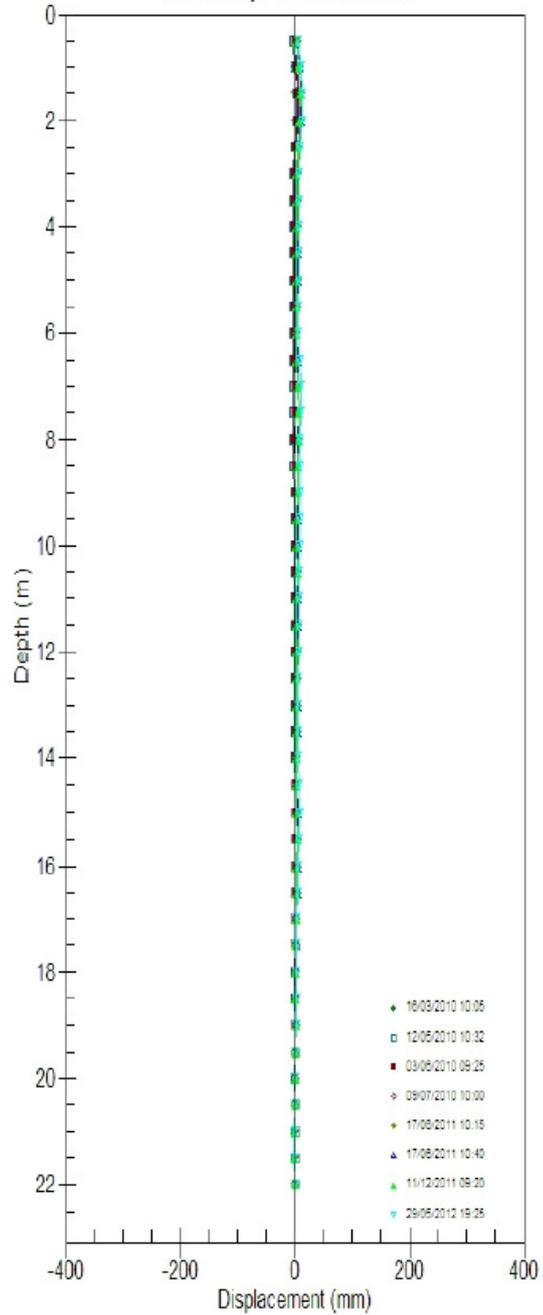
### RHB:BH2 - A Axis Cumulative

Initial survey: 16/03/2010 10:05



### RHB:BH2 - B Axis Cumulative

Initial survey: 16/03/2010 10:05



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Robin Hood's Bay

INSTALLATION: BH2

COMPANY: Mouchel Ltd

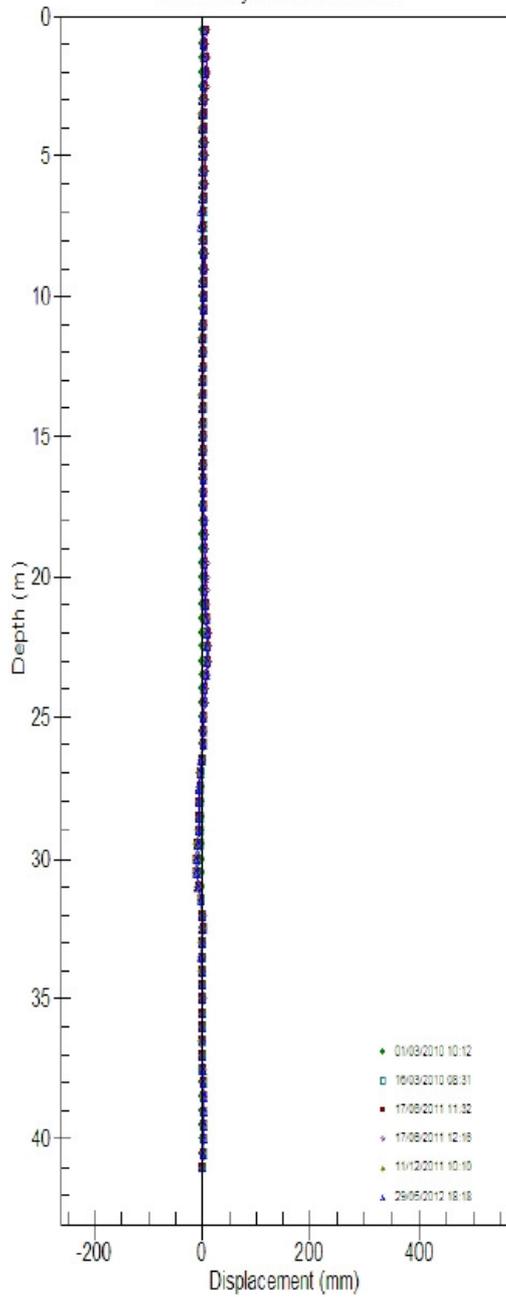
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = South East



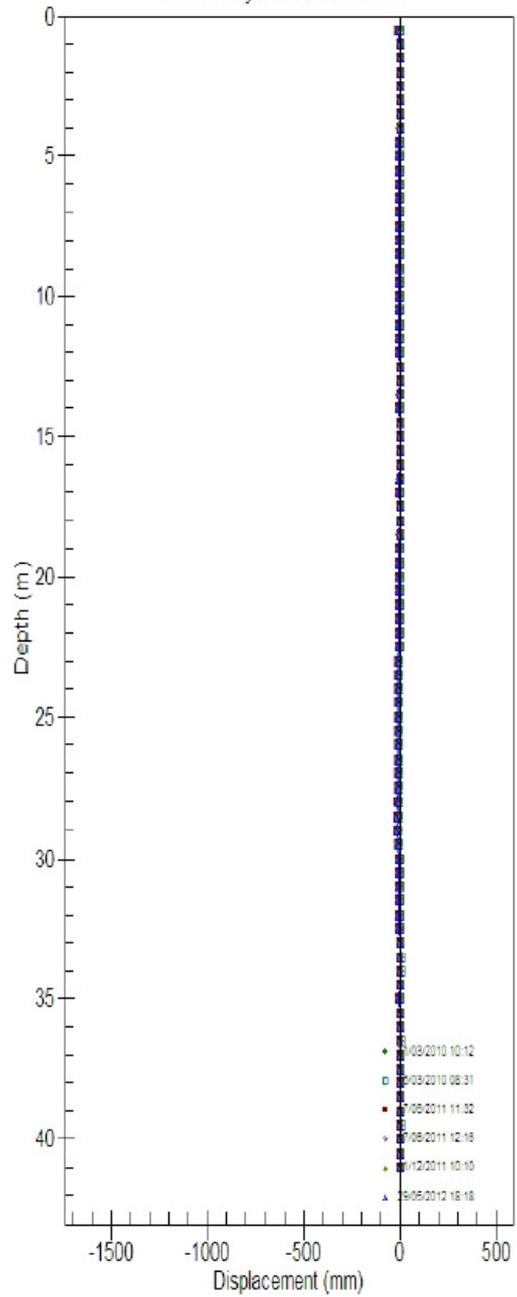
### RHB:BH4 - A Axis Cumulative

Initial survey: 01/03/2010 10:12



### RHB:BH4 - B Axis Cumulative

Initial survey: 01/03/2010 10:12



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Robin Hood's Bay

INSTALLATION: BH4

COMPANY: Mouchel Ltd

CLIENT: Scarborough Borough Council

NOTE: A0 Direction = South East



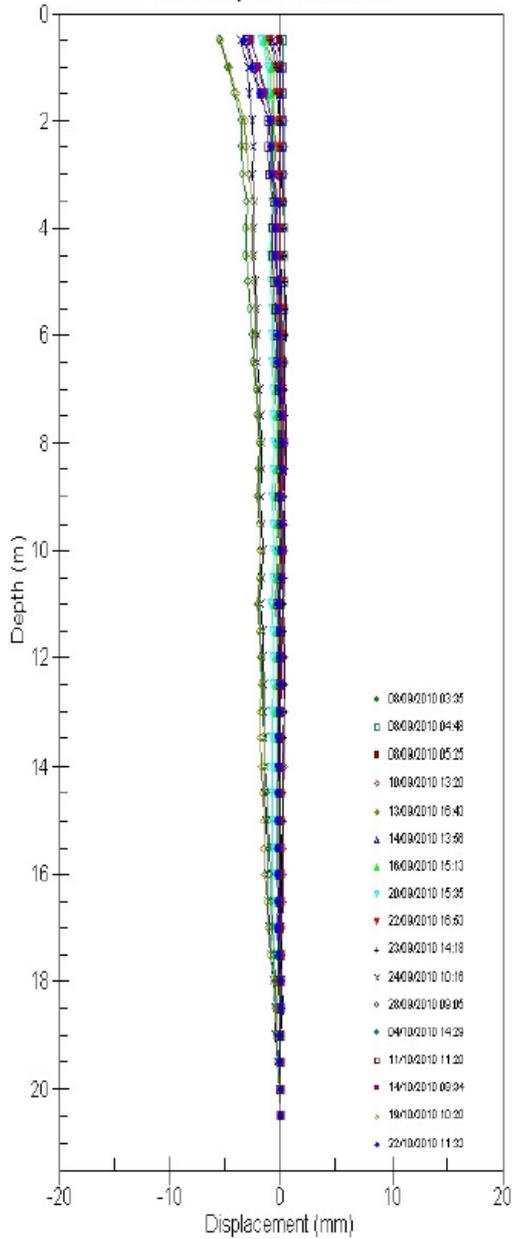


# **Appendix D Replacement Installation Inclinometer Graphs**



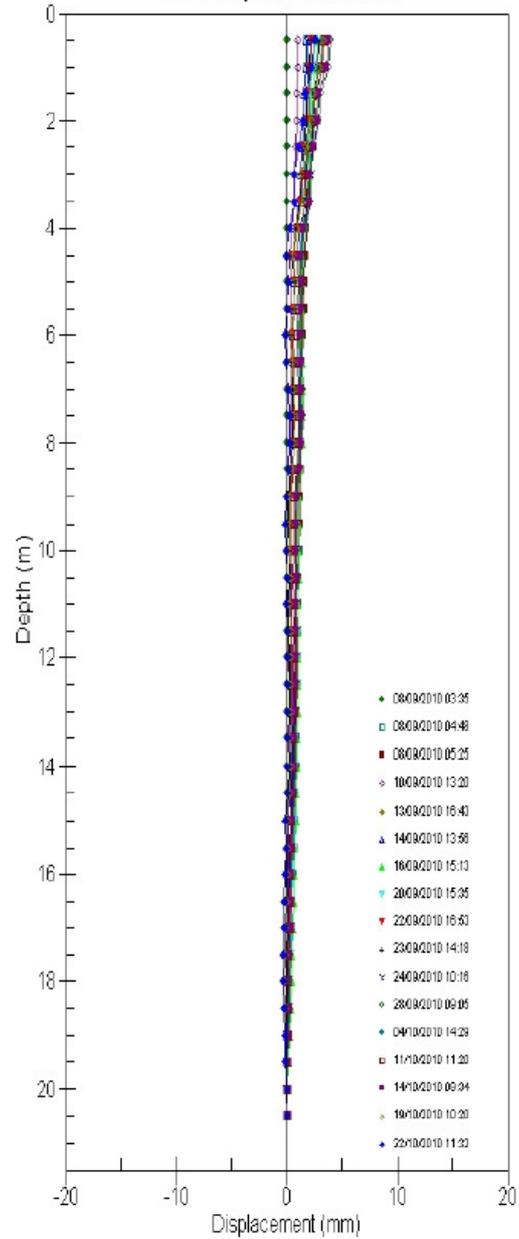
### A64274:BH7 - A Axis Cumulative

Initial survey: 08/09/2010 03:35



### A64274:BH7 - B Axis Cumulative

Initial survey: 08/09/2010 03:35



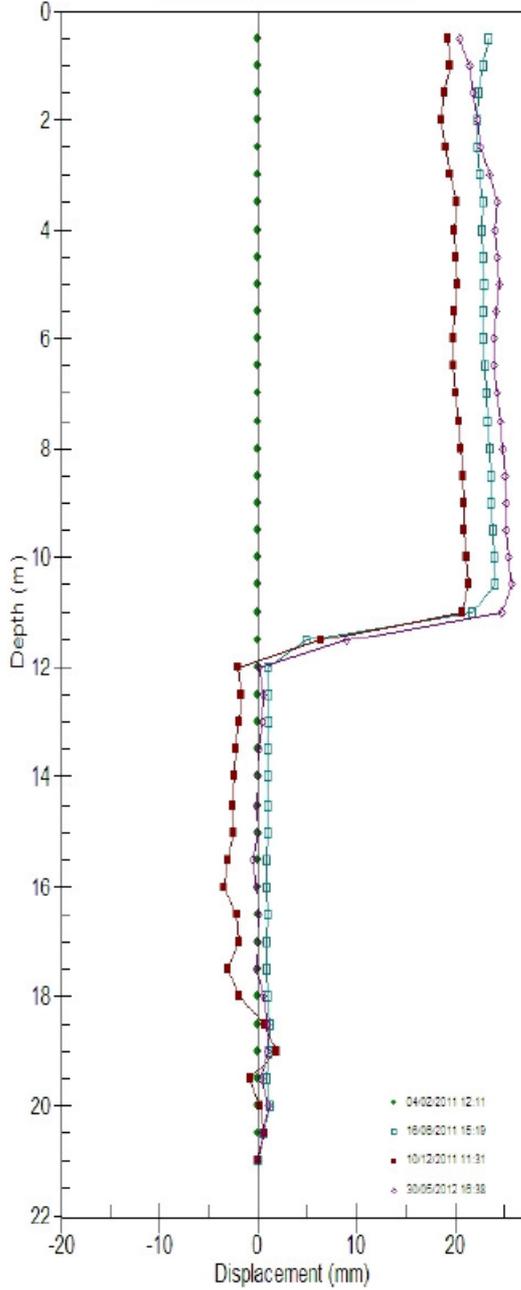
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME  
SITE: A64274  
INSTALLATION: BH7  
COMPANY: WYG  
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



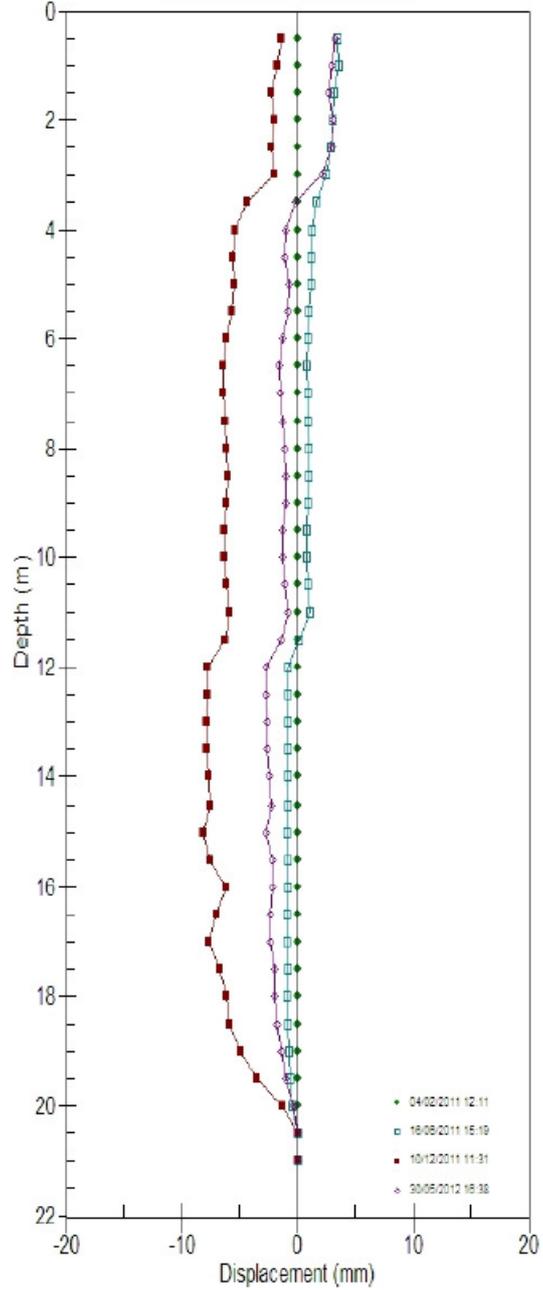
### SN:BH07 - A Axis Cumulative

Initial survey: 04/02/2011 12:11



### SN:BH07 - B Axis Cumulative

Initial survey: 04/02/2011 12:11



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scalby Ness

INSTALLATION: BH07

COMPANY: Mouchel Ltd

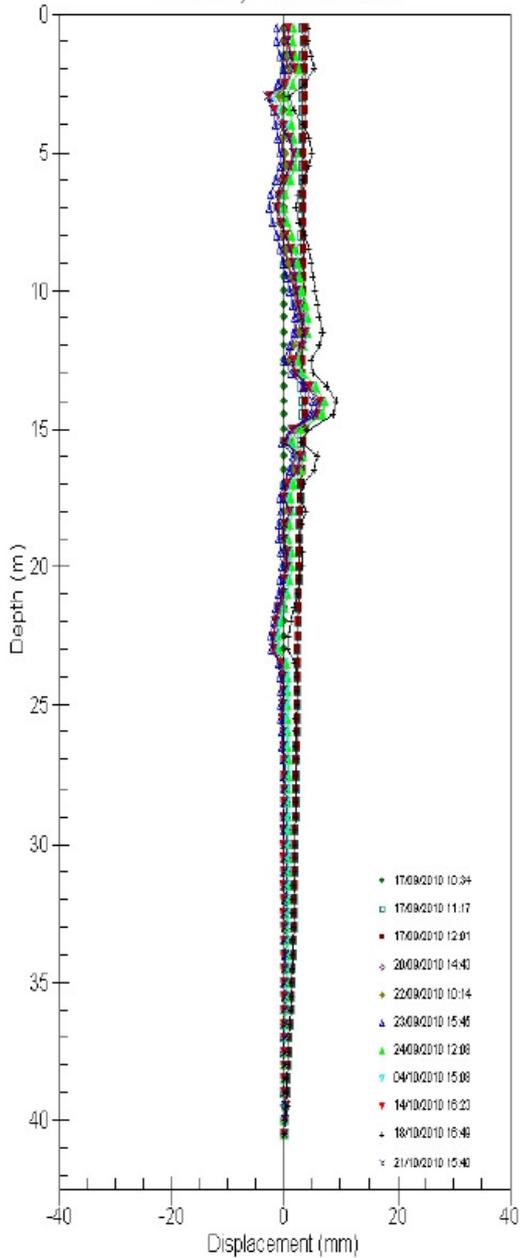
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East

mouchel 

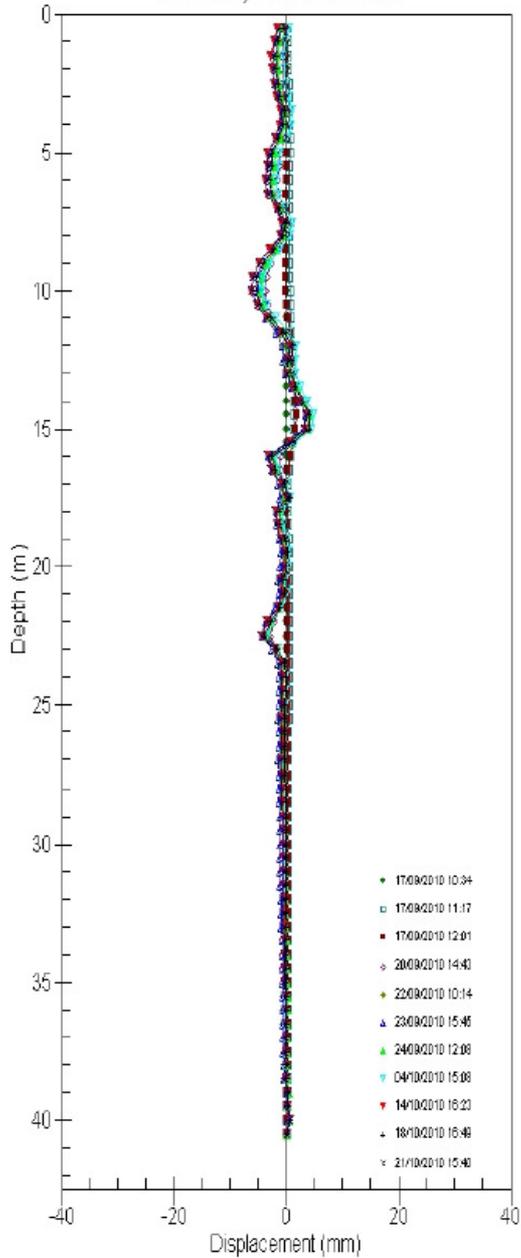
### A64274: BH10A - A Axis Cumulative

Initial survey: 17/09/2010 10:34



### A64274: BH10A - B Axis Cumulative

Initial survey: 17/09/2010 10:34



PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT SCHEME

SITE: A64274

INSTALLATION: BH10A

COMPANY: WYG

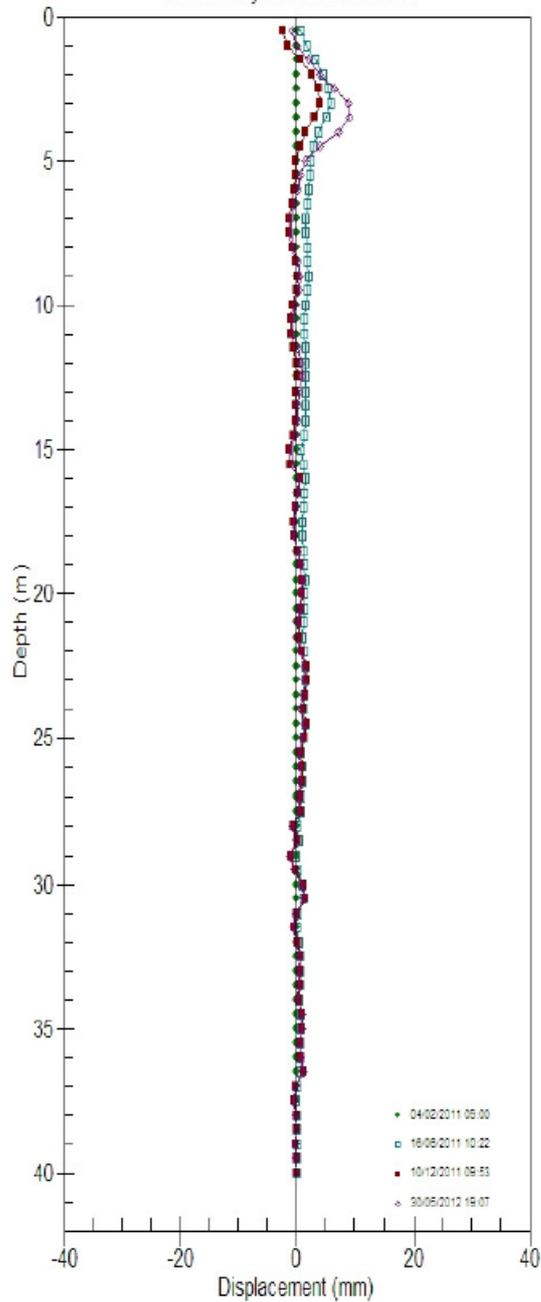
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



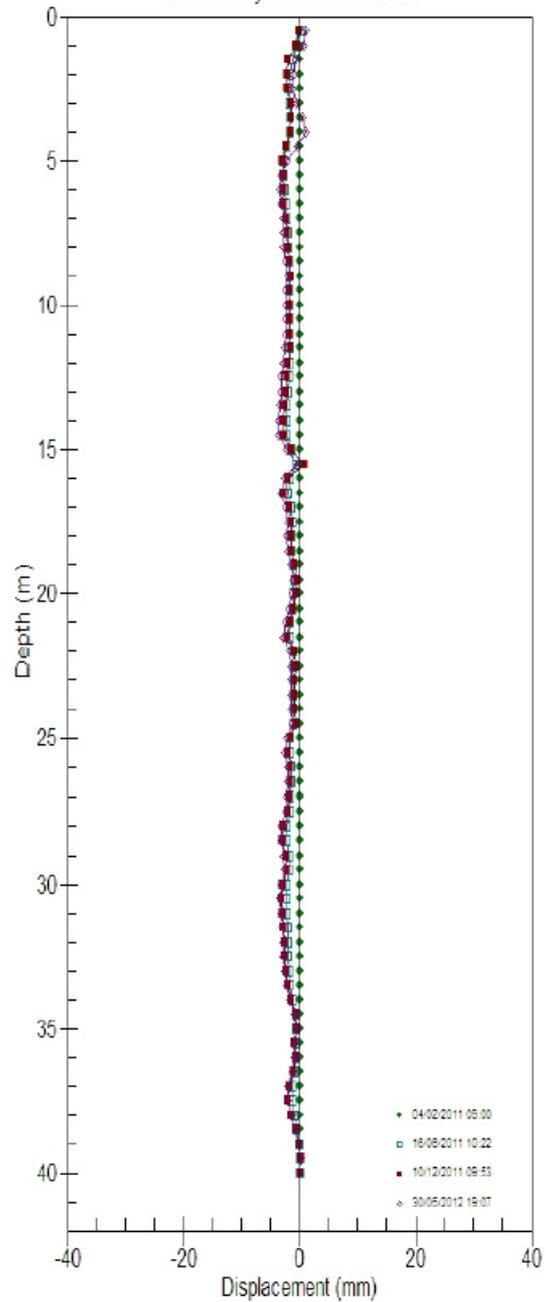
### SNB:BH10A - A Axis Cumulative

Initial survey: 04/02/2011 09:00



### SNB:BH10A - B Axis Cumulative

Initial survey: 04/02/2011 09:00



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough North Bay

INSTALLATION: BH10A

COMPANY: Mouchel Ltd

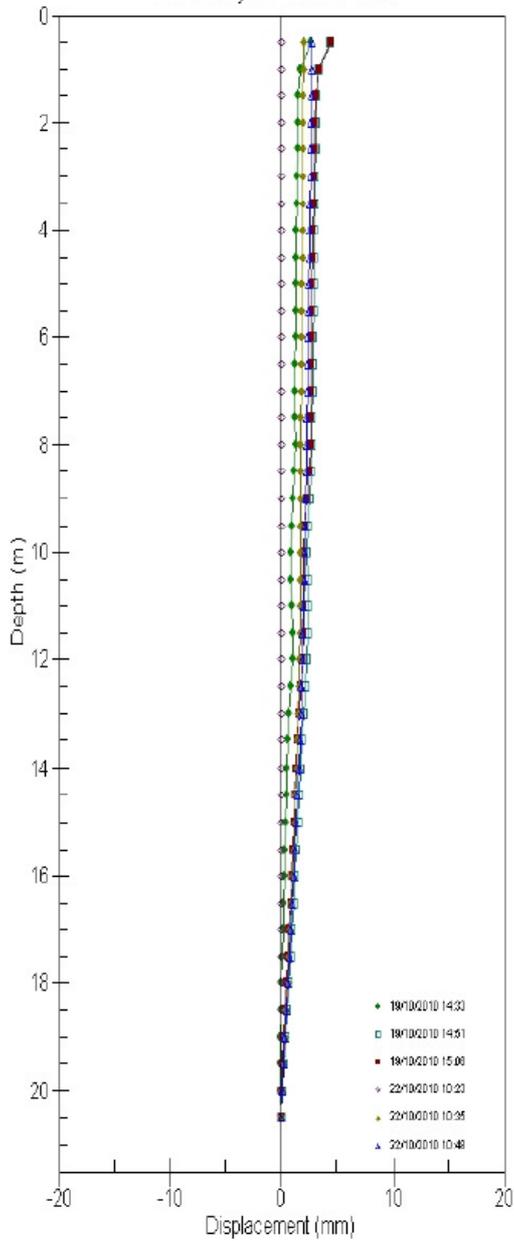
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = North East

mouchel 

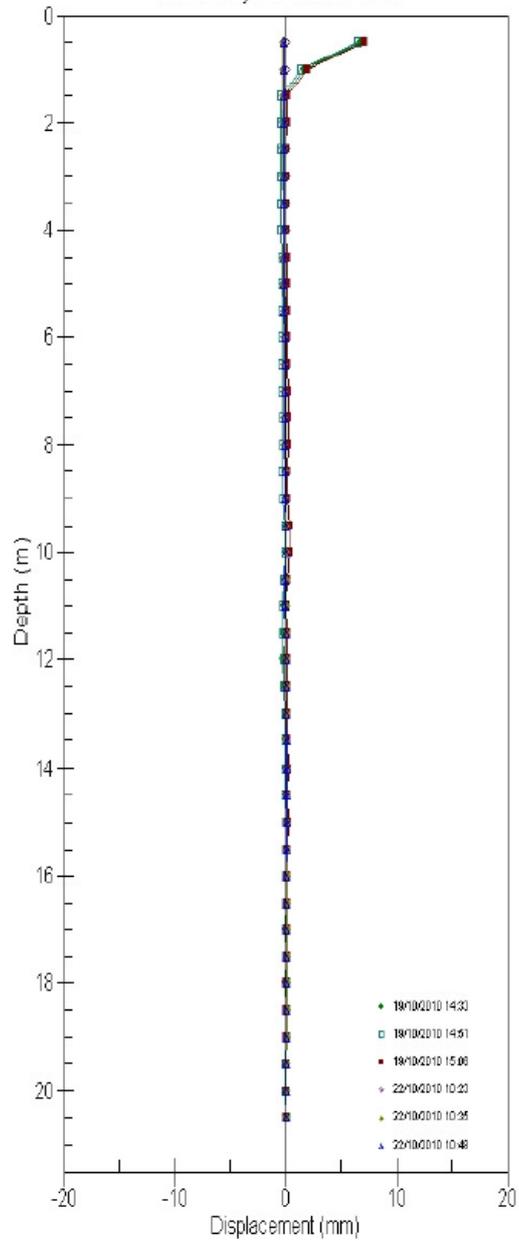
### A64274: BH11 - A Axis Cumulative

Initial survey: 22/10/2010 10:23



### A64274: BH11 - B Axis Cumulative

Initial survey: 22/10/2010 10:23



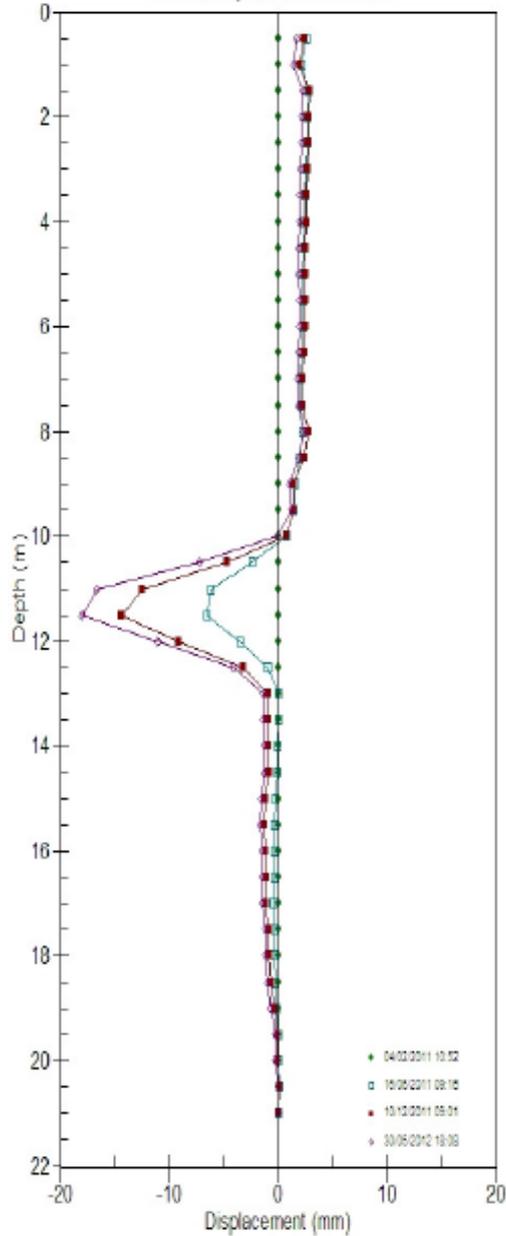
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT  
SITE: A64274  
INSTALLATION: BH11  
COMPANY: WYG  
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



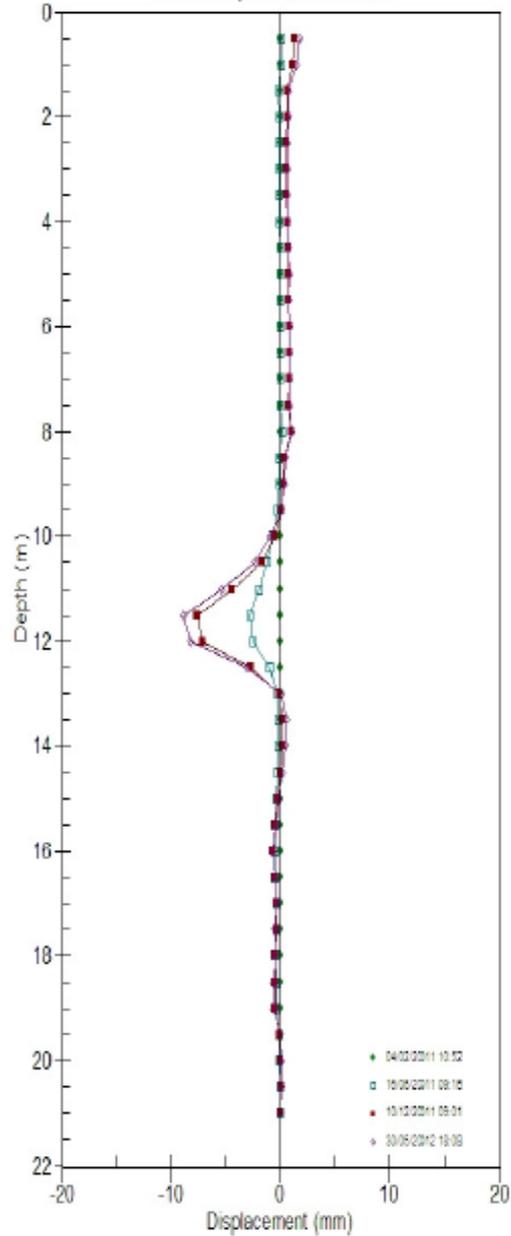
### SNB:BH11 - A Axis Cumulative

Initial survey: 04/02/2011 10:52



### SNB:BH11 - B Axis Cumulative

Initial survey: 04/02/2011 10:52

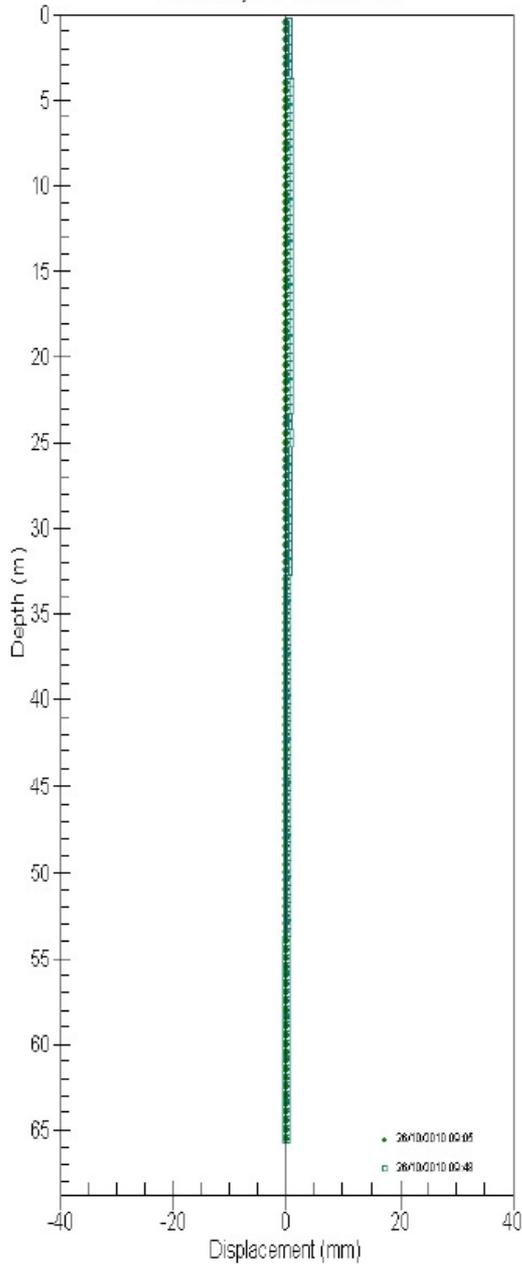


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
SITE: Scarborough North Bay  
INSTALLATION: BH11  
COMPANY: Mouchel Ltd  
CLIENT: Scarborough Borough Council  
NOTE: A0 Direction = North



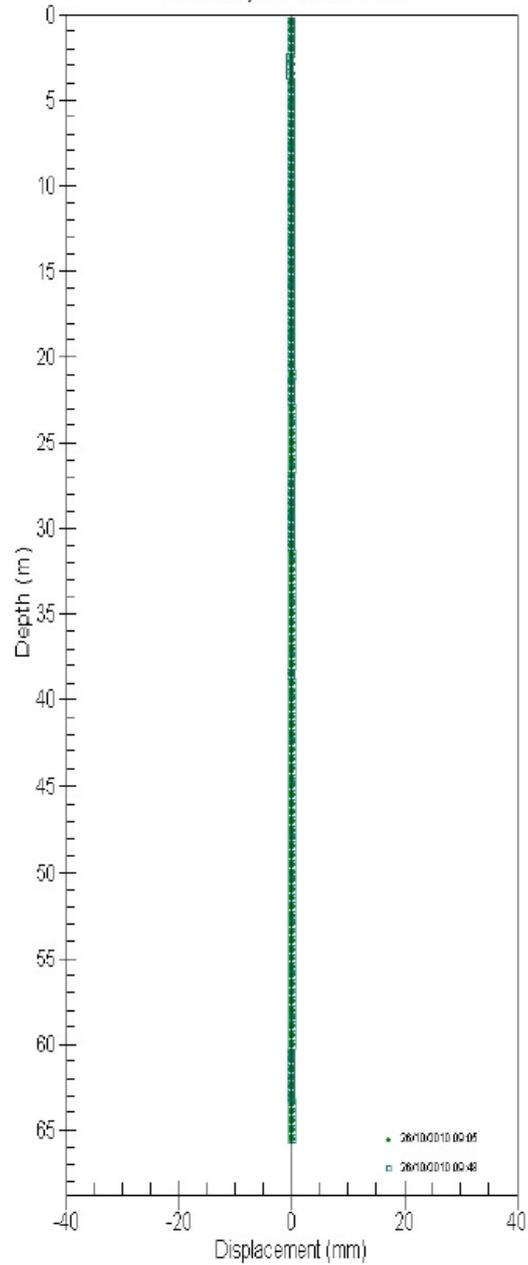
### A64274: BH12 - A Axis Cumulative

Initial survey: 26/10/2010 09:05



### A64274: BH12 - B Axis Cumulative

Initial survey: 26/10/2010 09:05



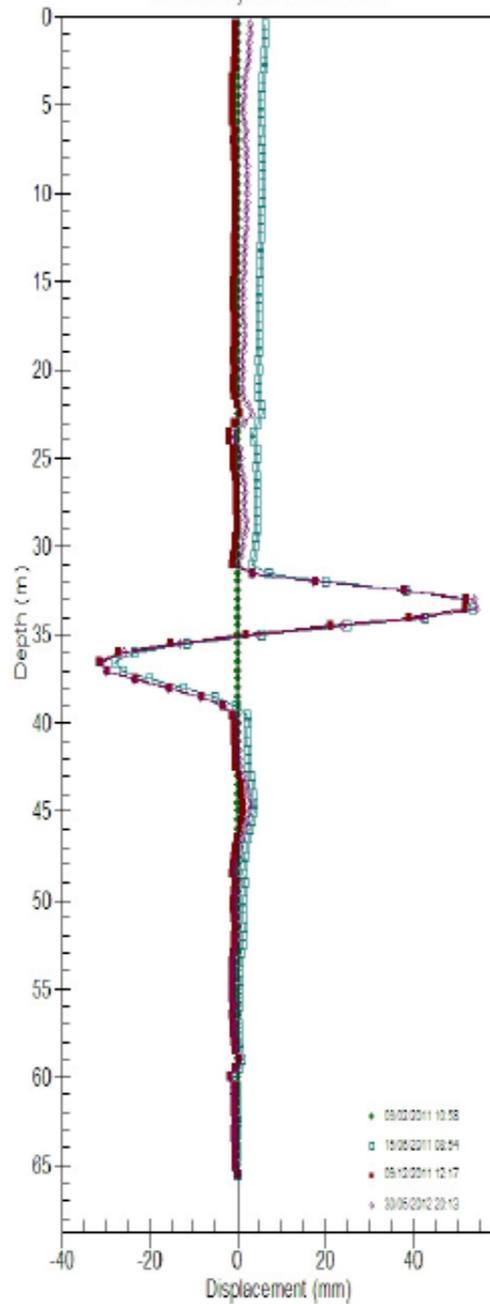
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT  
SITE: A64274  
INSTALLATION: BH12  
COMPANY: WYG  
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



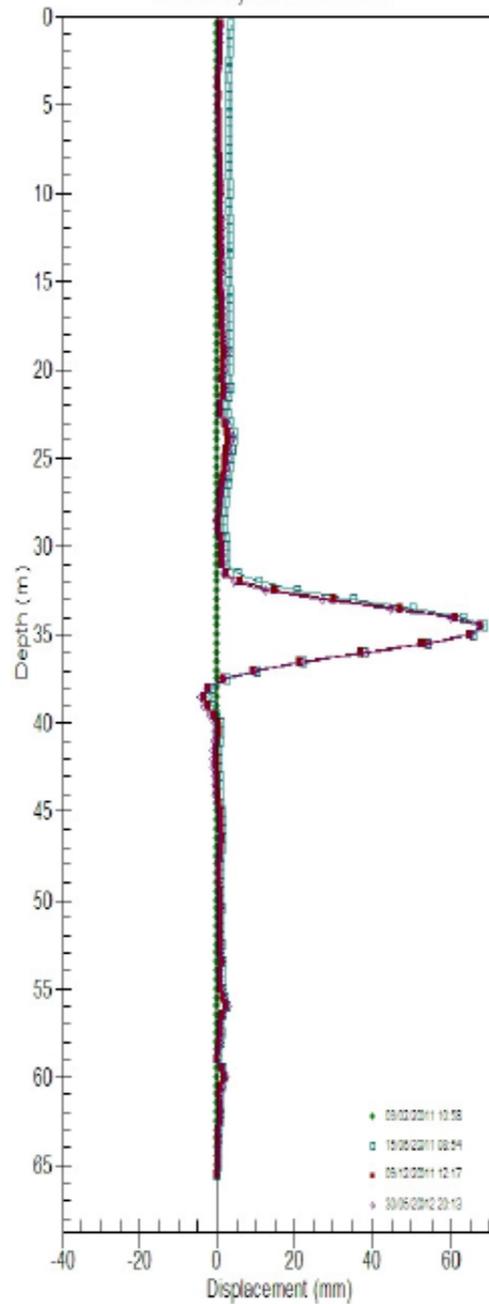
### SSC: BH12 - A Axis Cumulative

Initial survey: 03/02/2011 10:58



### SSC: BH12 - B Axis Cumulative

Initial survey: 03/02/2011 10:58

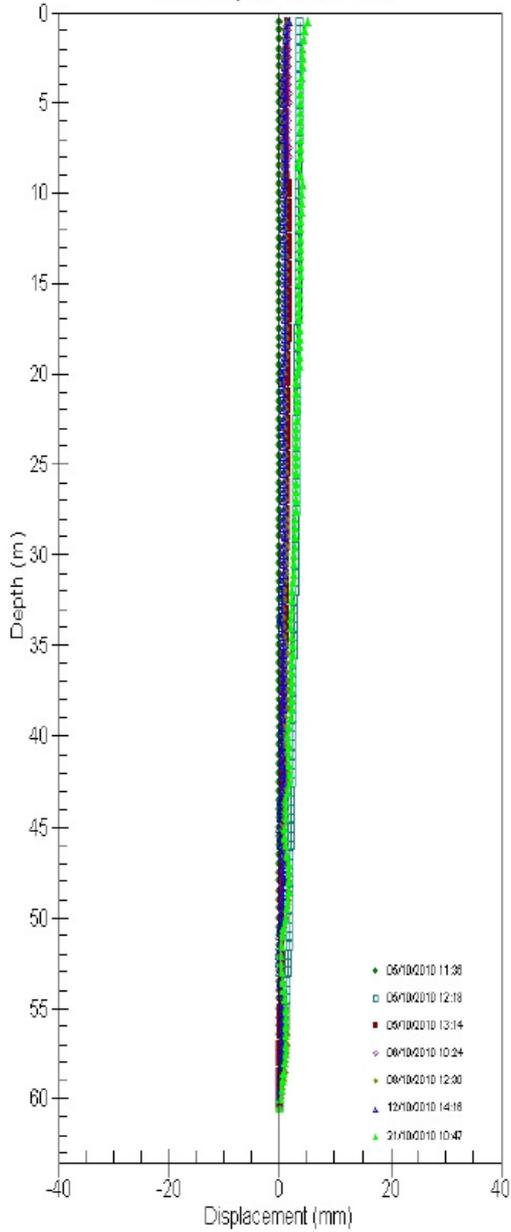


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
SITE: Scarborough South Cliffs  
INSTALLATION: BH12  
COMPANY: Mouchel Ltd  
CLIENT: Scarborough Borough Council  
NOTE: A0 Direction = East



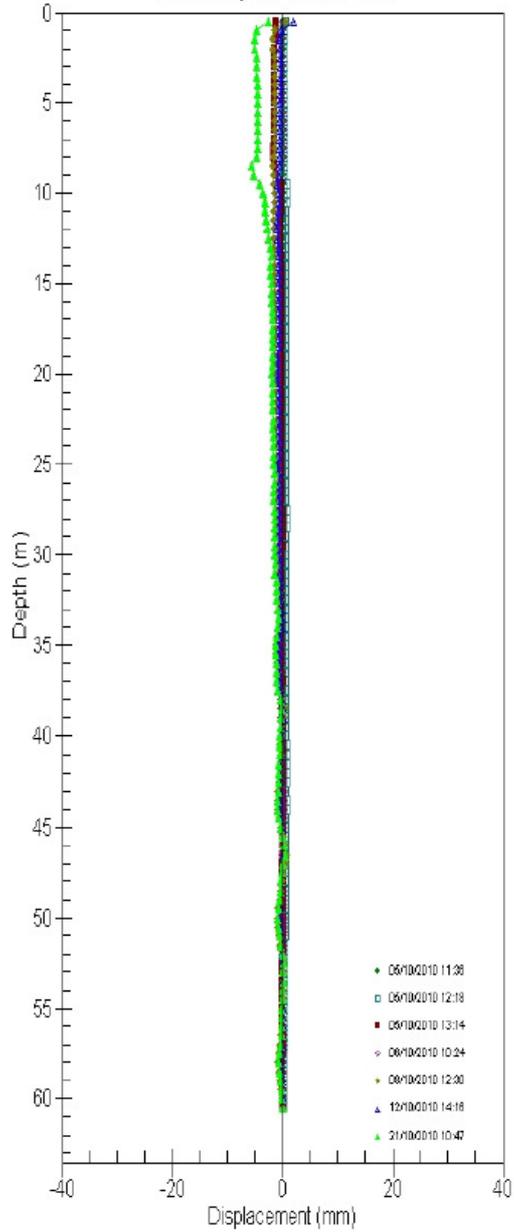
### A64274:BH13 - A Axis Cumulative

Initial survey: 05/10/2010 11:36



### A64274:BH13 - B Axis Cumulative

Initial survey: 05/10/2010 11:36



PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME

SITE: A64274

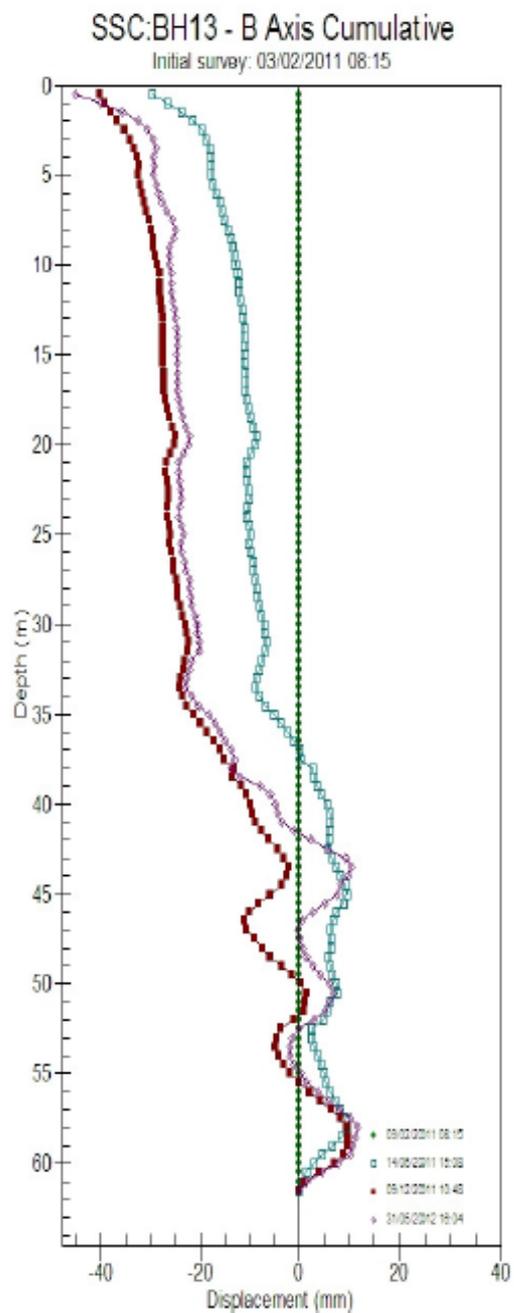
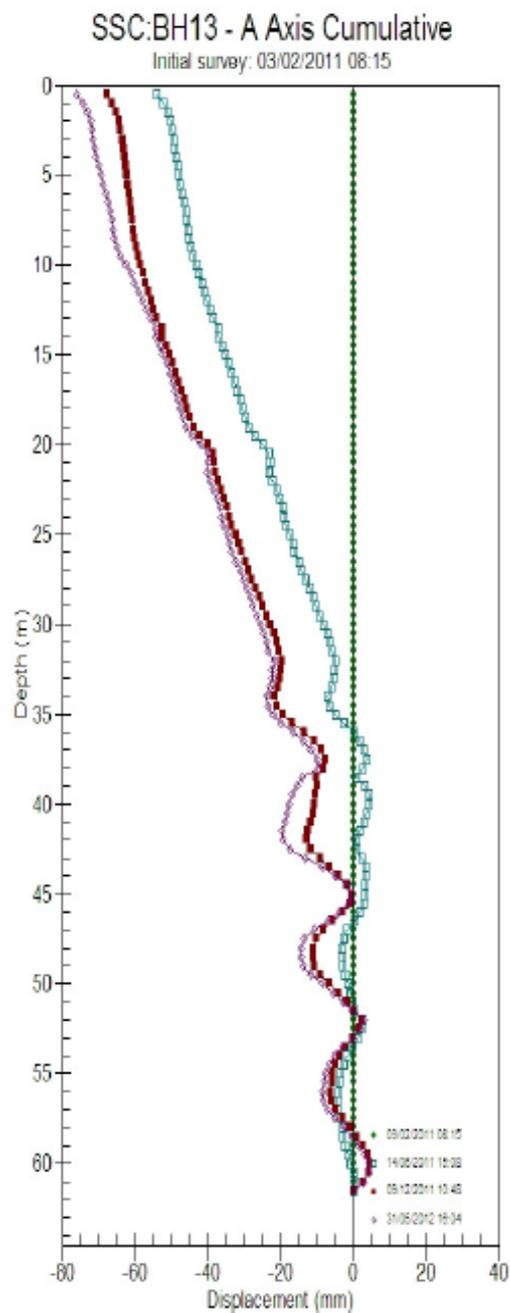
INSTALLATION: BH13

COMPANY: WYG

CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



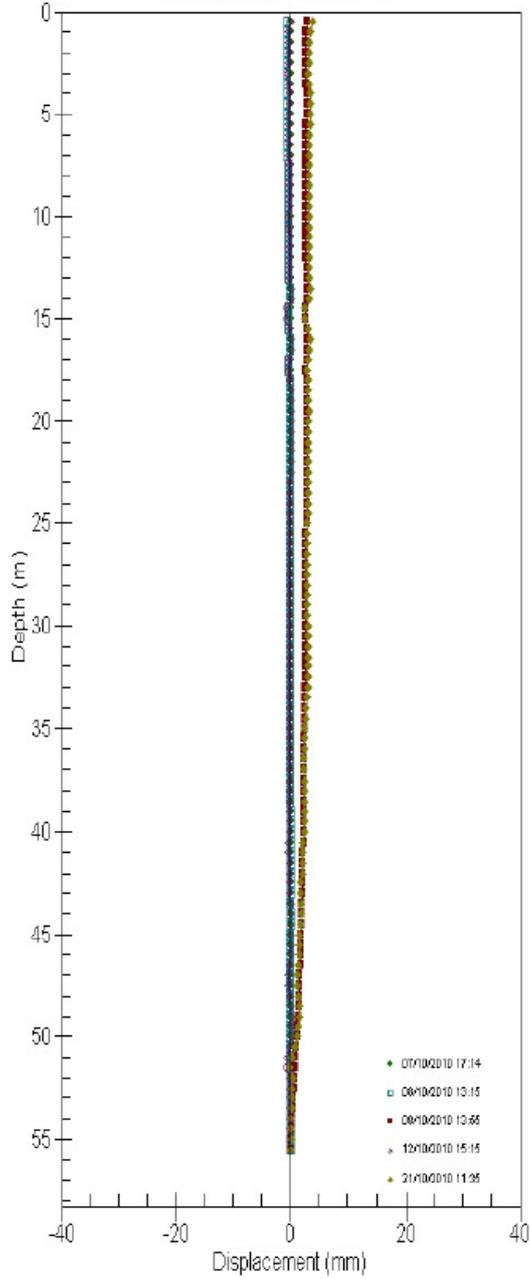


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
 SITE: Scarborough South Cliffs  
 INSTALLATION: BH13  
 COMPANY: Mouchel Ltd  
 CLIENT: Scarborough Borough Council  
 NOTE: A0 Direction = East



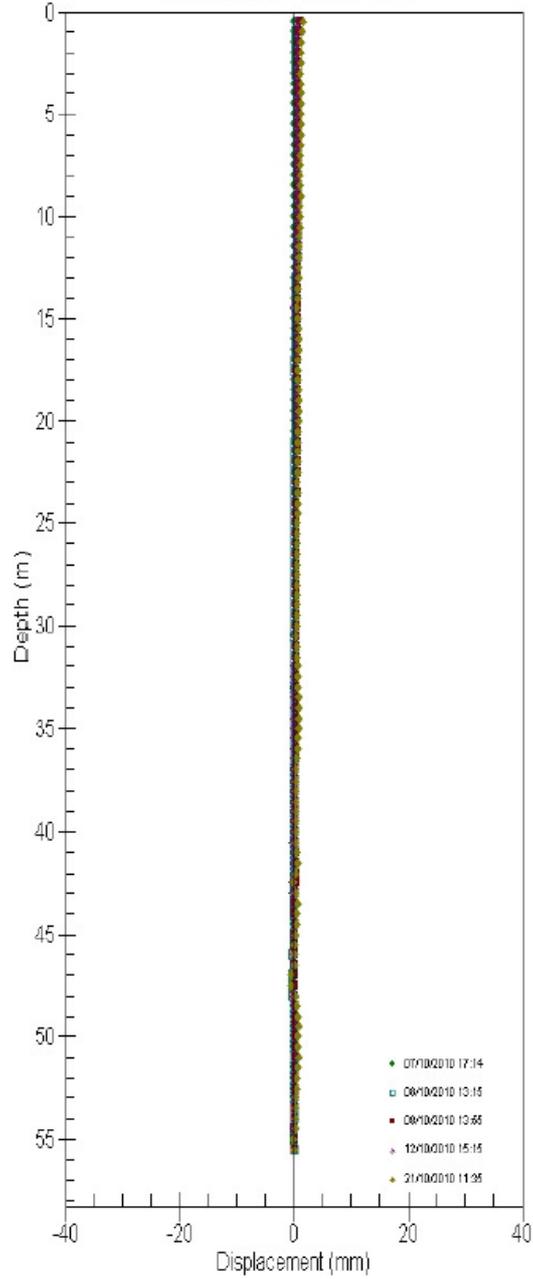
### A64274: BH14 - A Axis Cumulative

Initial survey: 07/10/2010 17:14



### A64274: BH14 - B Axis Cumulative

Initial survey: 07/10/2010 17:14



PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME

SITE: A64274

INSTALLATION: BH14

COMPANY: WYG

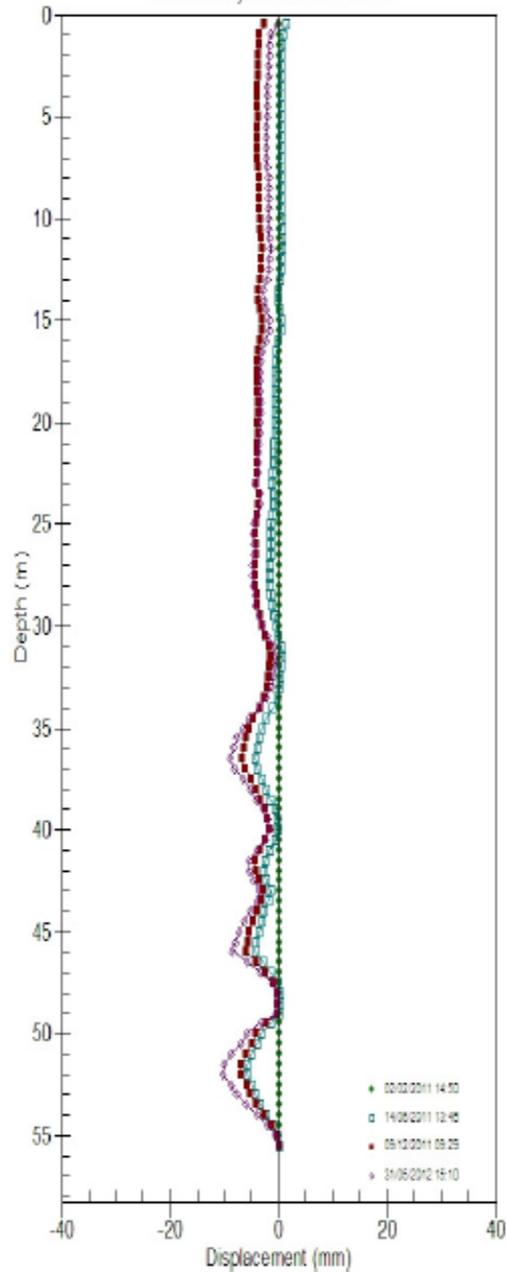
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



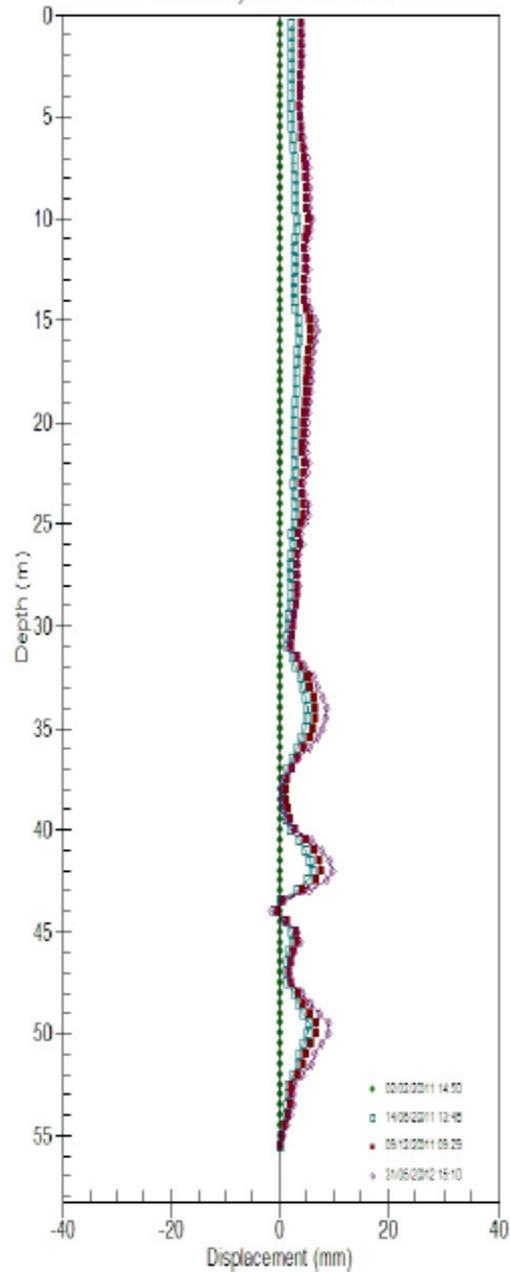
### SSC: BH14 - A Axis Cumulative

Initial survey: 02/02/2011 14:50



### SSC: BH14 - B Axis Cumulative

Initial survey: 02/02/2011 14:50



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough South Cliffs

INSTALLATION: BH14

COMPANY: Mouchel Ltd

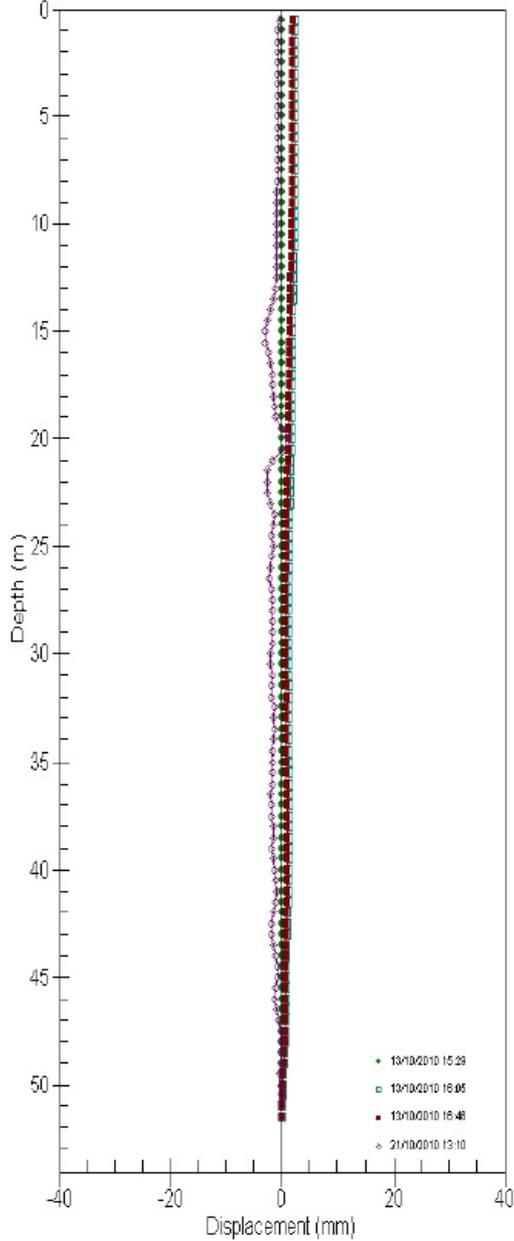
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East



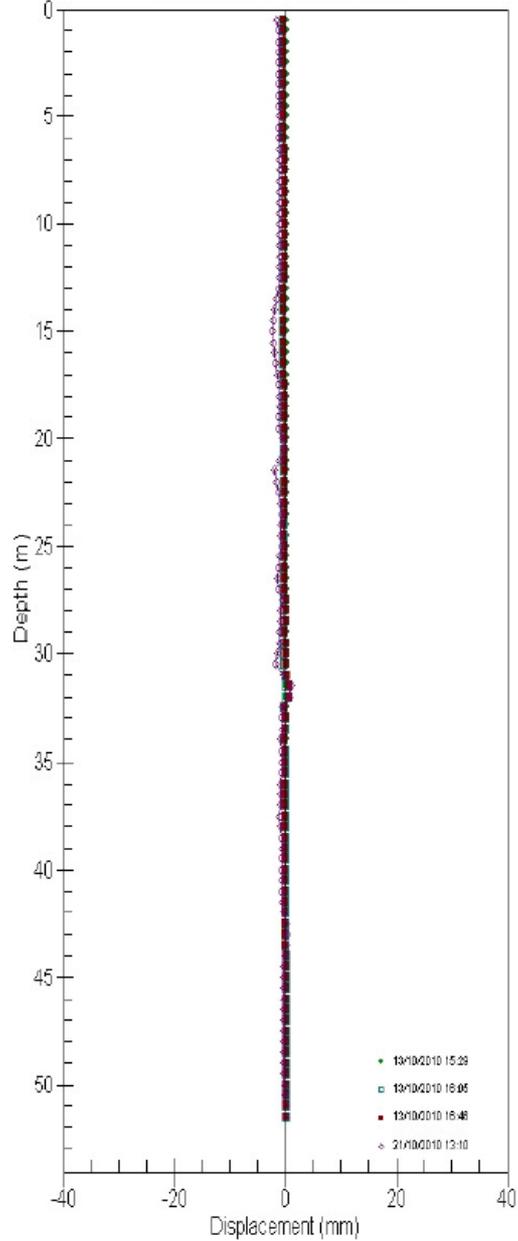
### A64274: BH16A - A Axis Cumulative

Initial survey: 13/10/2010 15:29



### A64274: BH16A - B Axis Cumulative

Initial survey: 13/10/2010 15:29



PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT

SITE: A64274

INSTALLATION: BH16A

COMPANY: WYG

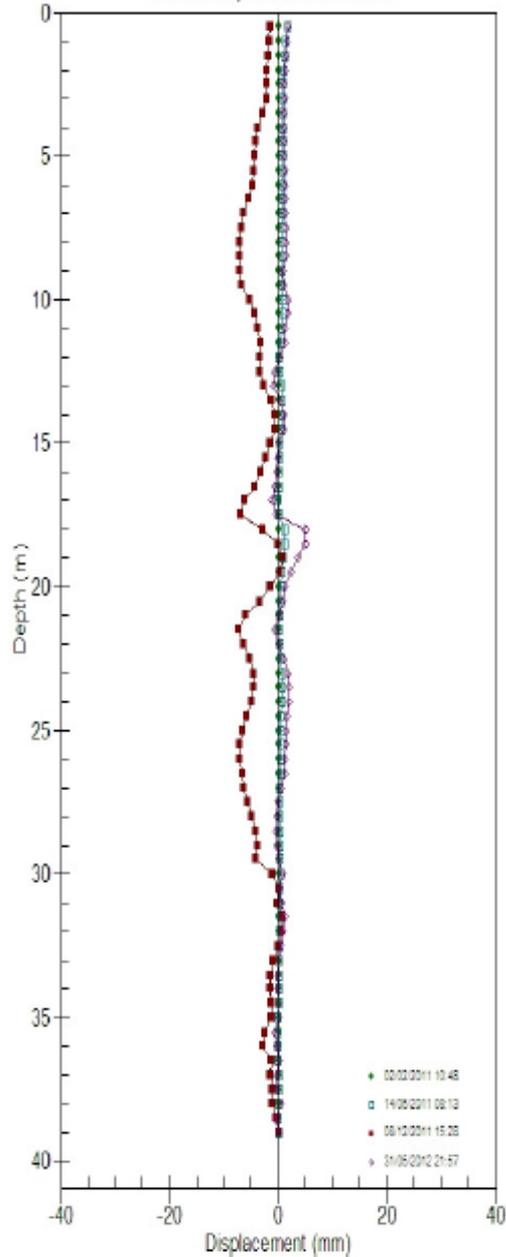
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



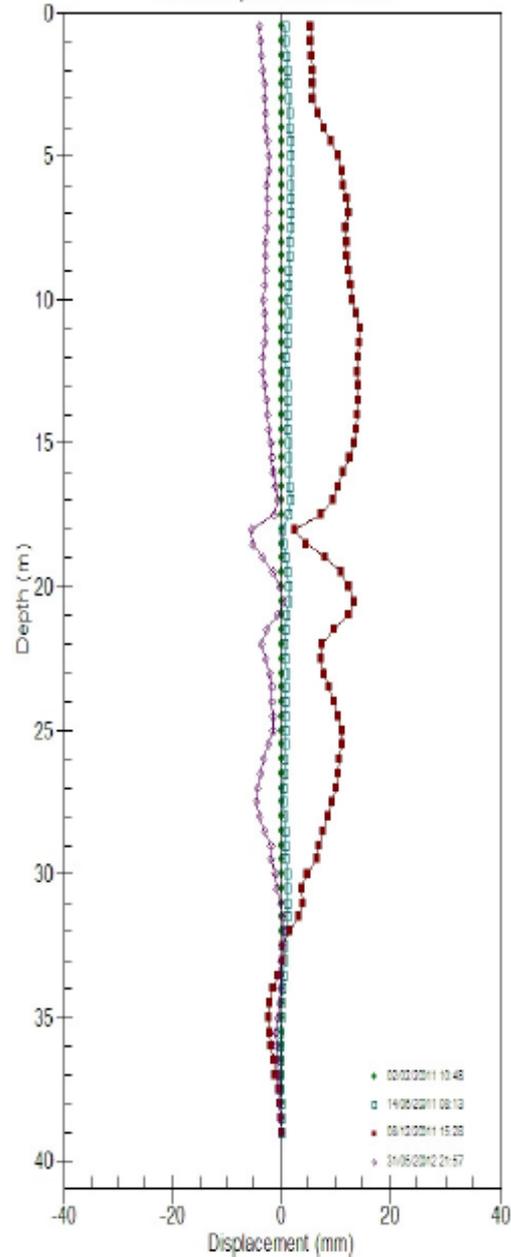
### SSC: BH16A - A Axis Cumulative

Initial survey: 02/02/2011 10:48



### SSC: BH16A - B Axis Cumulative

Initial survey: 02/02/2011 10:48

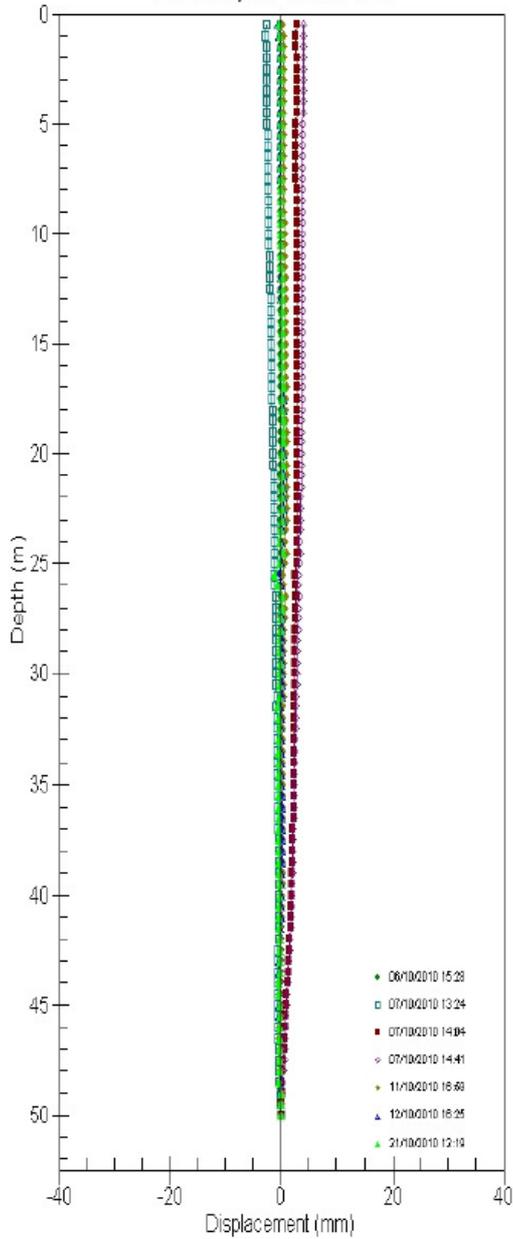


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
SITE: Scarborough South Cliffs  
INSTALLATION: BH16A  
COMPANY: Mouchel Ltd  
CLIENT: Scarborough Borough Council  
NOTE: A0 Direction = East



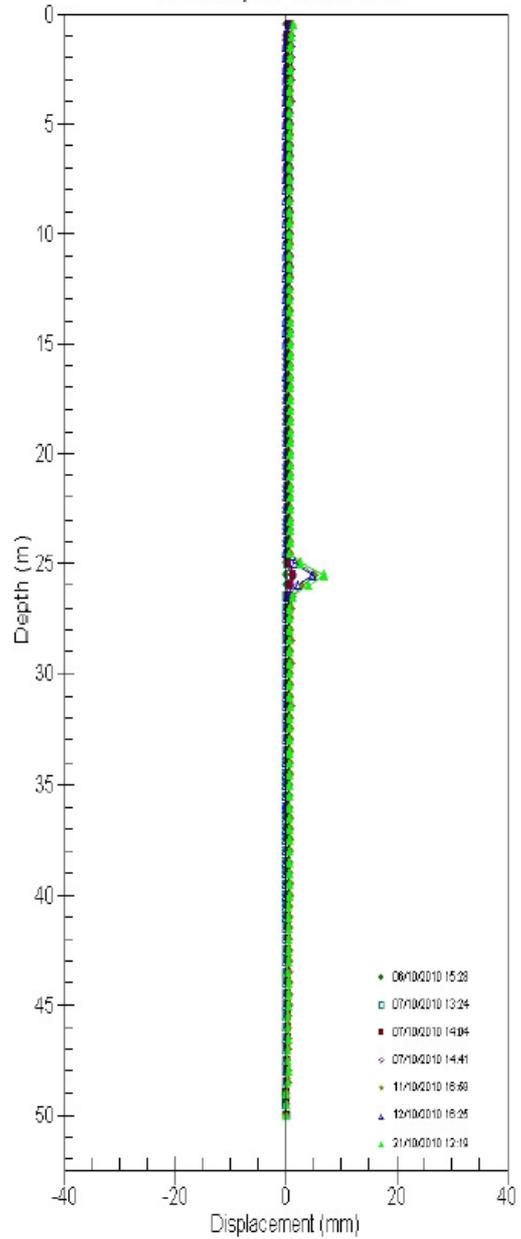
### A64274: BH17 - A Axis Cumulative

Initial survey: 06/10/2010 15:28



### A64274: BH17 - B Axis Cumulative

Initial survey: 06/10/2010 15:28



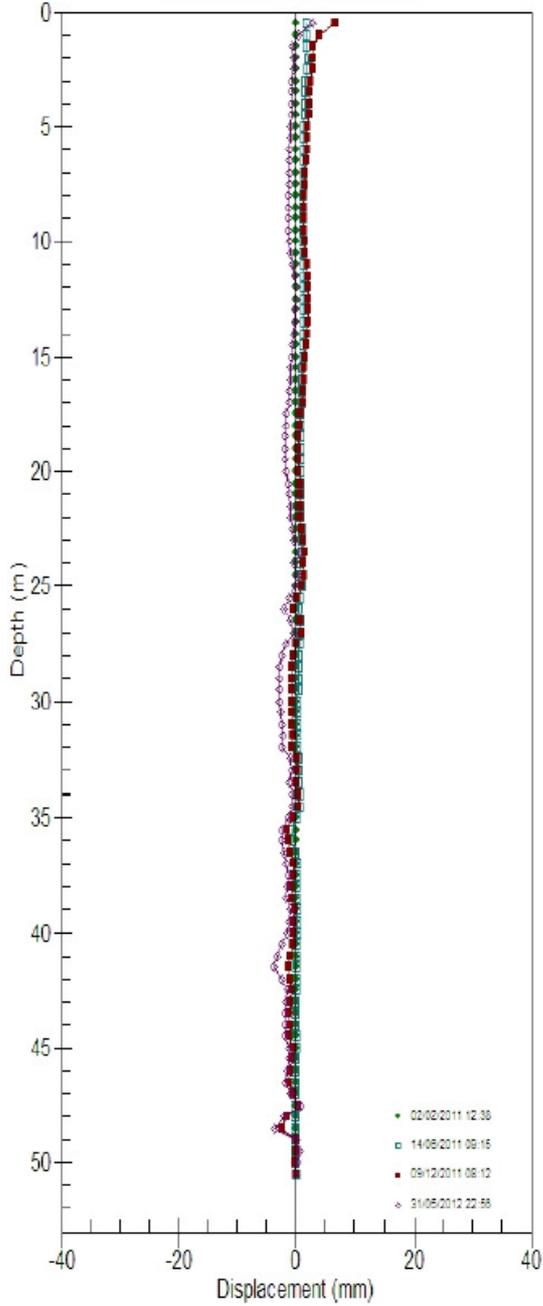
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME  
SITE: A64274  
INSTALLATION: BH17  
COMPANY: WYG  
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



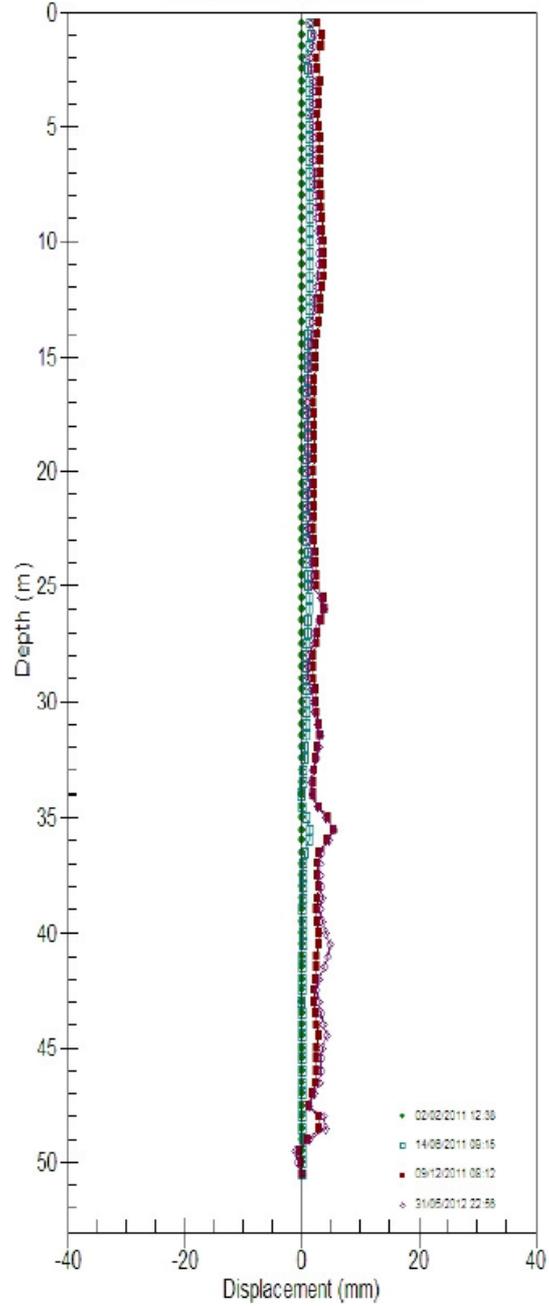
### SSC:BH17 - A Axis Cumulative

Initial survey: 02/02/2011 12:38



### SSC:BH17 - B Axis Cumulative

Initial survey: 02/02/2011 12:38

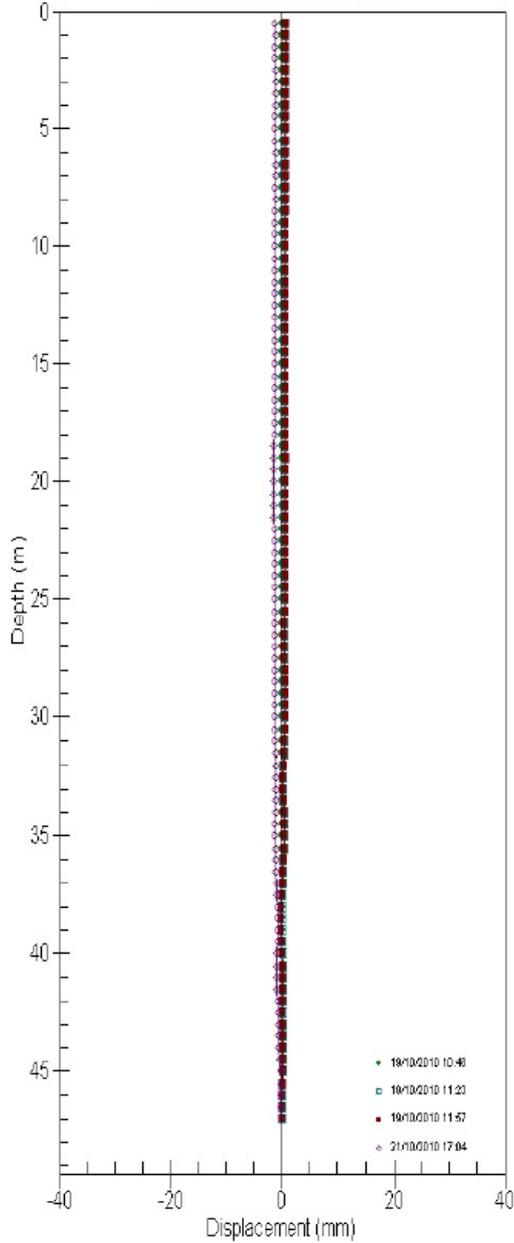


PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data  
SITE: Scarborough South Cliff  
INSTALLATION: BH17  
COMPANY: Mouchel Ltd  
CLIENT: Scarborough Borough Council  
NOTE: A0 Direction = East



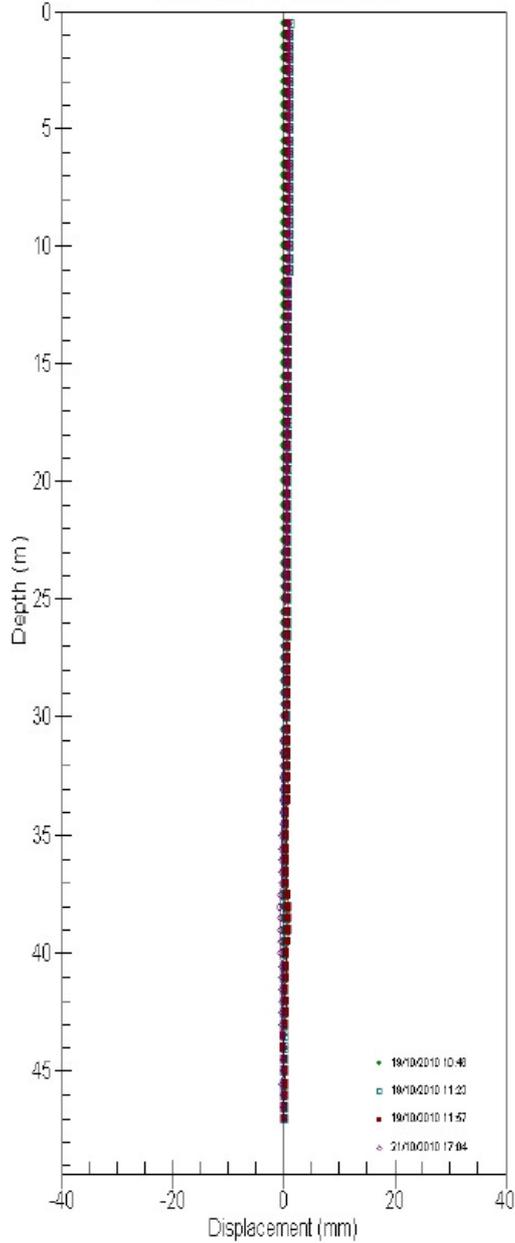
### A64274: BH20 - A Axis Cumulative

Initial survey: 19/10/2010 10:48



### A64274: BH20 - B Axis Cumulative

Initial survey: 19/10/2010 10:48



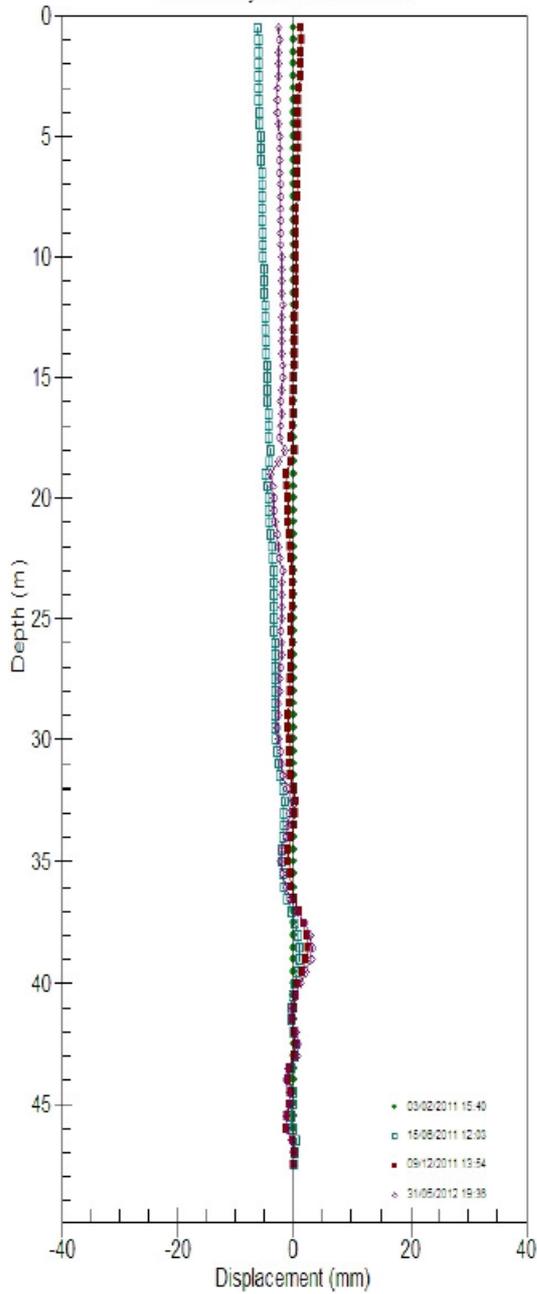
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT  
SITE: A64274  
INSTALLATION: BH20  
COMPANY: WYG  
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



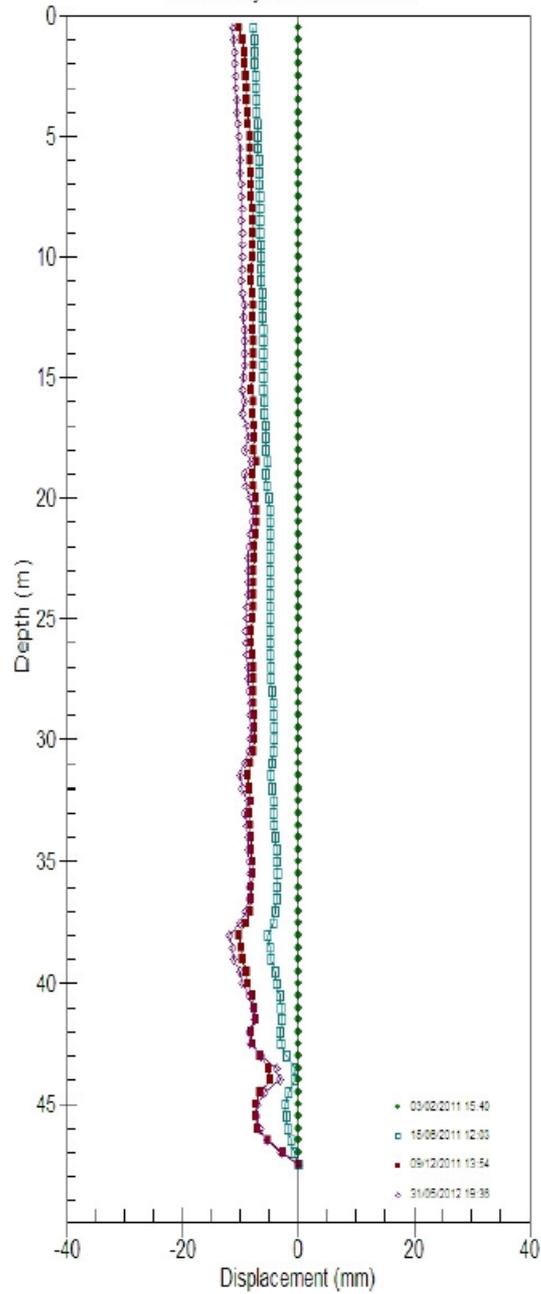
### SSC:BH20 - A Axis Cumulative

Initial survey: 03/02/2011 15:40



### SSC:BH20 - B Axis Cumulative

Initial survey: 03/02/2011 15:40



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough South Cliffs

INSTALLATION: BH20

COMPANY: Mouchel Ltd

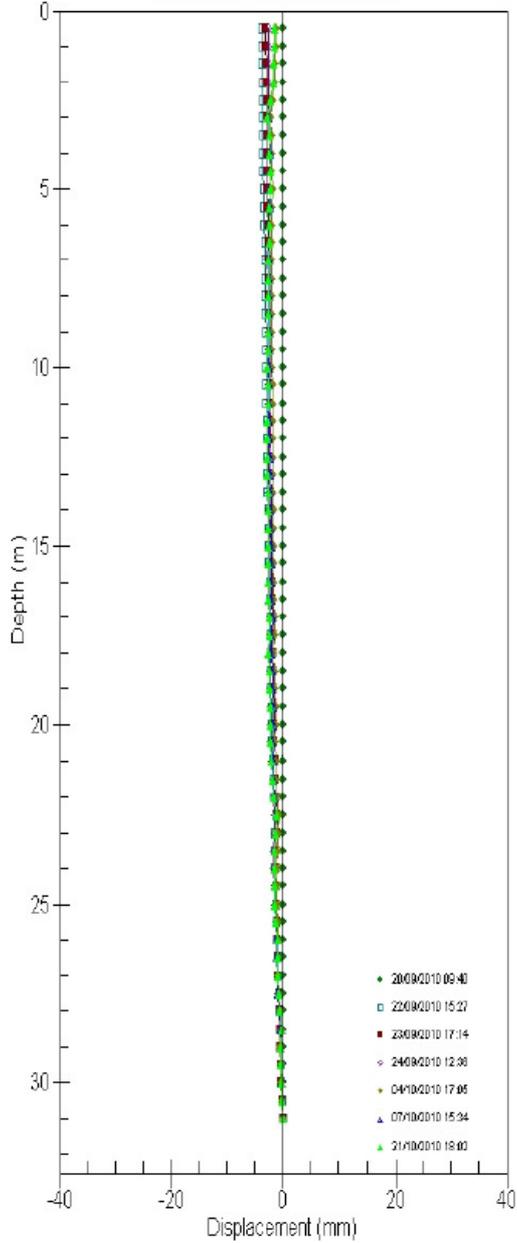
CLIENT: Scarborough Borough Council

NOTE: A0 Direction = East



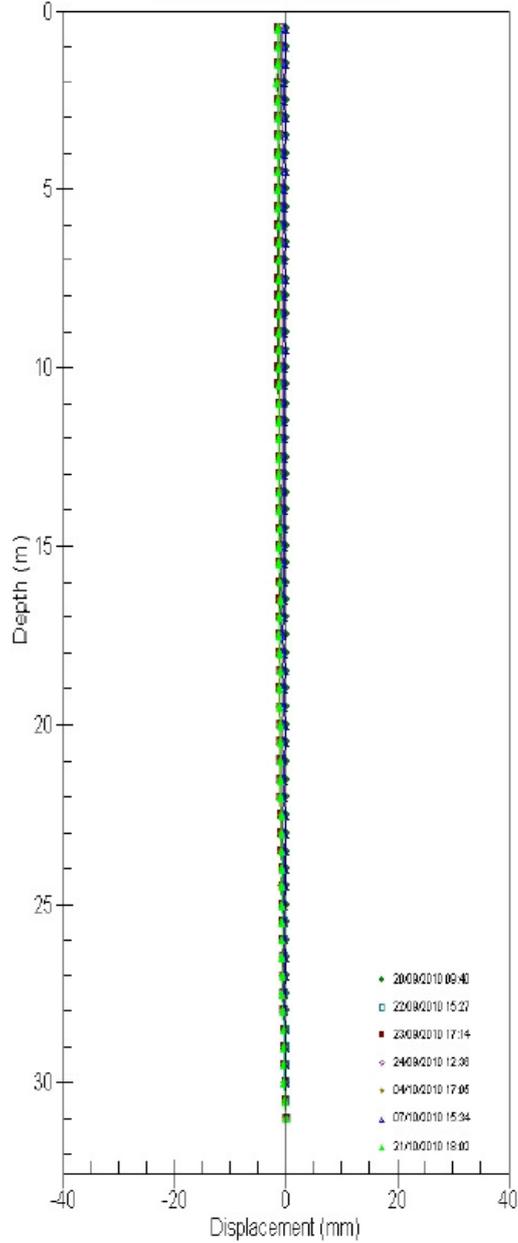
### A64274:BH21 - A Axis Cumulative

Initial survey: 20/09/2010 09:40



### A64274:BH21 - B Axis Cumulative

Initial survey: 20/09/2010 09:40



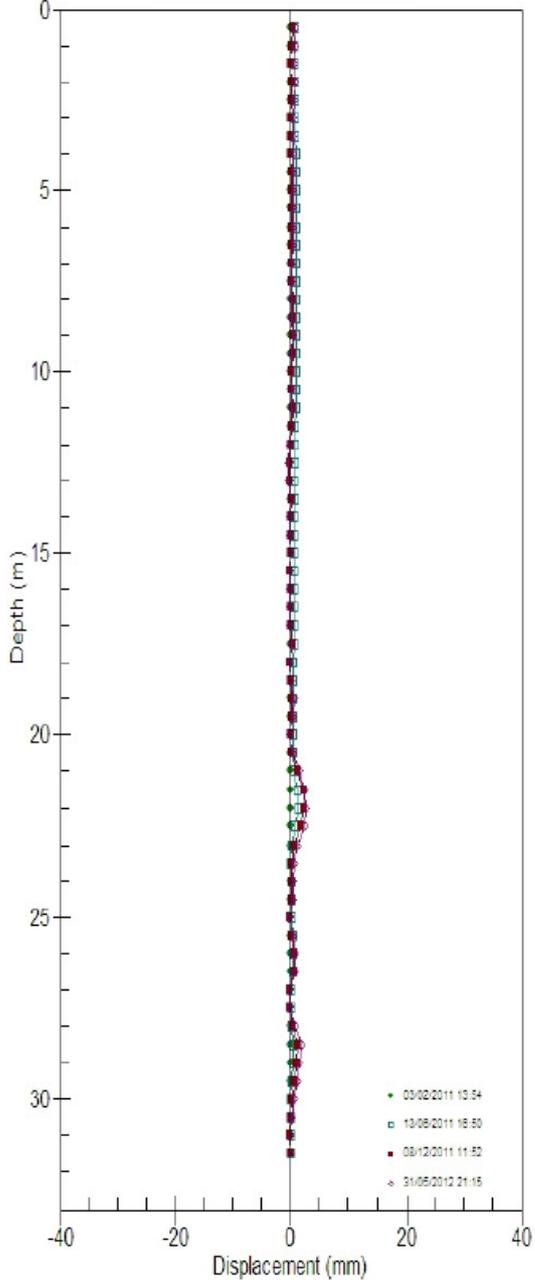
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME  
SITE: A64274  
INSTALLATION: BH21  
COMPANY: WYG  
CLIENT: SCARBOROUGH BOROUGH COUNCIL

NOTE:



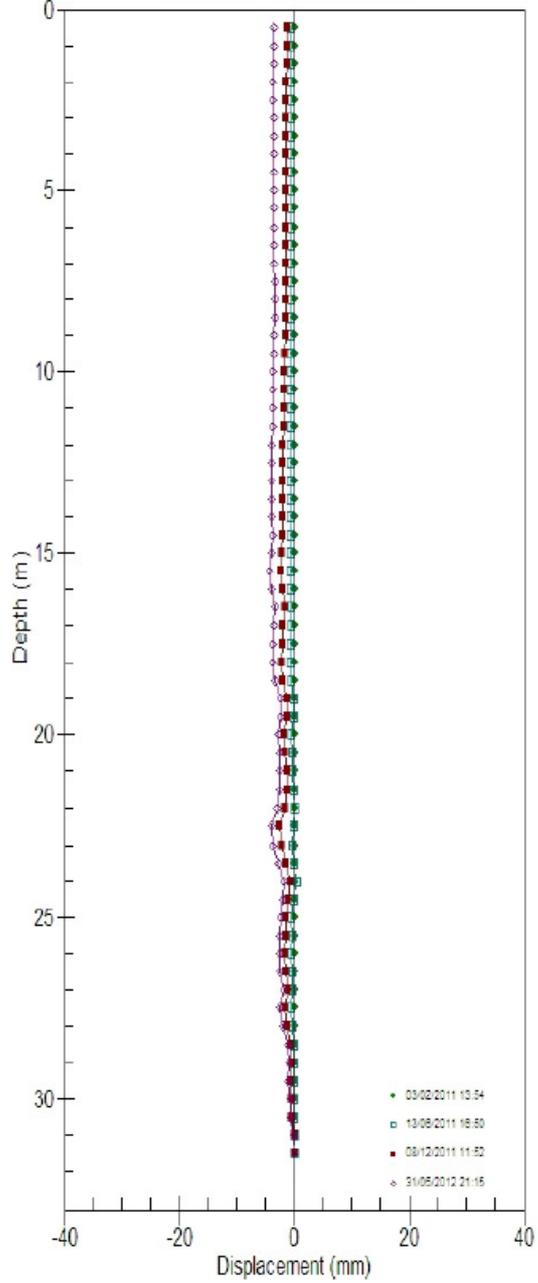
### SSC: BH21 - A Axis Cumulative

Initial survey: 03/02/2011 13:54



### SSC: BH21 - B Axis Cumulative

Initial survey: 03/02/2011 13:54



PROJECT: 1022971 Ongoing Analysis of Coastal Monitoring Data

SITE: Scarborough South Cliffs

INSTALLATION: BH21

COMPANY: Mouchel Ltd

CLIENT: Scarborough Borough Council

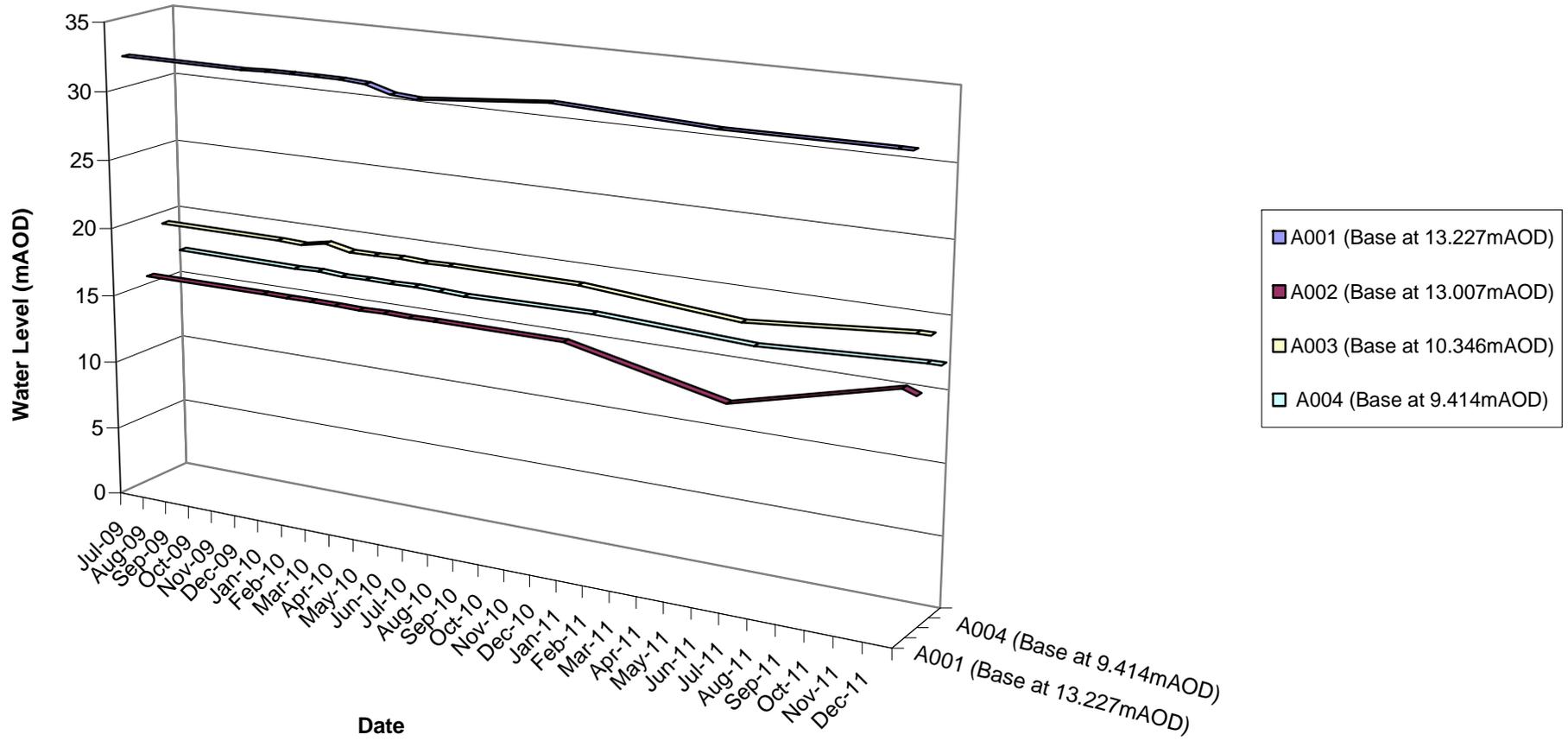
NOTE: A0 Direction = East

mouchel 

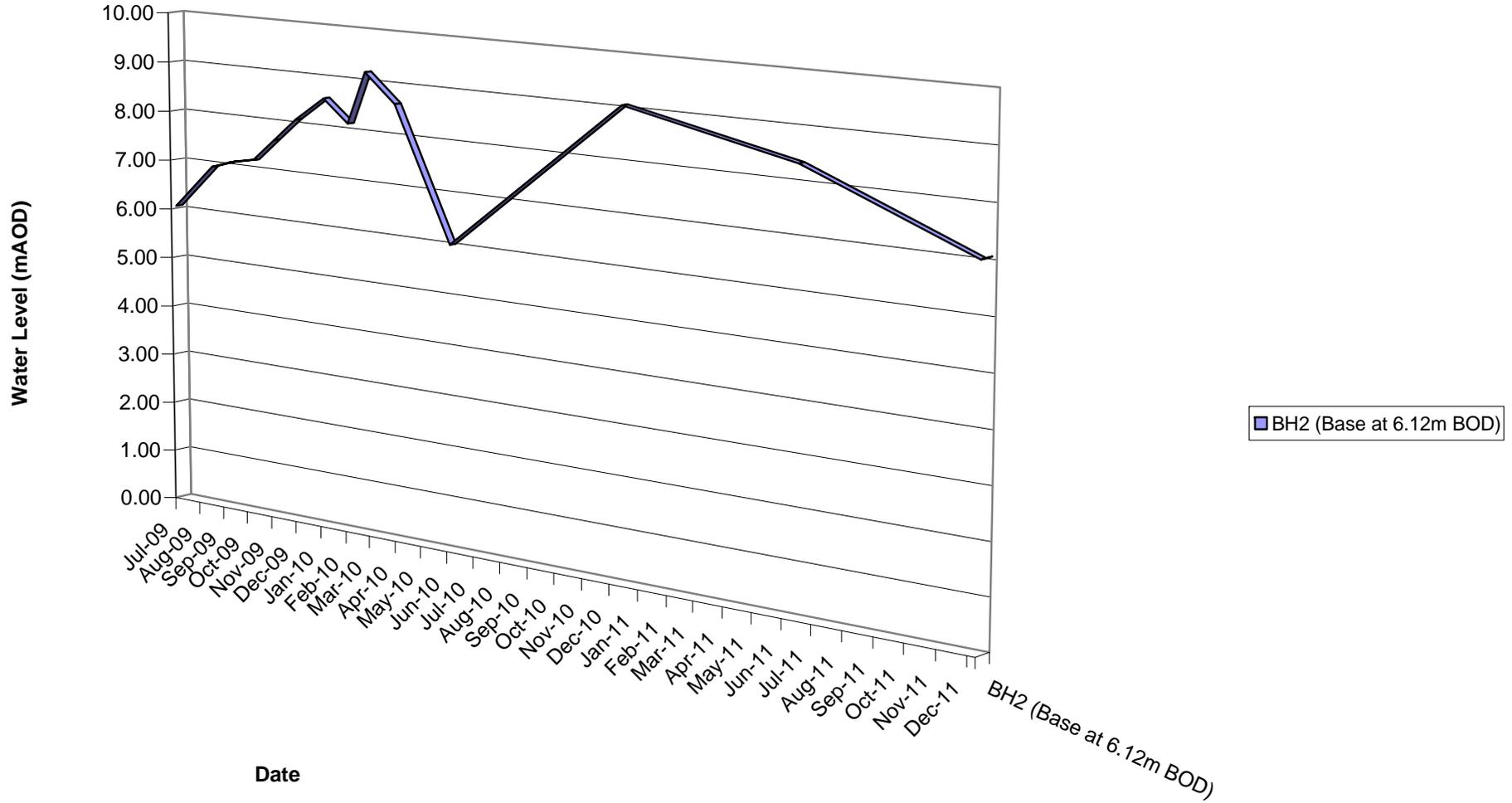
# **Appendix E    Groundwater Monitoring Graphs**



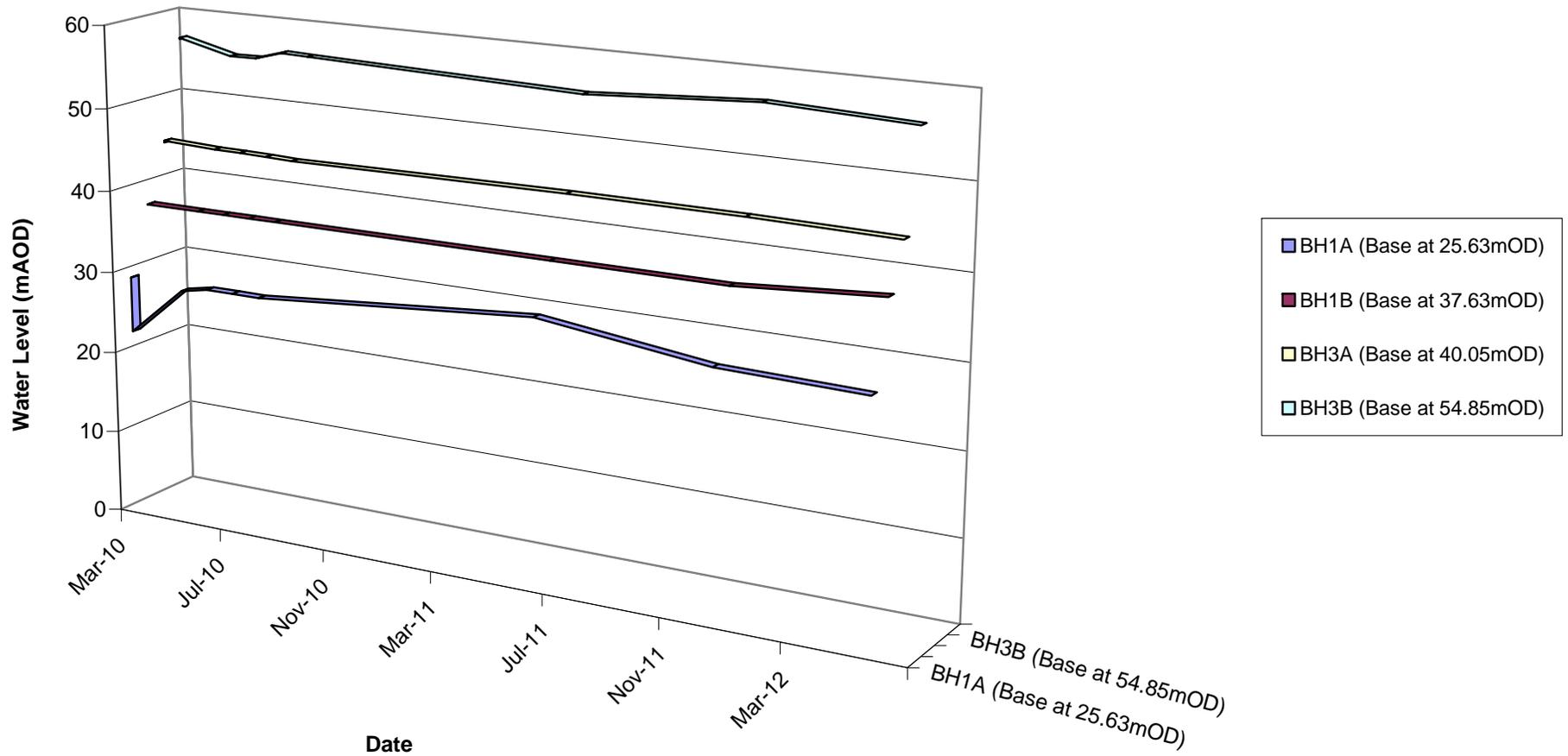
# RUNSWICK BAY GROUNDWATER LEVELS



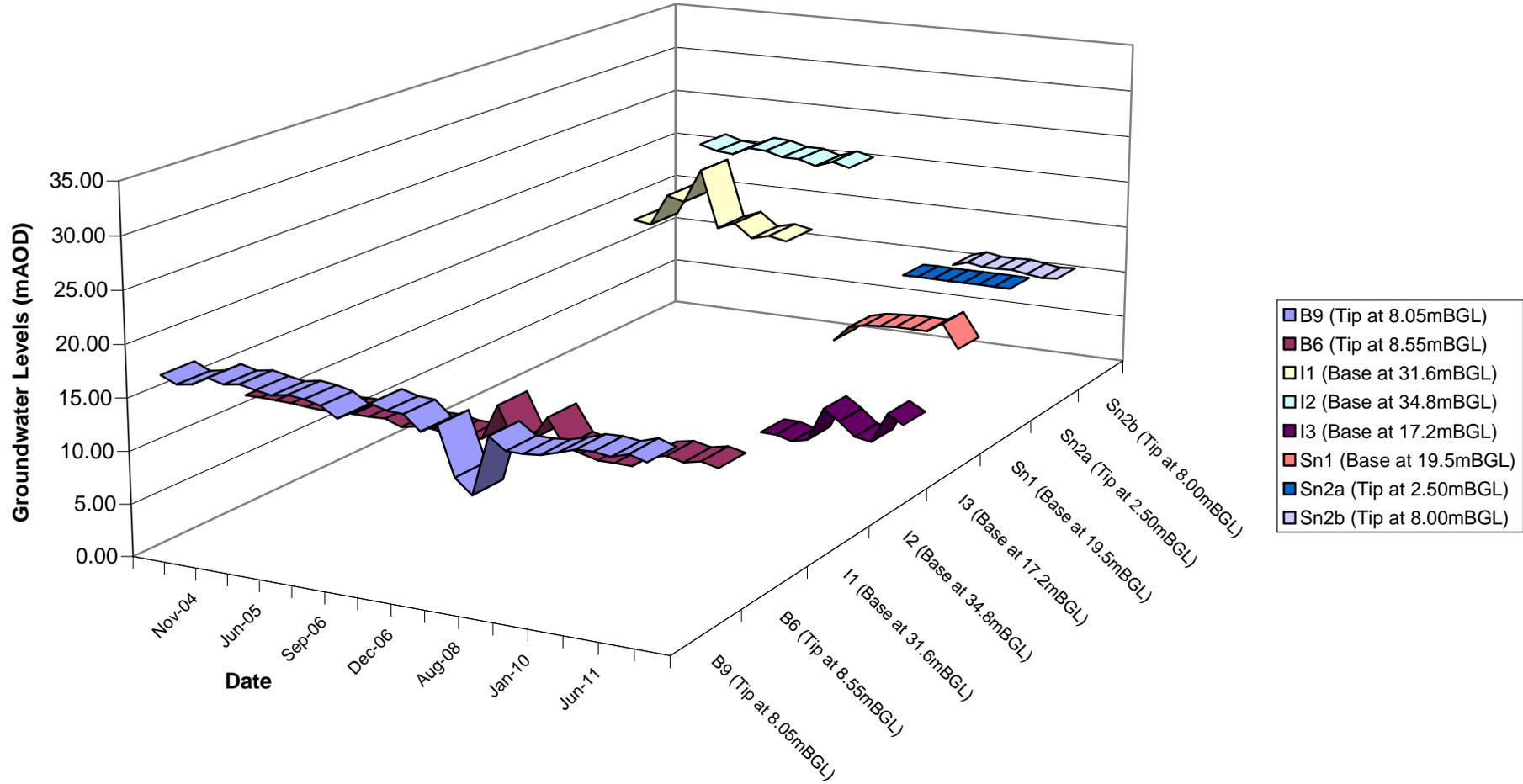
# WHITBY WEST CLIFF GROUNDWATER LEVELS



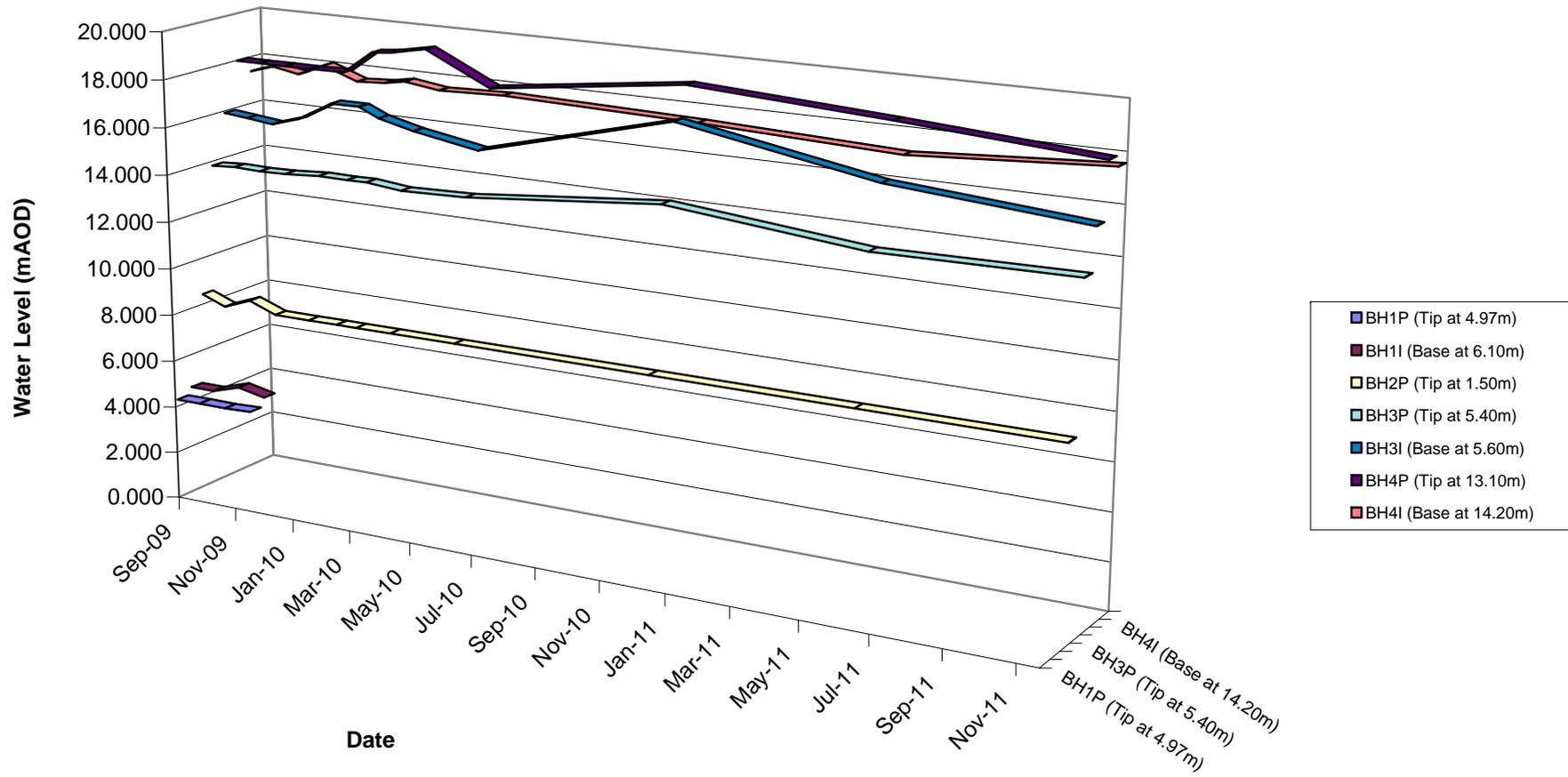
# ROBIN HOOD'S BAY GROUNDWATER LEVELS



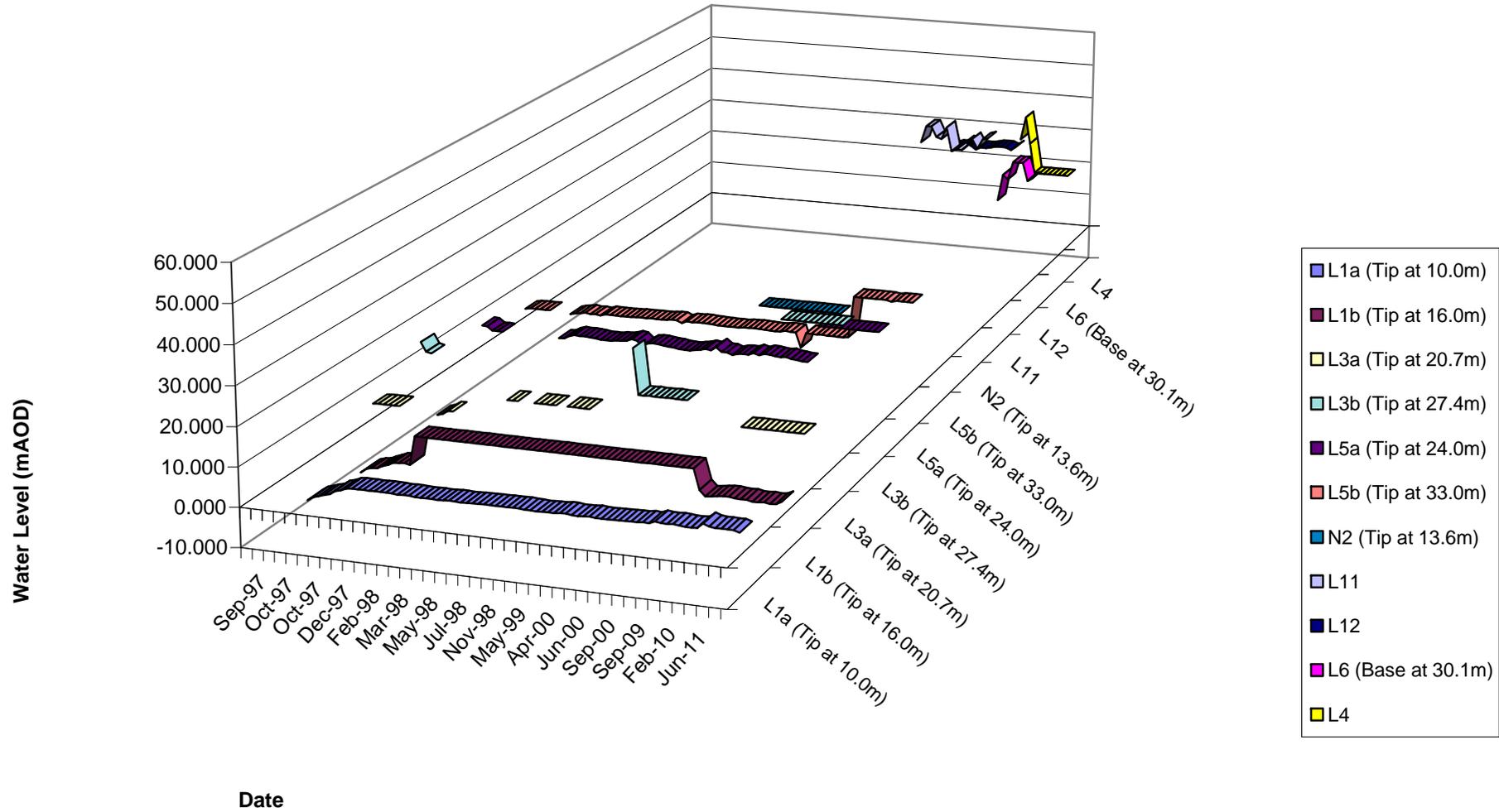
### SCALBY NESS GROUNDWATER LEVELS



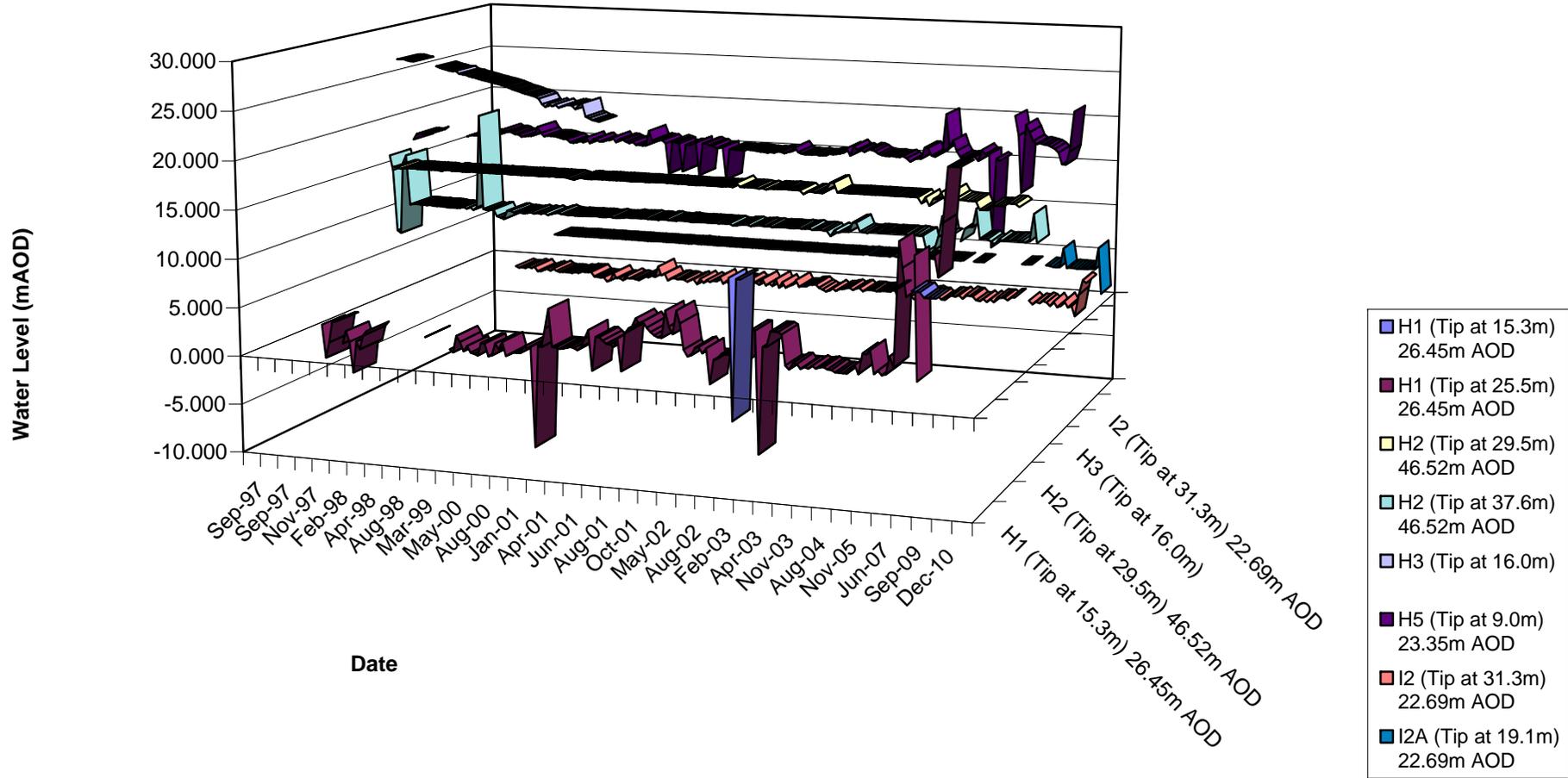
# OASIS CAFÉ GROUNDWATER LEVELS



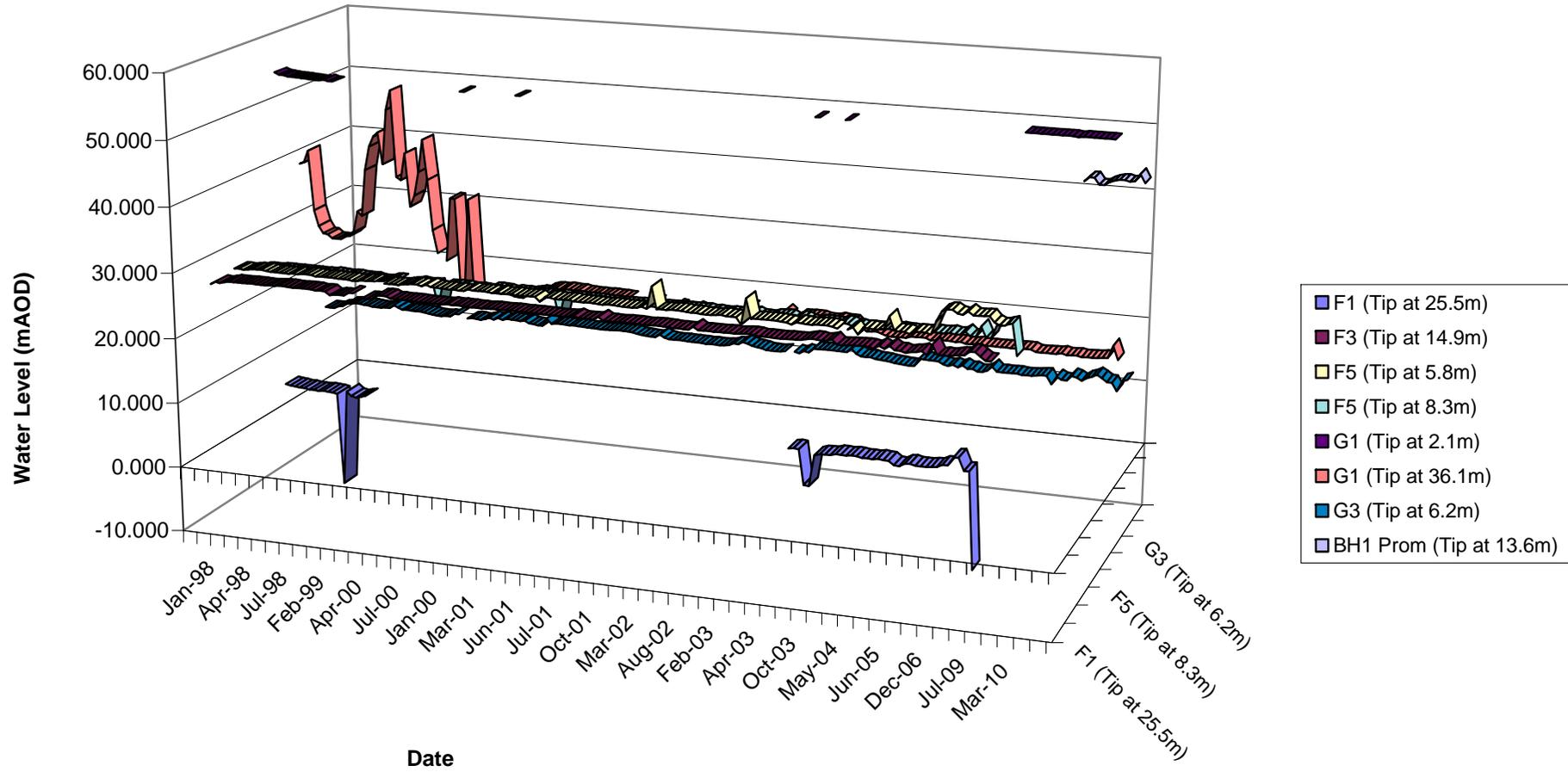
### SCARBOROUGH NORTH BAY GROUNDWATER LEVELS



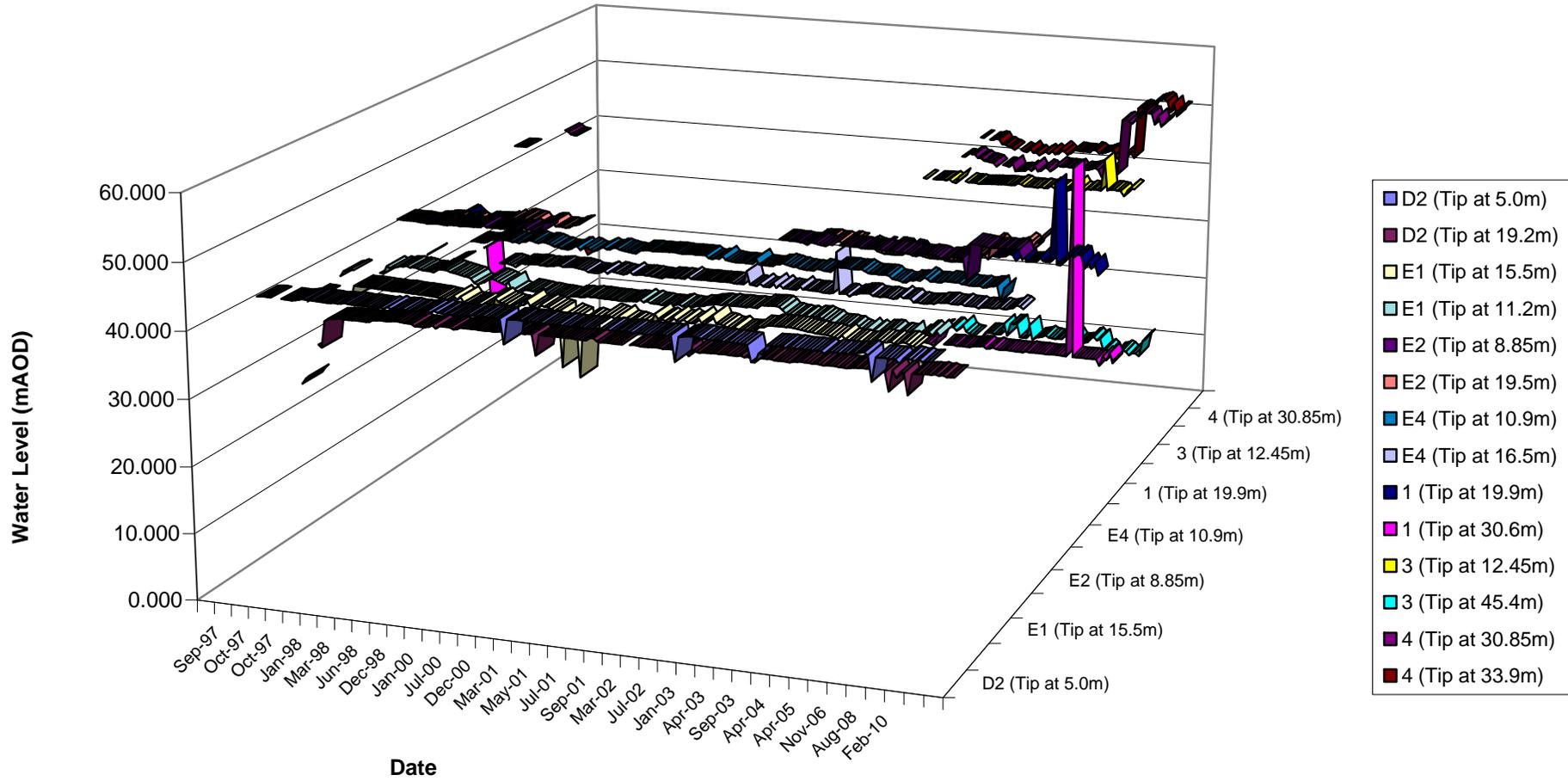
### SCARBOROUGH SOUTH CLIFF (NORTH) GROUNDWATER LEVELS



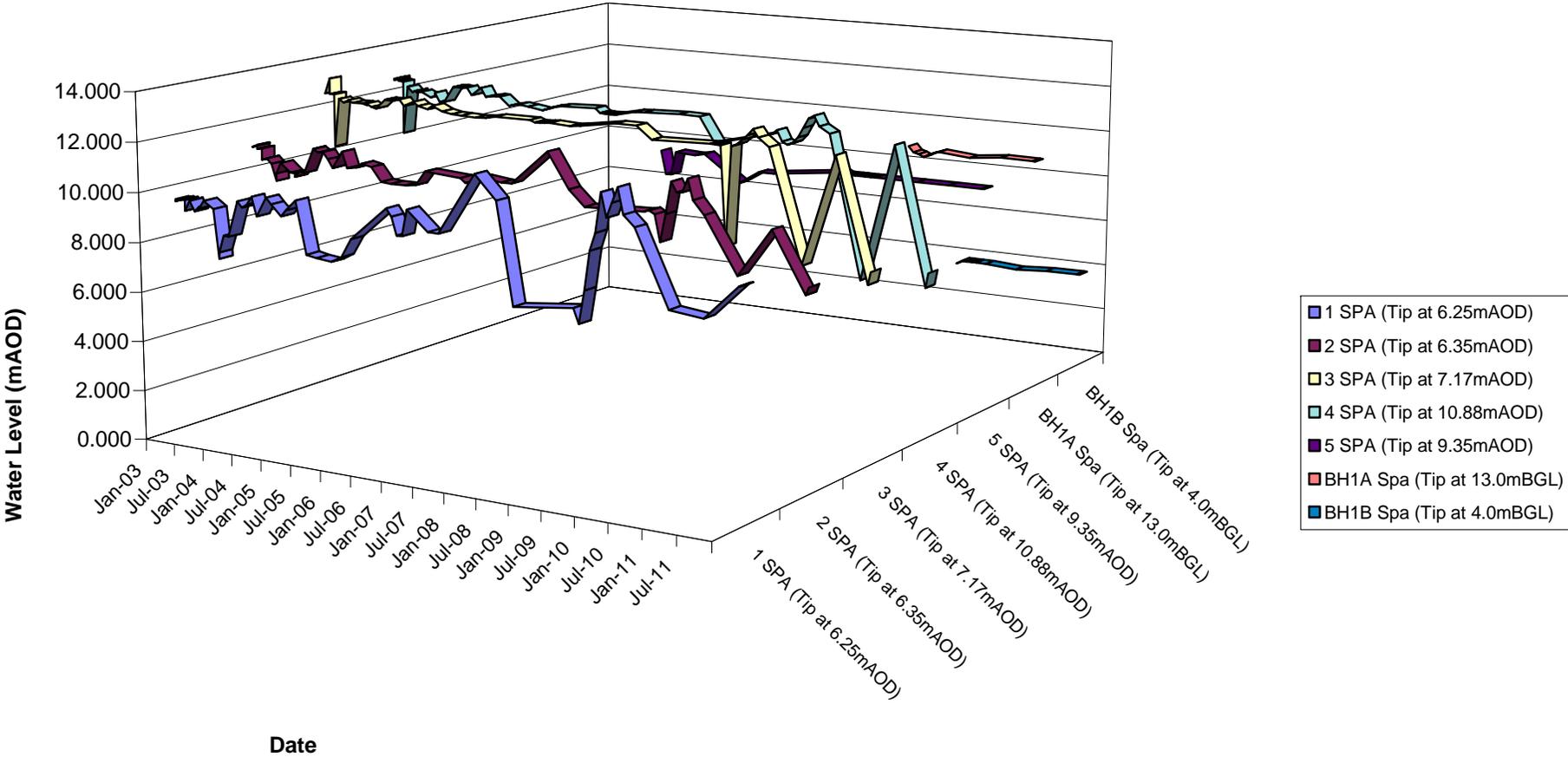
### SCARBOROUGH SOUTH CLIFF (MIDDLE) GROUNDWATER LEVELS



## SCARBOROUGH SOUTH CLIFF (SOUTH) GROUNDWATER LEVELS

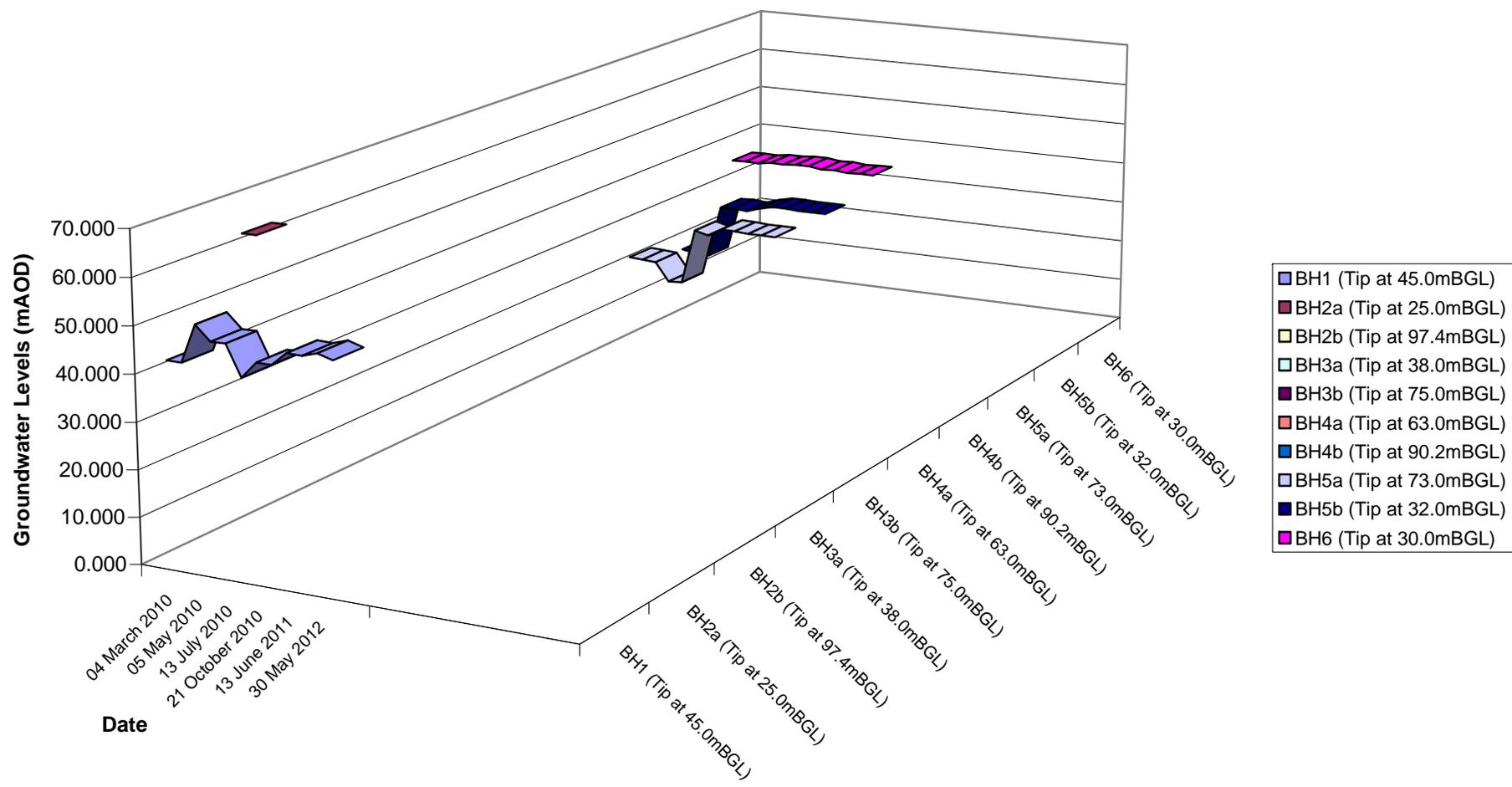


# SCARBOROUGH SPA GROUNDWATER LEVELS

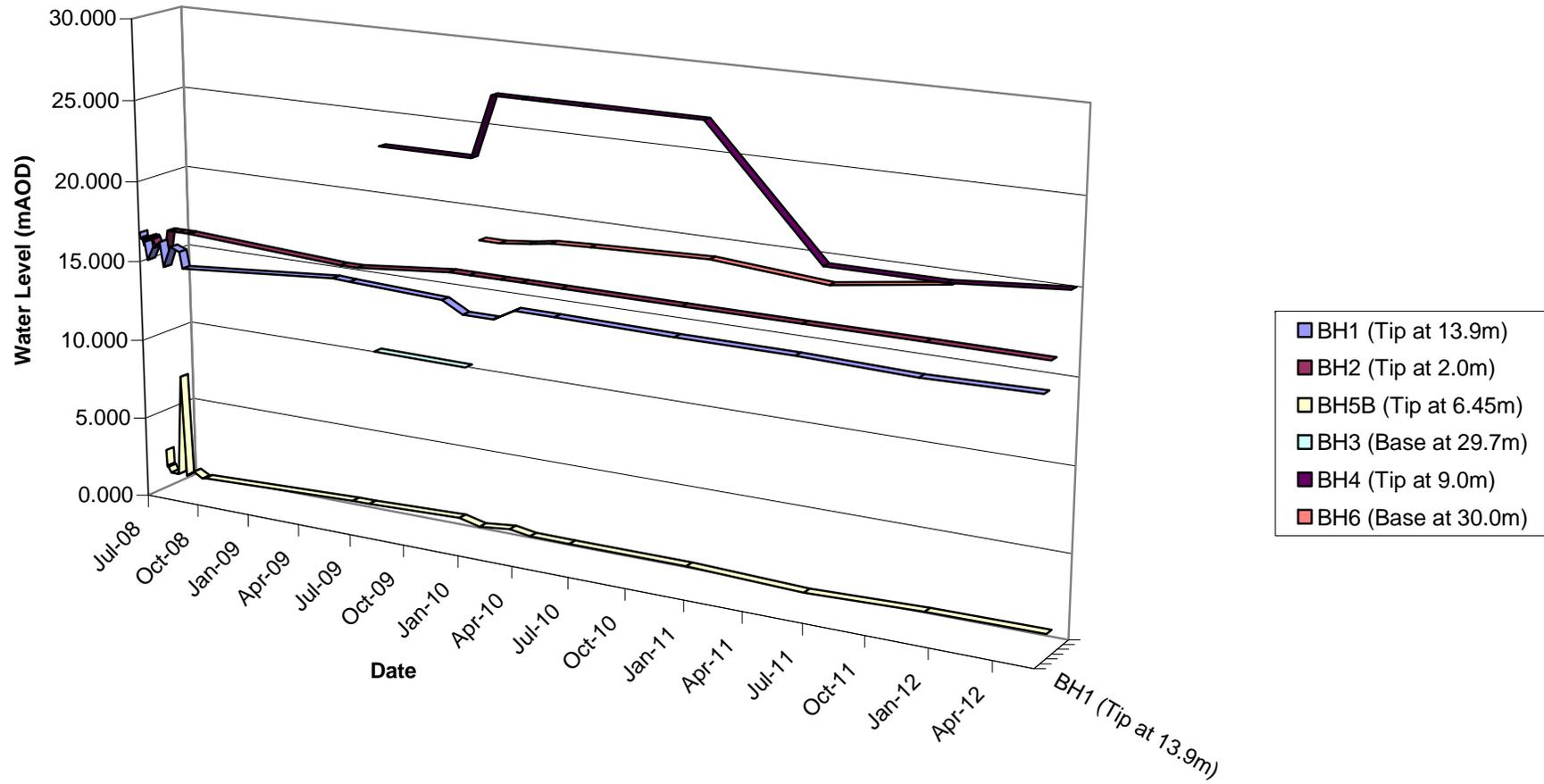




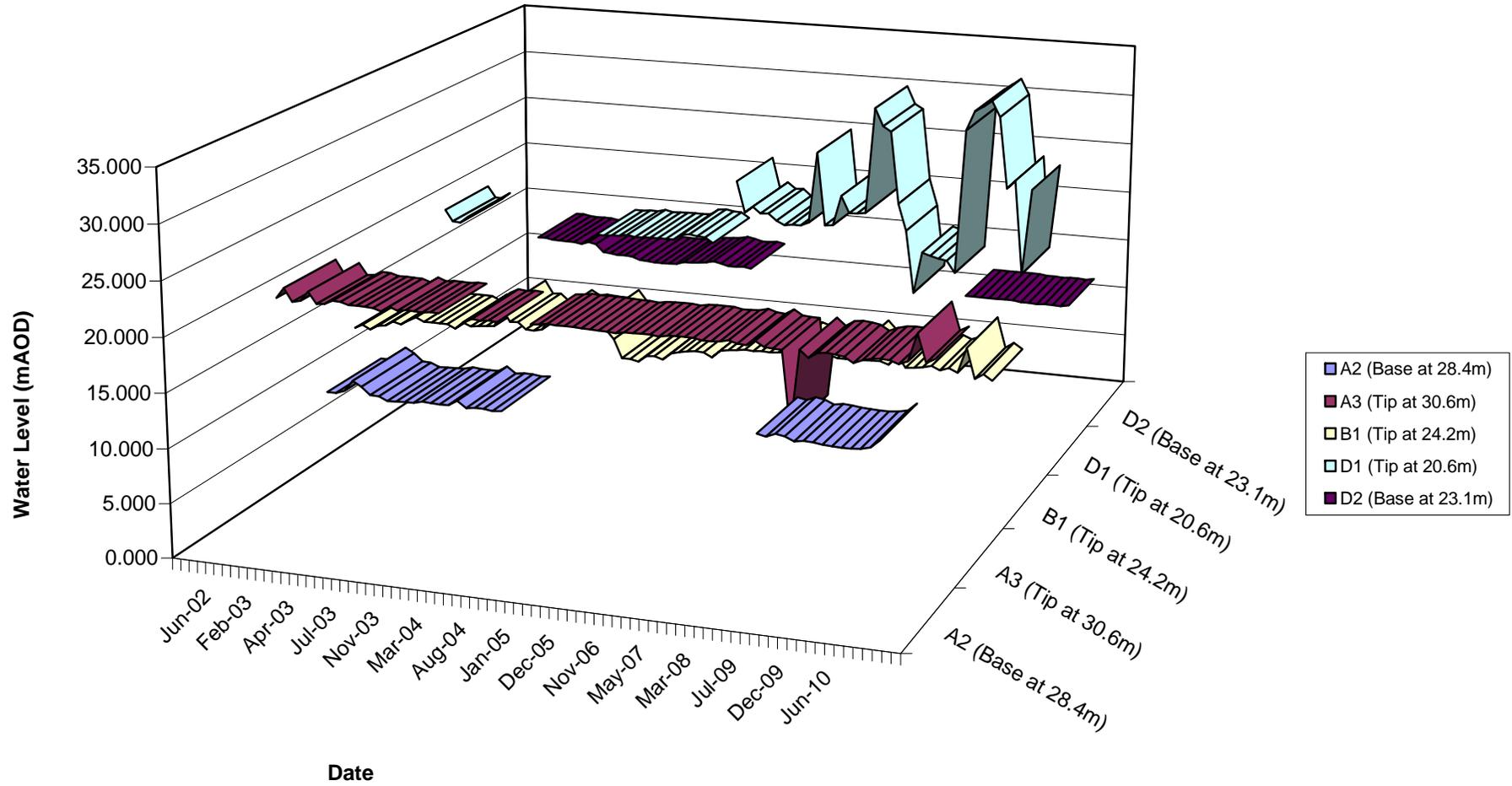
## KNIPE POINT GROUNDWATER LEVELS



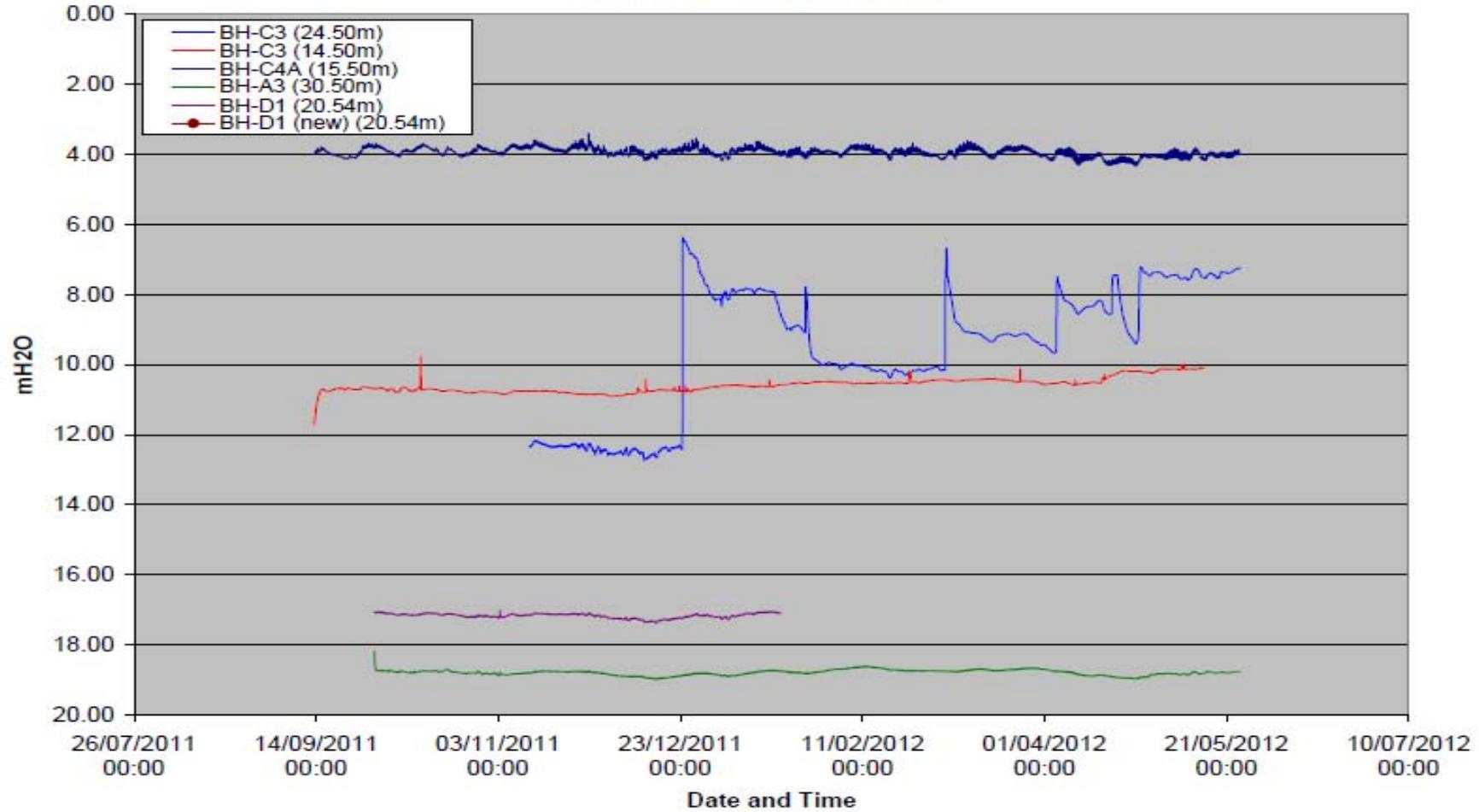
### FILEY TOWN GROUNDWATER LEVELS



### FILEY FLAT CLIFFS GROUNDWATER LEVELS



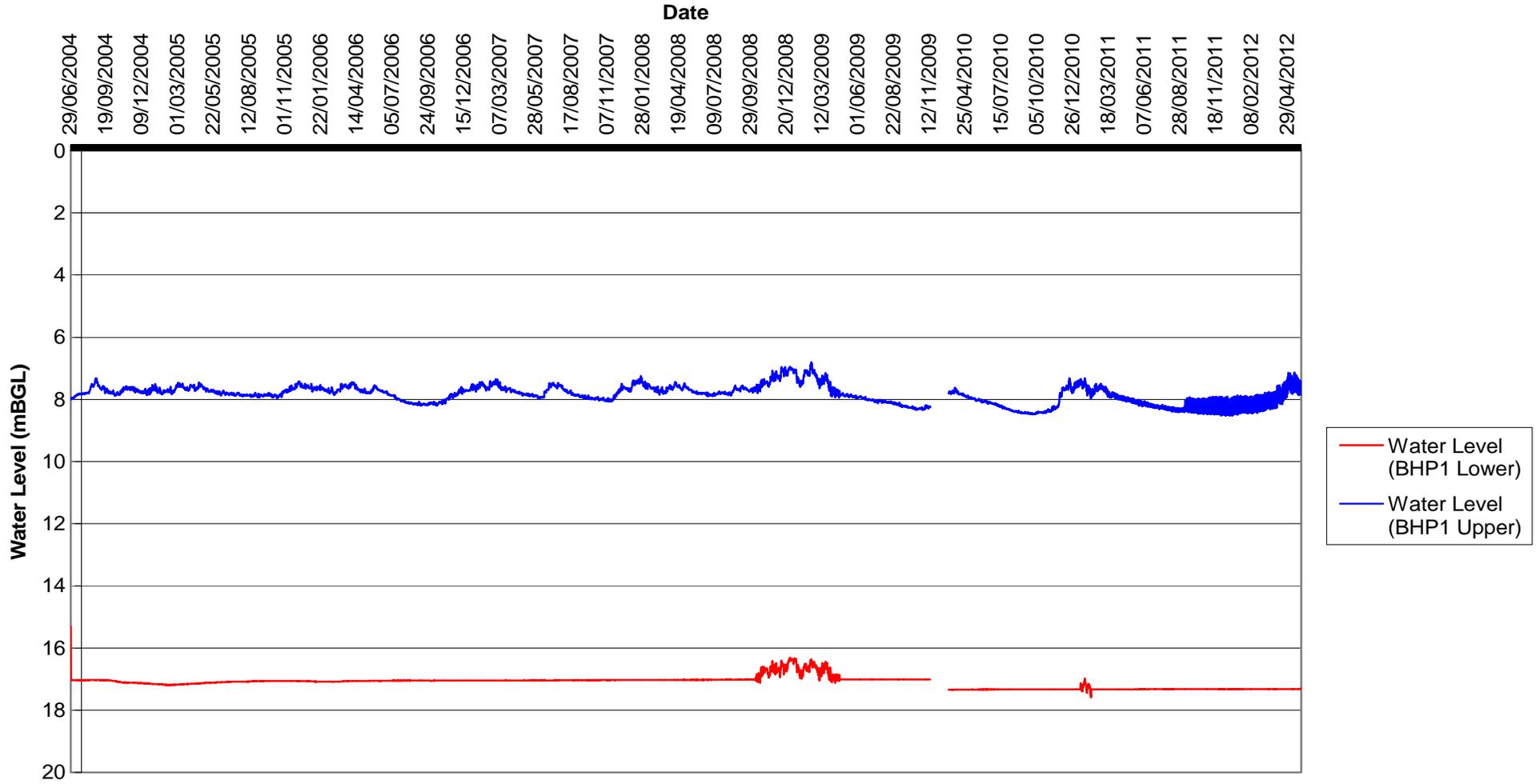
Mean water level (all boreholes)



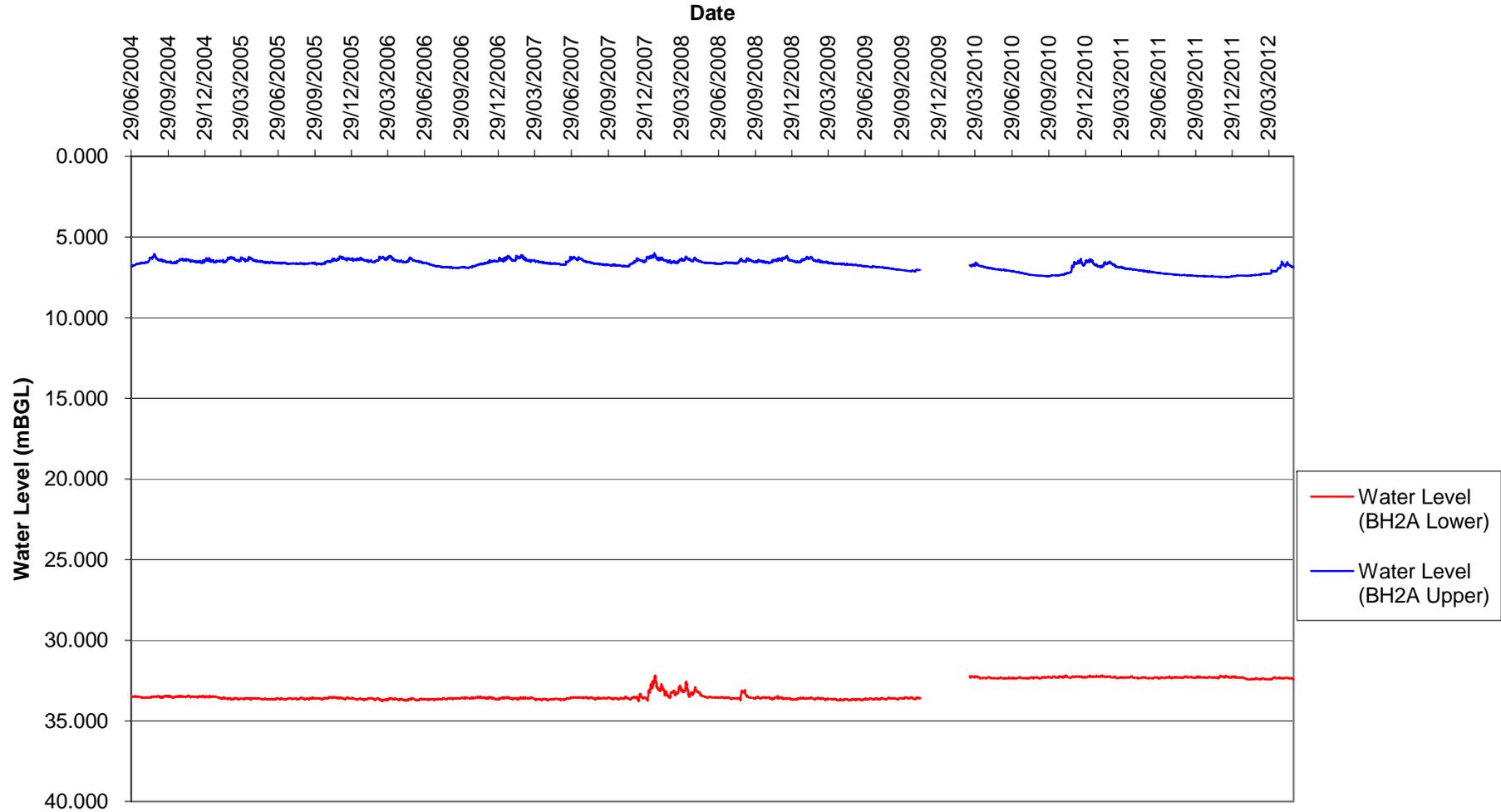
**Automated Piezometer Groundwater Monitoring  
Readings from Scalby Ness**



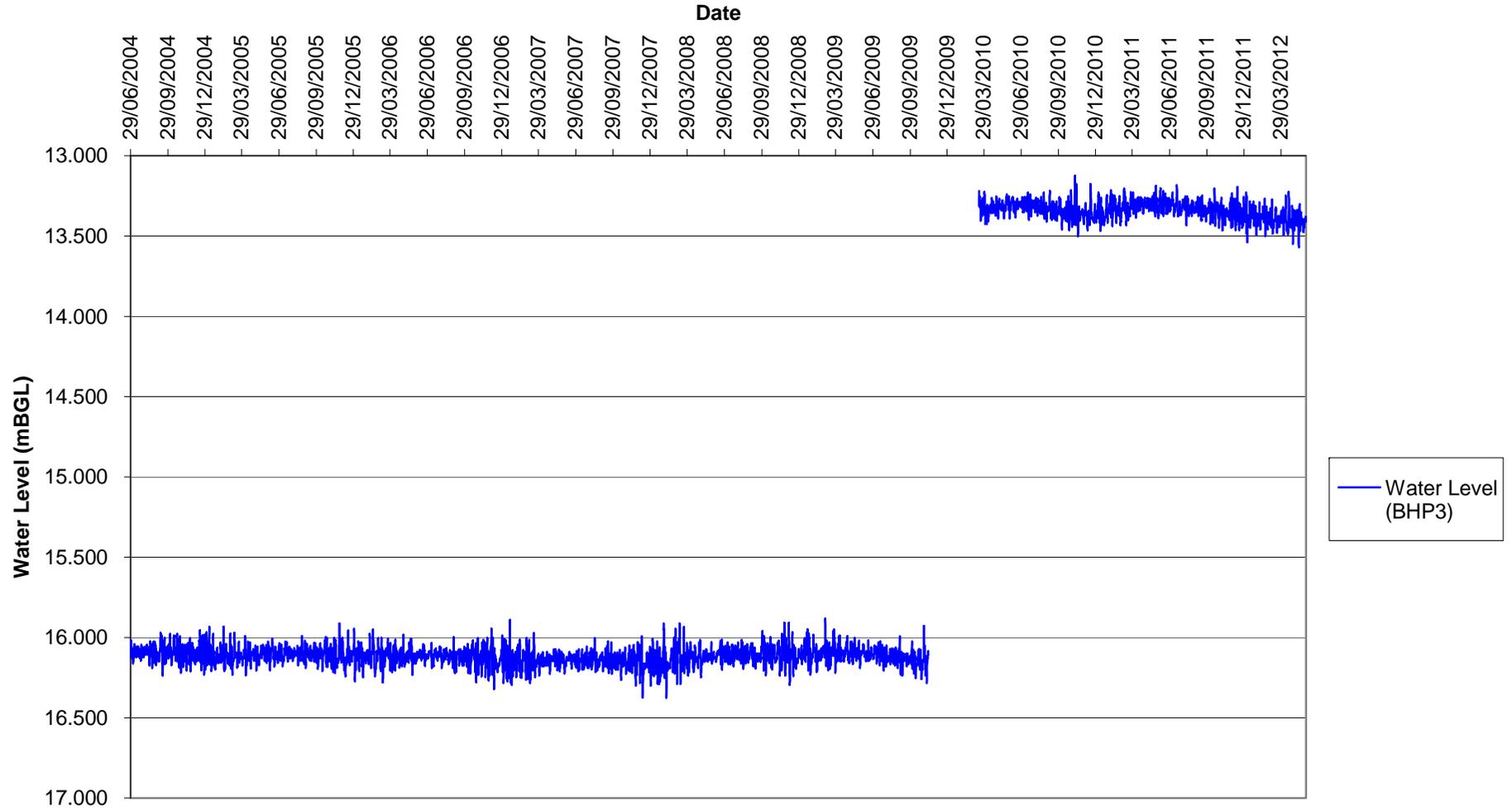
# SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



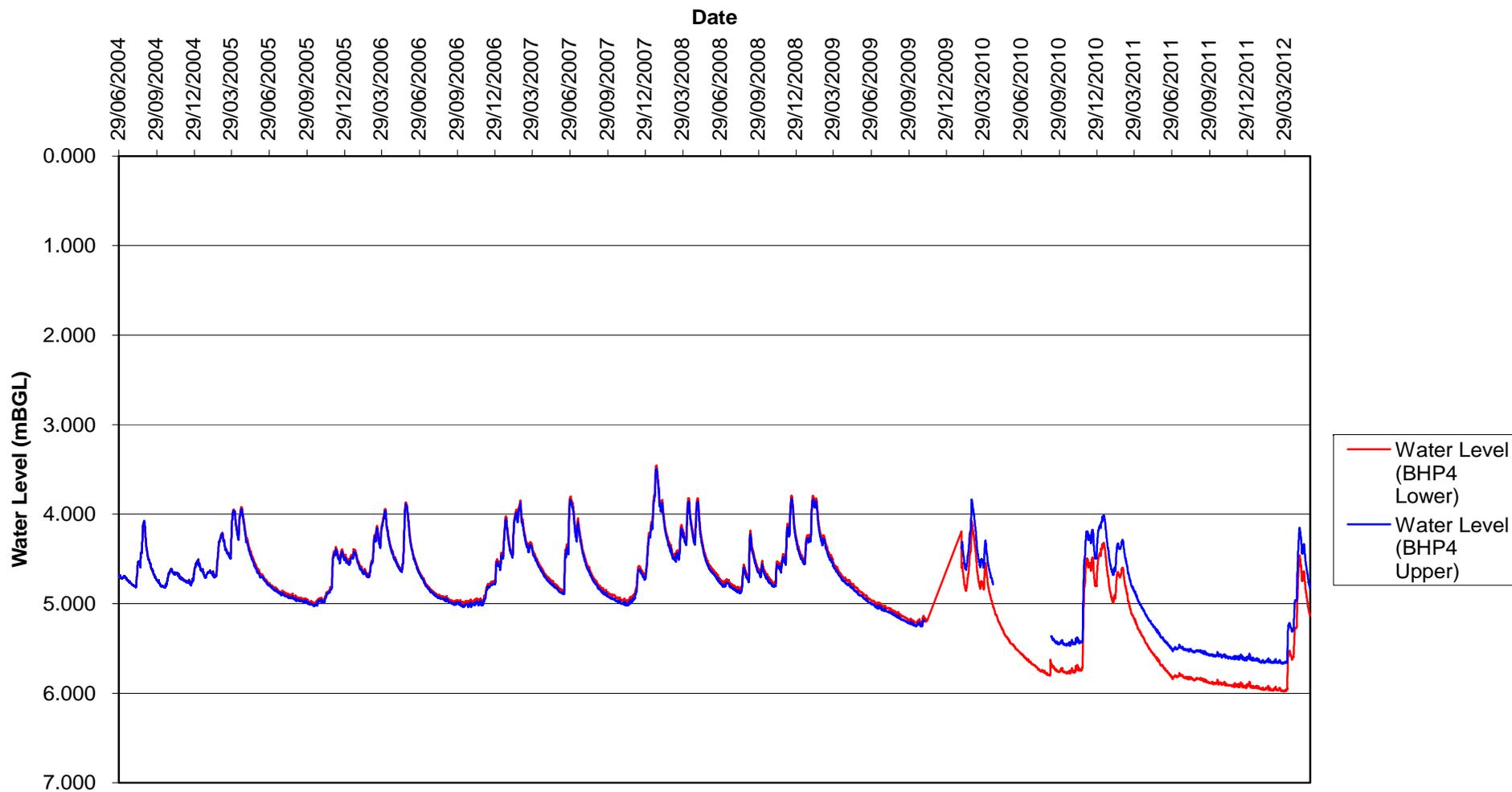
# SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



# SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



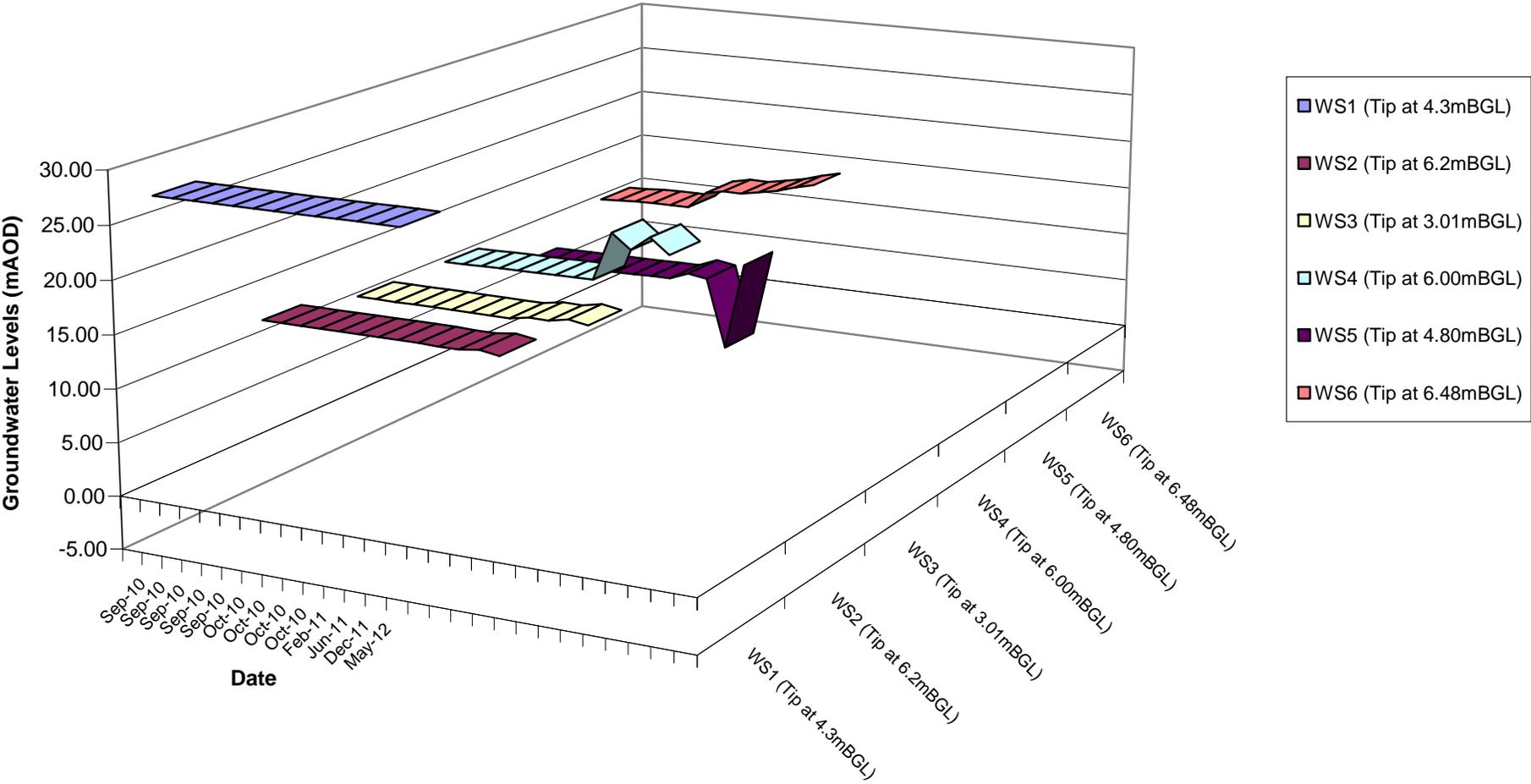
# SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



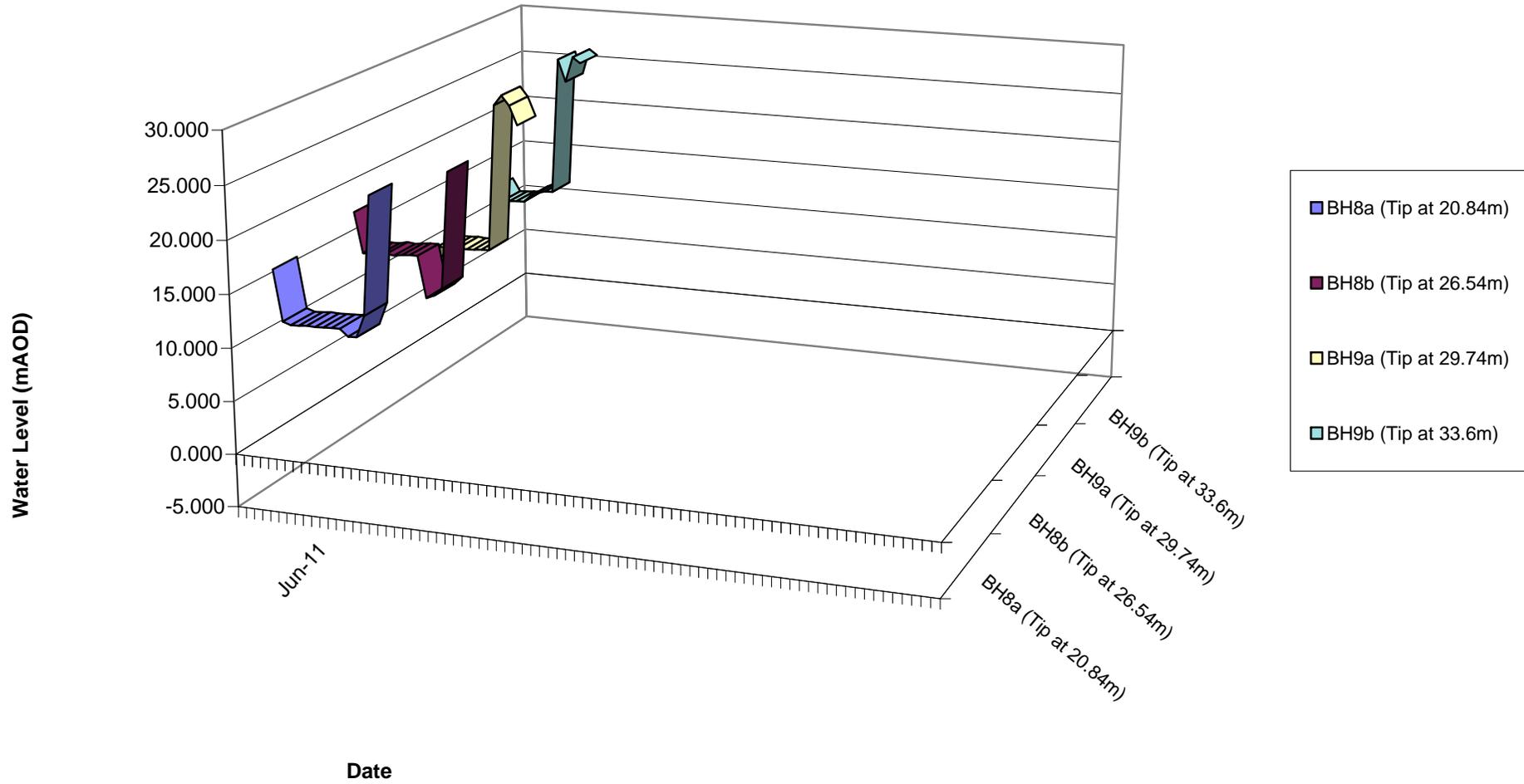
# **Appendix F Replacement Installation Groundwater Monitoring Graphs**



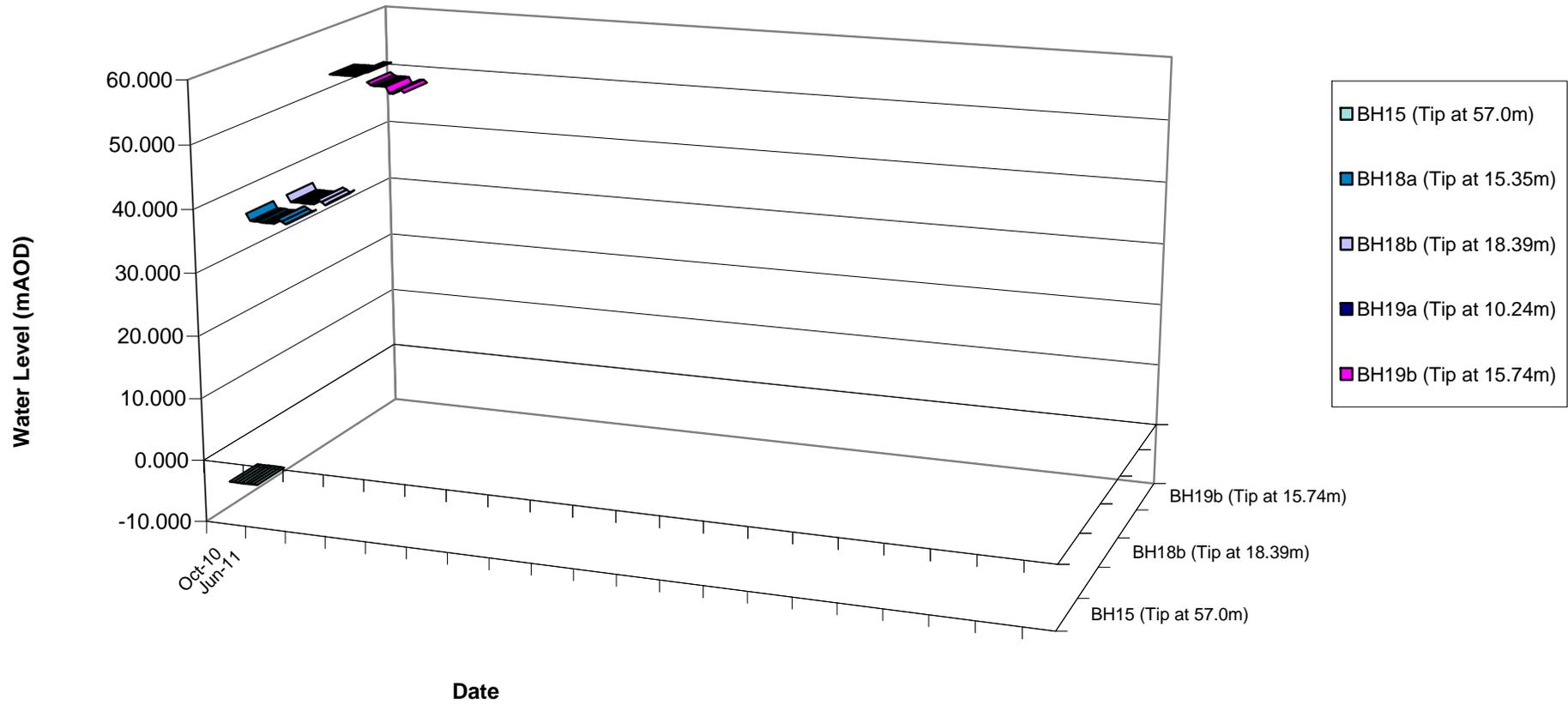
### SCALBY NESS REPLACEMENT INSTALLATION GROUNDWATER LEVELS



# THE HOLMS, SCARBOROUGH REPLACEMENT INSTALLATION GROUNDWATER LEVELS



# SCARBOROUGH SOUTH CLIFF REPLACEMENT INSTALLATION GROUNDWATER LEVELS



## Appendix G Survey Data



## Initial Monitoring of Survey Points – 22<sup>nd</sup> July 2009

Whitby West Cliff					
BH2	Easting	Northing	Height (m)	Slope Distance (m)	Remarks
MP1	489306.554	511468.120	40.864	8.319	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	489308.296	511474.546	35.887	7.869	
MP3	489310.241	511481.188	32.126	8.655	
MP4	489313.968	511487.066	26.988	12.623	
MP5	489315.765	511498.358	21.652	11.657	
MP6	489314.795	511508.928	16.825		

Scalby Ness					
	Easting	Northing	Height (m)	Slope Distance (m)	Remarks
MP1	503417.846	490962.702	35.853	3.15	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	503425.536	490962.701	36.059	4.30	
MP3	503429.459	490952.269	35.509	2.66	
MP4	503434.045	490941.940	34.969	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (m)	Slope Distance (m)	Remarks
MP1	504353.903	487885.382	48.508	7.206	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.701	487888.093	45.197	6.079	
MP3	504364.788	487888.922	41.974	9.117	
MP4	504372.839	487890.600	38.039	10.317	
MP5	504381.799	487893.850	34.090	9.246	
MP6	504389.334	487897.564	30.228		

**Initial Monitoring of Survey Points – 22<sup>nd</sup> July 2009 (Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (m)	Slope Distance (m)	Remarks
MP1	504549.325	487431.090	54.322	10.725	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.474	487434.499	53.691	12.990	
MP3	504571.837	487437.291	50.847	10.256	
MP4	504579.847	487440.336	45.212	13.849	
MP5	504592.579	487444.628	41.856		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (m)	Slope Distance (m)	Remarks
MP1	504754.082	487134.614	55.305	12.035	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.242	487137.096	49.350	6.004	
MP3	504769.607	487136.013	46.881	7.212	
MP4	504775.961	487137.850	44.007		

## Ongoing Coastal Monitoring of Survey Points – 24<sup>th</sup> August 2009

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.554	511468.120	40.864	8.311	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.296	511474.546	35.887	7.874	
MP3	489310.241	511481.188	32.126	8.657	
MP4	489313.968	511487.066	26.988	12.612	
MP5	489315.765	511498.358	21.652	11.665	
MP6	489314.795	511508.928	16.825		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.846	490962.702	35.853	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.536	490962.701	36.059	4.30	
MP3	503429.459	490952.269	35.509	2.65	
MP4	503434.045	490941.940	34.969	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.903	487885.382	48.508	7.206	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.701	487888.093	45.197	6.081	
MP3	504364.788	487888.922	41.974	9.114	
MP4	504372.839	487890.600	38.039	10.320	
MP5	504381.799	487893.850	34.090	9.246	
MP6	504389.334	487897.564	30.228		

**Ongoing Coastal Monitoring of Survey Points – 24<sup>th</sup> August 2009  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.325	487431.090	54.322	10.724	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.474	487434.499	53.691	12.983	
MP3	504571.837	487437.291	50.847	10.260	
MP4	504579.847	487440.336	45.212	13.855	
MP5	504592.579	487444.628	41.856		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.082	487134.614	55.305	12.050	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.242	487137.096	49.350	5.997	
MP3	504769.607	487136.013	46.881	7.236	
MP4	504775.961	487137.850	44.007		

## Ongoing Coastal Monitoring of Survey Points – 21<sup>st</sup> September 2009

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.567	511468.127	40.840	8.310	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.298	511474.546	35.879	7.870	
MP3	489310.263	511481.188	32.156	8.643	
MP4	489313.967	511487.050	26.974	12.617	
MP5	489315.744	511498.361	21.666	11.658	
MP6	489314.790	511508.925	16.801		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.839	490962.717	35.822	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.535	490962.710	36.027	4.30	
MP3	503429.464	490952.274	35.489	2.65	
MP4	503434.037	490941.924	34.953	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.945	487885.398	48.508	7.207	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.739	487888.114	45.193	6.082	
MP3	504364.829	487888.943	41.968	9.112	
MP4	504372.873	487890.619	38.039	10.323	
MP5	504381.838	487893.883	34.086	9.241	
MP6	504389.366	487897.596	30.221		

**Ongoing Coastal Monitoring of Survey Points – 21<sup>st</sup> September 2009  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.295	487431.105	54.318	10.719	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.441	487434.504	53.688	12.990	
MP3	504571.812	487437.273	50.852	10.264	
MP4	504579.833	487440.319	45.218	13.848	
MP5	504592.569	487444.599	41.863		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.076	487134.606	55.300	12.039	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.241	487137.088	49.346	6.000	
MP3	504769.602	487136.004	46.879	7.219	
MP4	504775.963	487137.837	44.999		

## Ongoing Coastal Monitoring of Survey Points – 12<sup>th</sup> October 2009

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.567	511468.127	40.840	8.313	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.298	511474.546	35.879	7.870	
MP3	489310.263	511481.188	32.156	8.657	
MP4	489313.967	511487.050	26.974	12.613	
MP5	489315.744	511498.361	21.666	11.656	
MP6	489314.790	511508.925	16.801		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.839	490962.717	35.822	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.535	490962.710	36.027	4.30	
MP3	503429.464	490952.274	35.489	2.65	
MP4	503434.037	490941.924	34.953	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.973	487885.396	48.512	7.211	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.771	487888.116	45.197	6.079	
MP3	504364.855	487888.946	41.970	9.110	
MP4	504372.897	487890.625	38.032	10.319	
MP5	504381.858	487893.891	34.092	9.247	
MP6	504389.389	487897.611	30.225		

**Ongoing Coastal Monitoring of Survey Points – 12<sup>th</sup> October 2009  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.310	487431.103	54.320	10.726	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.463	487434.503	53.688	12.978	
MP3	504571.821	487437.280	50.859	10.262	
MP4	504579.839	487440.330	45.227	13.848	
MP5	504592.573	487444.612	41.868		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.075	487134.604	55.300	12.050	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.249	487137.102	49.345	5.997	
MP3	504769.605	487136.013	46.878	7.225	
MP4	504775.968	487137.847	43.989		

## Ongoing Coastal Monitoring of Survey Points – 16<sup>th</sup> November 2009

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.563	511468.127	40.911	8.315	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.307	511474.548	35.933	7.871	
MP3	489310.278	511481.208	32.181	8.655	
MP4	489313.954	511487.061	26.987	12.618	
MP5	489315.753	511498.365	21.685	11.663	
MP6	489314.803	511508.927	16.838		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.830	490962.730	35.860	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.526	490962.706	36.066	4.30	
MP3	503429.456	490952.269	35.520	2.65	
MP4	503434.022	490941.926	34.975	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.978	487885.391	48.529	7.200	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.768	487888.104	45.218	6.082	
MP3	504364.856	487888.946	41.992	9.112	
MP4	504372.898	487890.614	38.050	10.318	
MP5	504381.859	487893.876	34.111	9.251	
MP6	504389.392	487897.598	30.241		

**Ongoing Coastal Monitoring of Survey Points – 16<sup>th</sup> November 2009  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.296	487431.089	54.307	10.723	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.463	487434.491	53.673	12.989	
MP3	504571.811	487437.268	50.844	10.265	
MP4	504579.828	487440.319	45.206	13.856	
MP5	504592.567	487444.614	41.852		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.080	487134.589	55.312	12.047	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.252	487137.084	49.359	6.000	
MP3	504769.608	487135.997	46.882	7.223	
MP4	504775.975	487137.827	44.004		

## Ongoing Coastal Monitoring of Survey Points – 14<sup>th</sup> December 2009

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.570	511468.135	40.864	8.309	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.301	511474.548	35.863	7.870	
MP3	489310.275	511481.195	32.104	8.657	
MP4	489313.963	511487.086	26.918	12.623	
MP5	489315.748	511498.376	21.605	11.657	
MP6	489314.790	511508.950	16.764		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.829	490962.715	35.861	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.527	490962.707	36.077	4.30	
MP3	503429.466	490952.282	35.546	2.65	
MP4	503434.021	490941.941	34.985	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.925	487885.364	48.513	7.207	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.724	487888.078	45.204	6.078	
MP3	504364.808	487888.912	41.979	9.112	
MP4	504372.852	487890.587	38.039	10.320	
MP5	504381.815	487893.847	34.098	9.252	
MP6	504389.352	487897.569	30.233		

**Ongoing Coastal Monitoring of Survey Points – 14<sup>th</sup> December 2009  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.289	487431.079	54.292	10.721	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.438	487434.479	53.670	12.999	
MP3	504571.816	487437.252	50.829	10.266	
MP4	504579.838	487440.302	45.195	13.849	
MP5	504592.573	487444.589	41.841		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.082	487134.597	55.319	12.046	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.252	487137.083	49.361	6.006	
MP3	504769.616	487135.994	46.888	7.219	
MP4	504775.976	487137.828	44.007		

## Ongoing Coastal Monitoring of Survey Points – 15<sup>th</sup> June 2010

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.572	511468.139	40.855	8.309	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.284	511474.571	35.878	7.868	
MP3	489310.272	511481.190	32.136	8.656	
MP4	489313.966	511487.068	26.950	12.620	
MP5	489315.756	511498.367	21.670	11.659	
MP6	489314.818	511508.950	16.814		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.829	490962.723	35.845	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.539	490962.715	36.060	4.30	
MP3	503429.476	490952.267	35.508	2.65	
MP4	503434.042	490941.921	34.962	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.919	487885.355	48.584	7.212	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.726	487888.064	45.274	6.073	
MP3	504364.807	487888.898	42.053	9.113	
MP4	504372.853	487890.572	38.115	10.321	
MP5	504381.818	487893.825	34.170	9.247	
MP6	504389.354	487897.535	30.303		

**Ongoing Coastal Monitoring of Survey Points – 15<sup>th</sup> June 2010  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.290	487431.118	54.317	10.724	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.444	487434.512	53.695	12.990	
MP3	504571.812	487437.279	50.848	10.258	
MP4	504579.831	487440.317	45.218	13.845	
MP5	504592.563	487444.598	41.863		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.082	487134.607	55.321	12.042	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.247	487137.100	49.366	6.006	
MP3	504769.611	487136.012	46.892	7.220	
MP4	504775.973	487137.846	44.014		

## Ongoing Coastal Monitoring of Survey Points – 13<sup>th</sup> December 2010

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.563	511468.153	40.884	8.310	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.320	511474.585	35.928	7.869	
MP3	489310.271	511481.215	32.163	8.660	
MP4	489313.963	511487.061	26.965	12.618	
MP5	489315.765	511498.356	21.642	11.661	
MP6	489314.785	511508.926	16.784		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.843	490962.717	35.844	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.536	490962.704	36.068	4.30	
MP3	503429.471	490952.278	35.514	2.65	
MP4	503434.040	490941.922	34.954	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.965	487885.386	48.503	7.216	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.771	487888.103	45.190	6.073	
MP3	504364.859	487888.937	41.968	9.113	
MP4	504372.900	487890.621	38.026	10.321	
MP5	504381.858	487893.884	34.088	9.247	
MP6	504389.394	487897.601	30.221		

**Ongoing Coastal Monitoring of Survey Points – 13<sup>th</sup> December 2010  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.312	487431.084	54.312	10.722	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.459	487434.491	53.691	12.999	
MP3	504571.835	487437.273	50.849	10.248	
MP4	504579.838	487440.312	45.215	13.850	
MP5	504592.574	487444.599	41.862		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.093	487134.604	55.324	12.042	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.259	487137.098	49.371	6.011	
MP3	504769.629	487136.012	46.898	7.215	
MP4	504775.985	487137.840	44.015		

## Ongoing Coastal Monitoring of Survey Points – 24<sup>th</sup> June 2011

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.563	511468.153	40.884	8.307	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.320	511474.585	35.928	7.872	
MP3	489310.271	511481.215	32.163	8.660	
MP4	489313.963	511487.061	26.965	12.618	
MP5	489315.765	511498.356	21.642	11.662	
MP6	489314.785	511508.926	16.784		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.843	490962.717	35.844	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.536	490962.704	36.068	4.30	
MP3	503429.471	490952.278	35.514	2.65	
MP4	503434.040	490941.922	34.954	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.965	487885.386	48.503	7.213	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.771	487888.103	45.190	6.086	
MP3	504364.859	487888.937	41.968	9.108	
MP4	504372.900	487890.621	38.026	10.322	
MP5	504381.858	487893.884	34.088	9.249	
MP6	504389.394	487897.601	30.221		

**Ongoing Coastal Monitoring of Survey Points – 24<sup>th</sup> June 2011  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.312	487431.084	54.312	10.720	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.459	487434.491	53.691	12.992	
MP3	504571.835	487437.273	50.849	10.255	
MP4	504579.838	487440.312	45.215	13.853	
MP5	504592.574	487444.599	41.862		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.093	487134.604	55.324	12.042	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.259	487137.098	49.371	6.004	
MP3	504769.629	487136.012	46.898	7.222	
MP4	504775.985	487137.840	44.015		

## Ongoing Coastal Monitoring of Survey Points – 15<sup>th</sup> December 2011

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.563	511468.153	40.884	8.316	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.320	511474.585	35.928	7.874	
MP3	489310.271	511481.215	32.163	8.655	
MP4	489313.963	511487.061	26.965	12.624	
MP5	489315.765	511498.356	21.642	11.660	
MP6	489314.785	511508.926	16.784		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.843	490962.717	35.844	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.536	490962.704	36.068	4.30	
MP3	503429.471	490952.278	35.514	2.65	
MP4	503434.040	490941.922	34.954	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.965	487885.386	48.503	7.213	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.771	487888.103	45.190	6.079	
MP3	504364.859	487888.937	41.968	9.111	
MP4	504372.900	487890.621	38.026	10.320	
MP5	504381.858	487893.884	34.088	9.246	
MP6	504389.394	487897.601	30.221		

**Ongoing Coastal Monitoring of Survey Points – 15<sup>th</sup> December 2011  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.312	487431.084	54.312	10.723	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.459	487434.491	53.691	12.988	
MP3	504571.835	487437.273	50.849	10.265	
MP4	504579.838	487440.312	45.215	13.855	
MP5	504592.574	487444.599	41.862		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.093	487134.604	55.324	12.037	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.259	487137.098	49.371	6.008	
MP3	504769.629	487136.012	46.898	7.224	
MP4	504775.985	487137.840	44.015		

## Ongoing Coastal Monitoring of Survey Points – 14<sup>th</sup> June 2012

Whitby West Cliff					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	489306.563	511468.153	40.884	8.319	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	489308.320	511474.585	35.928	7.861	
MP3	489310.271	511481.215	32.163	8.659	
MP4	489313.963	511487.061	26.965	12.623	
MP5	489315.765	511498.356	21.642	11.664	
MP6	489314.785	511508.926	16.784		

Scalby Ness					
	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	503417.843	490962.717	35.844	3.15	Monitor point co-ordinates derived directly from GPS observations. Distances to edge measured with tape measure.
MP2	503425.536	490962.704	36.068	4.30	
MP3	503429.471	490952.278	35.514	2.65	
MP4	503434.040	490941.922	34.954	4.18	

Scarborough South Cliff (North Section)					
H4	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504353.965	487885.386	48.503	7.213	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504359.771	487888.103	45.190	6.083	
MP3	504364.859	487888.937	41.968	9.110	
MP4	504372.900	487890.621	38.026	10.318	
MP5	504381.858	487893.884	34.088	9.249	
MP6	504389.394	487897.601	30.221		

**Ongoing Coastal Monitoring of Survey Points – 14<sup>th</sup> June 2012  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>					
E3	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504549.312	487431.084	54.312	10.721	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504559.459	487434.491	53.691	12.997	
MP3	504571.835	487437.273	50.849	10.259	
MP4	504579.838	487440.312	45.215	13.851	
MP5	504592.574	487444.599	41.862		

<b>Scarborough South Cliff (South Section)</b>					
BH2	Easting	Northing	Height (mAOD)	Slope Distance (m)	Remarks
MP1	504754.093	487134.604	55.324	12.042	Monitor point co-ordinates derived directly from GPS observations. Slope distances calculated from separate TPS observations.
MP2	504764.259	487137.098	49.371	6.008	
MP3	504769.629	487136.012	46.898	7.221	
MP4	504775.985	487137.840	44.015		

## Ongoing Coastal Monitoring of Survey Points - Monthly Comparison

Whitby West Cliff						
BH2	Slope Distance 22/07/09	Slope Distance 24/08/09	Slope Distance 21/09/09	Slope Distance 12/10/09	Slope Distance 16/11/09	Slope Distance 14/12/09
MP1	8.319m	8.311m	8.310m	8.313m	8.315m	8.309m
MP2	7.869m	7.874m	7.870m	7.870m	7.871m	7.870m
MP3	8.655m	8.657m	8.643m	8.657m	8.655m	8.657m
MP4	12.623m	12.612m	12.617m	12.613m	12.618m	12.623m
MP5	11.657m	11.665m	11.658m	11.656m	11.663m	11.657m
MP6						

Scalby Ness						
	Distance to Edge 22/07/09	Distance to Edge 24/08/09	Distance to Edge 21/09/09	Distance to Edge 12/10/09	Distance to Edge 16/11/09	Distance to Edge 14/12/09
MP1	3.15m	3.15m	3.15m	3.15m	3.15m	3.15m
MP2	4.30m	4.30m	4.30m	4.30m	4.30m	4.30m
MP3	2.66m	2.65m	2.65m	2.65m	2.65m	2.65m
MP4	4.18m	4.18m	4.18m	4.18m	4.18m	4.18m

Scarborough South Cliff (North Section)						
H4	Slope Distance 22/07/09	Slope Distance 24/08/09	Slope Distance 21/09/09	Slope Distance 12/10/09	Slope Distance 16/11/09	Slope Distance 14/12/09
MP1	7.206m	7.204m	7.207m	7.211m	7.200m	7.207m
MP2	6.079m	6.081m	6.082m	6.079m	6.082m	6.078m
MP3	9.117m	9.114m	9.112m	9.110m	9.112m	9.112m
MP4	10.317m	10.320m	10.323m	10.319m	10.318m	10.320m
MP5	9.246m	9.246m	9.241m	9.247m	9.251m	9.252m
MP6						

**Ongoing Coastal Monitoring of Survey Points - Monthly Comparison  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>						
<b>E3</b>	Slope Distance 22/07/09	Slope Distance 24/08/09	Slope Distance 21/09/09	Slope Distance 12/10/09	Slope Distance 16/11/09	Slope Distance 14/12/09
MP1	10.724m	10.724m	10.719m	10.726m	10.723m	10.721m
MP2	12.989m	12.983m	12.990m	12.978m	12.989m	12.999m
MP3	10.254m	10.260m	10.264m	10.262m	10.265m	10.266m
MP4	13.849m	13.855m	13.848m	13.848m	13.856m	13.849m
MP5						

<b>Scarborough South Cliff (South Section)</b>						
<b>BH2</b>	Slope Distance 22/07/09	Slope Distance 24/08/09	Slope Distance 21/09/09	Slope Distance 12/10/09	Slope Distance 16/11/09	Slope Distance 14/12/09
MP1	12.050m	12.050m	12.039m	12.050m	12.047m	12.046m
MP2	6.004m	5.997m	6.000m	5.997m	6.000m	6.006m
MP3	7.211m	7.236m	7.219m	7.225m	7.223m	7.219m
MP4						

## Ongoing Coastal Monitoring of Survey Points – Bi-annual Comparison

Whitby West Cliff						
BH2	Slope Distance 14/12/09	Slope Distance 15/06/10	Slope Distance 13/12/10	Slope Distance 24/06/11	Slope Distance 15/12/11	Slope Distance 14/06/12
MP1	8.309m	8.309m	8.310m	8.307m	8.316m	8.319m
MP2	7.870m	7.868m	7.869m	7.872m	7.874m	7.861m
MP3	8.657m	8.656m	8.660m	8.660m	8.655m	8.659m
MP4	12.623m	12.620m	12.618m	12.618m	12.624m	12.623m
MP5	11.657m	11.659m	11.661m	11.662m	11.660m	11.664m
MP6						

Scalby Ness						
	Distance to Edge 14/12/09	Distance to Edge 15/06/10	Distance to Edge 13/12/10	Distance to Edge 24/06/11	Distance to Edge 15/12/11	Distance to Edge 14/06/12
MP1	3.15m	3.15m	3.15m	3.15m	3.15m	3.15m
MP2	4.30m	4.30m	4.30m	4.30m	4.30m	4.30m
MP3	2.65m	2.65m	2.65m	2.65m	2.65m	2.65m
MP4	4.18m	4.18m	4.18m	4.18m	4.18m	4.18m

Scarborough South Cliff (North Section)						
H4	Slope Distance 14/12/09	Slope Distance 15/06/10	Slope Distance 13/12/10	Slope Distance 24/06/11	Slope Distance 15/12/11	Slope Distance 14/06/12
MP1	7.207m	7.212m	7.216m	7.213m	7.213m	7.213m
MP2	6.078m	6.073m	6.080m	6.086m	6.079m	6.083m
MP3	9.112m	9.113m	9.112m	9.108m	9.111m	9.110m
MP4	10.320m	10.321m	10.315m	10.322m	10.320m	10.318m
MP5	9.252m	9.247m	9.250m	9.249m	9.246m	9.249m
MP6						

**Ongoing Coastal Monitoring of Survey Points – Bi-annual Comparison  
(Continued)**

<b>Scarborough South Cliff (Central Section)</b>						
<b>E3</b>	Slope Distance 14/12/09	Slope Distance 15/06/10	Slope Distance 13/12/10	Slope Distance 24/06/11	Slope Distance 15/12/11	Slope Distance 14/06/12
MP1	10.721m	10.724m	10.722m	10.720m	10.723m	10.721m
MP2	12.999m	12.990m	12.999m	12.992m	12.988m	12.997m
MP3	10.266m	10.258m	10.248m	10.255m	10.265m	10.259m
MP4	13.849m	13.845m	13.850m	13.853m	13.855m	13.851m
MP5						

<b>Scarborough South Cliff (South Section)</b>						
<b>BH2</b>	Slope Distance 14/12/09	Slope Distance 15/06/10	Slope Distance 13/12/10	Slope Distance 24/06/11	Slope Distance 15/12/11	Slope Distance 14/06/12
MP1	12.046m	12.042m	12.042m	12.042m	12.037m	12.042m
MP2	6.006m	6.006m	6.011m	6.004m	6.004m	6.008m
MP3	7.219m	7.220m	7.215m	7.222m	7.224m	7.221m
MP4						

## Ongoing Coastal Monitoring of Survey Points - Monthly Comparison

Knife Point						
Marker ID	Baseline Distance 12/02/10	Slope Distance 09/03/10	Slope Distance 14/04/10	Slope Distance 05/05/10	Slope Distance 17/06/10	Slope Distance 13/07/10
<b>Knife Point Headscarp</b>						
H01	12.25m	12.30m	12.28m	12.22m	12.22m	12.22m
H02	5.30m	5.35m	5.35m	5.40m	5.33m	5.33m
H03	4.40m	4.41m	4.44m	4.40m	4.36m	4.36m
H04	6.20m	6.20m	6.15m	6.15m	6.21m	6.21m
H05	19.80m	19.24m	19.22m	19.55m	19.20m	19.20m
H06	20.90m	20.72m	20.96m	20.85m	20.63m	20.63m
H07	19.10m	18.88m	18.73m	18.73m	18.77m	18.77m
H08	3.60m	3.65m	3.62m	3.64m	3.60m	3.60m
H09	7.40m	7.35m	7.30m	7.41m	7.34m	7.34m
H10a	10.70m	10.64m	10.59m	10.59m	10.39m	10.39m
H10b	14.00m	14.00m	14.01m	14.00m	14.05m	14.05m
H11	7.40m	7.05m	6.81m	6.78m	6.87m	6.87m
H12	15.90m	15.88m	15.90m	15.80m	15.84m	15.84m
H13	4.90m	5.10m	4.85m	4.74m	4.78m	4.78m
H14	4.07m	4.08m	4.04m	4.04m	4.05m	4.05m
H14	8.80m	8.80m	8.80m	8.81m	8.79m	8.79m
H14	11.18m	11.20m	11.19m	11.23m	11.21m	11.21m
<b>A165 Old Filey Road Headscarp</b>						
R01	8.21m	8.21m	8.21m	8.21m	8.21m	8.21m
R01	17.25m	17.25m	17.25m	17.25m	17.25m	17.25m
R01	11.21m	11.21m	11.21m	11.21m	11.21m	11.21m
R01	3.10m	3.10m	3.10m	3.10m	3.10m	3.10m
R1l	20.10m	19.96m	19.96m	19.96m	19.96m	19.96m
R02	11.10m	11.14m	11.14m	11.14m	11.14m	11.14m
R03	9.20m	9.39m	9.39m	9.39m	9.39m	9.39m
R04	6.20m	6.35m	6.35m	6.35m	6.35m	6.35m
R05	7.60m	7.99m	7.99m	7.99m	7.99m	7.99m
R06	*	*	*		*	*
<b>Cornelian Bay Headscarp</b>						
C01	3.70m	3.70m	3.70m	3.66	3.70m	3.70m
C04	3.90m	3.90m	3.88m	3.89	3.90m	3.90m
C08	N2.20,E3.01m	N2.20,E3.01m	N2.01,E2.98m	N1.93,E3.00	N1.92,E3.01m	N1.92,E3.01m

\* - Inaccessible due to blackthorn cuttings. Red text indicates cliff recession

## Ongoing Coastal Monitoring of Survey Points - Monthly Comparison

Knife Point						
Marker ID	Baseline Distance 12/02/10	Slope Distance 04/08/10	Slope Distance 21/10/10	Slope Distance 13/12/10	Slope Distance 17/06/11	Slope Distance 12/12/11
<b>Knife Point Headscarp</b>						
H01	12.25m	12.22m	12.26m	12.24m	12.20m	12.20m
H02	5.30m	5.27m	5.54m	5.50m	5.38m	5.36m
H03	4.40m	4.46m	4.42m	4.41m	4.40m	4.40m
H04	6.20m	6.15m	6.20m	6.20m	6.15m	6.18m
H05	19.80m	18.78m	Pin Gone	-	-	-
H06	20.90m	20.85m	20.78m	20.75m	18.55m	18.45m
H07	19.10m	18.73m	18.75m	18.63m	18.60m	18.53m
H08	3.60m	3.63m	3.63m	3.61m	3.72m	3.65m
H09	7.40m	7.36m	7.36m	7.33m	7.25m	7.25m
H10a	10.70m	10.35m	10.15m	10.17m	10.20m	10.20m
H10b	New	11.83m	11.86m	11.82m	11.60m	11.45m
H11	7.40m	6.77m	6.82m	6.80m	6.80m	6.80m
H12	15.90m	15.86m	15.87m	15.86m	15.86m	15.85m
H13	4.90m	4.77m	4.79m	4.79m	4.83m	4.77m
H14	4.07m	4.08m	4.02m	4.03m	Pin Gone	-
H14	8.80m	8.79m	8.77m	8.77m	Pin Gone	-
H14	11.18m	11.21m	11.12m	11.12m	Pin Gone	-
<b>A165 Old Filey Road Headscarp</b>						
R01	8.21m	8.21m	8.21m	8.21m	8.21m	8.20m
R01	17.25m	17.25m	17.25m	17.27m	17.25m	17.27m
R01	11.21m	11.21m	11.21m	11.22m	11.21m	11.22m
R01	3.10m	3.10m	3.10m	3.10m	3.10m	3.10m
R01I	20.10m	19.96m	19.96m	19.97m	19.97m	19.97m
R02	11.10m	11.15m	11.15m	11.12m	11.14m	11.12m
R03	9.20m	9.37m	9.37m	9.39m	9.39m	9.39m
R04	6.20m	6.35m	6.35m	6.31m	6.32m	6.31m
R05	7.60m	7.98m	7.98m	7.67m	7.66m	7.67m
R06	*	*	*	*	*	*
<b>Cornelian Bay Headscarp</b>						
C01	3.70m	3.70m	3.59m	3.53m	3.70m	3.55m
C04	3.90m	3.90m	3.90m	3.91m	Pin Gone	Pin Gone
C08	N2.20,E3.01m	N1.86,E3.01m	N1.89,E3.03	N1.73,E2.00	Pin Gone	Pin Gone

\* - Inaccessible due to blackthorn cuttings. Red text indicates cliff recession

## Ongoing Coastal Monitoring of Survey Points - Monthly Comparison

Knife Point						
Marker ID	Baseline Distance 12/02/10	Slope Distance 29/05/12	Slope Distance	Slope Distance	Slope Distance	Slope Distance
<b>Knife Point Headscarp</b>						
H01	12.25m	12.22m	-	-	-	-
H02	5.30m	5.36m	-	-	-	-
H03	4.40m	4.41m	-	-	-	-
H04	6.20m	6.17m	-	-	-	-
H05	19.80m	-	-	-	-	-
H06	20.90m	18.40m	-	-	-	-
H07	19.10m	18.49m	-	-	-	-
H08	3.60m	3.63m	-	-	-	-
H09	7.40m	7.26m	-	-	-	-
H10a	10.70m	10.20m	-	-	-	-
H10b	New	11.44m	-	-	-	-
H11	7.40m	6.77m	-	-	-	-
H12	15.90m	15.86m	-	-	-	-
H13	4.90m	4.77m	-	-	-	-
H14	4.07m	-	-	-	-	-
H14	8.80m	-	-	-	-	-
H14	11.18m	-	-	-	-	-
<b>A165 Old Filey Road Headscarp</b>						
R01	8.21m	8.20m	-	-	-	-
R01	17.25m	17.25m	-	-	-	-
R01	11.21m	11.21m	-	-	-	-
R01	3.10m	3.10m	-	-	-	-
R01I	20.10m	19.96m	-	-	-	-
R02	11.10m	11.14m	-	-	-	-
R03	9.20m	9.37m	-	-	-	-
R04	6.20m	6.30m	-	-	-	-
R05	7.60m	7.67m	-	-	-	-
R06	*	*	*	*	*	*
<b>Cornelian Bay Headscarp</b>						
C01	3.70m	3.56m	-	-	-	-
C04	3.90m	Pin Gone	-	-	-	-
C08	N2.20,E3.01m	Pin Gone	-	-	-	-

\* - Inaccessible due to blackthorn cuttings. Red text indicates cliff recession



## **Appendix H Installation Photographs**





Plate 1 Runswick Bay A001



Plate 2 Runswick Bay A002



Plate 3 Runswick Bay A003



Plate 4 Runswick Bay A004



Plate 5 Whitby West Cliff Bh2



Plate 6 Scalby Ness MP1



Plate 7 Scalby Ness MP2



Plate 8 Scalby Ness MP3



Plate 9 Scalby Ness MP4



Plate 10 Scalby Ness I1



Plate 11 Scalby Ness I2



Plate 12 Scalby Ness I3



Plate 13 Scalby Ness P1



Plate 14 Scalby Ness P2



Plate 15 Scalby Ness P3



Plate 16 Scalby Ness P4



Plate 17 Scalby Ness B6



Plate 18 Scalby Ness B9



Plate 19 Scalby Ness Sn1



Plate 20 Scalby Ness Sn2



Plate 21 Scarborough North Bay L1



Plate 22 Scarborough North Bay L11



Plate 23 Scarborough North Bay L12



Plate 24 Scarborough North Bay L3



Plate 25 Scarborough North Bay L4



Plate 26 Scarborough North Bay L5



Plate 27 Scarborough North Bay L6



Plate 28 Scarborough North Bay (Oasis Café) BH11



Plate 29 Scarborough North Bay (Oasis Café) BH1P



Plate 30 Scarborough North Bay (Oasis Café) BH2P



Plate 31 Scarborough North Bay (Oasis Café) BH3I



Plate 32 Scarborough North Bay (Oasis Café) BH3P



Plate 33 Scarborough North Bay (Oasis Café) BH4I



Plate 34 Scarborough North Bay (Oasis Café) BH4P



Plate 35 Scarborough South Cliff I1 (AA01)



Plate 36 Scarborough South Cliff H4 (AA02)



Plate 37 Scarborough South Cliff BH1 SPA (Top)



Plate 38 Scarborough South Cliff H6 (AA03)



Plate 39 Scarborough South Cliff G2 (AA04)



Plate 40 Scarborough South Cliff F2 (AA10)



Plate 41 Scarborough South Cliff F4 (AA11)



Plate 42 Scarborough South Cliff E3 (AA09)



Plate 43 Scarborough South Cliff E5 (AA05)



Plate 44 Scarborough South Cliff D3 (AA08)



Plate 45 Scarborough South Cliff D1 (AA06)



Plate 46 Scarborough South Cliff Bh2 (AA07)



Plate 47 Scarborough South Cliff I2



Plate 48 Scarborough South Cliff I2A



Plate 49 Scarborough South Cliff H2



Plate 50 Scarborough South Cliff H1



Plate 51 Scarborough South Cliff H5



Plate 52 Scarborough South Cliff 1 Spa



Plate 53 Scarborough South Cliff 2 Spa



Plate 54 Scarborough South Cliff 3 Spa



Plate 55 Scarborough South Cliff 4 Spa



Plate 56 Scarborough South Cliff G3



Plate 57 Scarborough South Cliff 5 Spa



Plate 58 Scarborough South Cliff BH01 SPA



Plate 59 Scarborough South Cliff F5



Plate 60 Scarborough South Cliff F3



Plate 61 Scarborough South Cliff E2



Plate 62 Scarborough South Cliff E1



Plate 63 Scarborough South Cliff E4



Plate 64 Scarborough South Cliff D2



Plate 65 Scarborough South Cliff Bh3



Plate 66 Scarborough South Cliff Bh4



Plate 67 Scarborough South Cliff Bh1



Plate 68 Scarborough South Cliff A1 (AA12)



Plate 69 Scarborough South Cliff H4 (AA02) Survey Points



Plate 70 Scarborough South Cliff H4 (AA02) Survey Points



Plate 71 Scarborough South Cliff E3 (AA09) Survey Points



Plate 72 Scarborough South Cliff E3 (AA09) Survey Points



Plate 73 Scarborough South Cliff E3 (AA09) Survey Points



Plate 74 Scarborough South Cliff BH2 (AA12) Survey Points



Plate 75 Scarborough South Cliff BH2 (AA12) Survey Points



Plate 76 Knipe Point BH01 (4<sup>th</sup> March 2010)



Plate 77 Knipe Point BH02 (4<sup>th</sup> March 2010)



Plate 78 Knipe Point BH03 (4<sup>th</sup> March 2010)



Plate 79 Knipe Point BH04 (4<sup>th</sup> March 2010)



Plate 80 Knipe Point BH05



Plate 81 Knipe Point BH06



Plate 82 Filey Town BH01



Plate 83 Filey Town BH02



Plate 84 Filey Town BH03



Plate 85 Filey Town BH04



Plate 86 Filey Town BH05B



Plate 87 Filey Town BH06



Plate 88 Filey Flat Cliffs A2 (BB02)



Plate 89 Filey Flat Cliffs B1



Plate 90 Filey Flat Cliffs D1



Plate 91 Filey Flat Cliffs A3



Plate 92 Bh1 Robin Hood's Bay



Plate 93 BH2 Robin Hood's Bay



Plate 94 BH3 Robin Hood's Bay



Plate 95 BH4 Robin Hood's Bay

# **Appendix I Replacement Installation Photographs**





Plate 1 WS1 located at Scalby Ness



Plate 2 WS2 located at Scalby Ness



Plate 3 WS3 located at Scalby Ness



Plate 4 WS4 located at Scalby Ness



Plate 5 WS5 located at Scalby Ness



Plate 6 BH7 located at Scalby Ness



Plate 7 BH8 located at The Holms, Scarborough North Bay



Plate 8 BH9 located at The Holms, Scarborough North Bay



Plate 9 BH10A located at The Holms, Scarborough North Bay



Plate 10 BH11 located above The Holms, Scarborough North Bay



Plate 11 BH12 located on The Promenade above Spa Chalet Cliff



Plate 12 BH13 located on The Promenade above Spa Cliff



Plate 13 BH14 located on The Promenade above Spa Cliff



Plate 14 BH15 located landward of The Promenade above South Cliff Gardens



Plate 15 BH16A located on The Promenade above The Rose Gardens



Plate 16 BH17 located on The Promenade north of The Rose Gardens



Plate 17 BH18 located mid-slope below The Rose Gardens



Plate 18 BH19 located on The Promenade above The Italian Garden



Plate 19 BH20 located mid-slope below The Rose Gardens



Plate 20 BH21 located mid-slope at Wheatcroft Cliff





## **Appendix J Site Photographs of Knipe Point**





Plate 1 Cornelian Bay side of Knipe Point looking northwest (13<sup>th</sup> December 2010)



Plate 2 Cornelian Bay side of Knipe Point looking northwest (7<sup>th</sup> December 2011)



Plate 3 Cornelian Bay side of Knipe Point looking northwest (30<sup>th</sup> May 2012)



Plate 4 Cornelian Bay side of Knipe Point looking east (17<sup>th</sup> June 2011)

*(Note loss of survey pins C08 & C04 and boundary fence since last site visit of December 2011)*



Plate 5 Cornelian Bay side of Knipe Point looking east (7<sup>th</sup> December 2011)



Plate 6 Cornelian Bay side of Knipe Point looking east (30<sup>th</sup> May 2012)



Plate 7 Cliff recession at Knipe Point Headscarp (13<sup>th</sup> December 2010)



Plate 8 Cliff recession at Knipe Point Headscarp (7<sup>th</sup> December 2011)



Plate 9 Cliff recession at Knipe Point Headscarp (30<sup>th</sup> May 2012)



Plate 10 Cliff recession at Knipe Point Headscarp (30<sup>th</sup> May 2012)



Plate 11 Cliff recession at Knipe Point Headscarp looking east (17<sup>th</sup> June 2010)



Plate 12 Cliff recession at Knipe Point Headscarp looking east (7<sup>th</sup> December 2011))



Plate 13 Cliff recession at Knipe Point Headland (13<sup>th</sup> December 2010)



Plate 14 Cliff recession at Knipe Point Headland (30<sup>th</sup> May 2012)



Plate 15 Cliff recession at Knipe Point Headland looking east (13<sup>th</sup> December 2010)



Plate 16 Cliff recession at Knipe Point Headland looking east (7<sup>th</sup> December 2011)



Plate 17 Cliff recession at Knipe Point Headland looking east (30<sup>th</sup> May 2012)



Plate 18 Cliff recession at Knipe Point Headland looking west (30<sup>th</sup> May 2012)



Plate 19 Cliff recession at Knipe Point Headland looking east (30<sup>th</sup> May 2012)



Plate 20 Knipe Point Residential Plan



Plate 21 Knipe Point Weather Station with Chalet No. 50 behind.



## **Appendix K    Site Photographs of Robin Hood's Bay**





Plate 1 View of Robin Hood's Bay with the Rocket House in background and remediated coastal slopes below in foreground.



Plate 2 View looking north towards Victoria Hotel from remediated coastal slopes