Ongoing Analysis and Interpretation of Coastal Monitoring Data

Fifth Review of Full Suite Monitoring

Geotechnical Interpretative Report

August 2011

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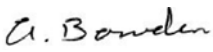
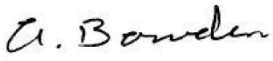
B	Final	 29/07/11	 29/07/11	 29/07/11

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New information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

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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 **Fifth Full Suite** monitoring event undertaken, in June 2011, as part of the monitoring regime recommended in the preceding 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.

A summary of the observations made from the start of monitoring (July 2009) and, a comparison of observations made since the last Full monitoring event of December 2010 are presented below in Table 1.

Recommendations for further actions with regard to of increased monitoring events and/or remedial works to installed instrumentation for each site are summarised and presented below.

Runswick Bay – No additional actions recommended.

Whitby West Cliff – No additional actions recommended.

Robin Hood's Bay – Monitoring of inclinometer BH2 to be increased from six monthly intervals to two monthly intervals. Additional monitoring events should be undertaken in August and October, reverting back to the original monitoring regime in December 2011.

Scalby Ness – No additional actions recommended.

Scarborough North Bay (and Oasis Café) – Flush and clean out piezometers in BH09

Scarborough South Cliff – Flush and clean out water wells SPA 1 to 5 located behind The Spa. Monitoring of inclinometers BH12 and BH14 to be increased from six monthly intervals to two monthly intervals. Additional monitoring events should be undertaken in August and October, reverting back to the original monitoring regime in December 2011.

Knipe Point – Monitoring of coastal headscarps at this site to be increased to two monthly intervals. Additional monitoring events should be undertaken in August and October, reverting back to the original monitoring regime in December 2011.

Filey Town – No additional actions recommended.

Filey Flat Cliffs – No additional actions recommended.

Table 1 Summary of Site Observations

SITE	Observations made since 4th Monitoring Event (December 2010)*	Total observed movement since first Monitoring Event (July 2009)
Runswick Bay	No ground movements indicated within inclinometers A001, A003 & A004. 6 mm movement shown in A002. Ground water levels reduced across site	5mm movement indicated in A001 between 22.0 and 20.0 metres depth. 5mm movement indicated in A004 from 10.0m depth increasing to 15mm at 2.0m depth. Groundwater relatively static
Whitby West Cliff	Survey pins show a total -4mm 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
Robin Hood's Bay	New instruction for June 2011. Insufficient data collected to-date to confirm previously noted ground movements	New instruction for June 2011
Scalby Ness	No further cliff recession observed from any survey stations. Inclinometers indicate slopes are stable	10mm cliff recession recorded at MP3 between July-August 2009, none at other three stations
Oasis Cafe	Slopes stable. Groundwater levels raised in boreholes above café.	Slopes stable, limited movement of <4mm indicated in BH1 and 3
North Bay	Unreliable groundwater results. 4 mm movements in BH11 at 13 to 10 m depth	Slopes stable as Oasis Café, no coverage of The Holms area
South Cliff	AA10 and 08 show slight ground movements at shallow depths. Movements at depth in BH12 and 14. No movements in remaining inclinometers. General reduction in site wide groundwater levels except water wells at The Spa	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
Knipe Point	Increased rates of recession along Cornelian headscarp, cessation of recession along A165 headscarp. Mudslide below pin H06. Knipe Point headscarp remains active. Groundwater low in BH1, 5 and 6	Recession rates slowing down from March 2010 at Cornellian and Knipe Point and limited at A165 headscarps.*
Filey Town	Slopes indicated as stable around Glen Gardens above Royal Parade. Ground water levels reduced across site	2mm ground movement indicated in BH06 between 10.5 and 7.0 metres depth. Slopes stable BH03 'lost' to vandalism
Filey Flat Cliffs	Slopes indicated as stable though very limited inclinometer coverage of site. Ground water levels	Slopes indicated as stable though very limited coverage of site

	reduced across site	

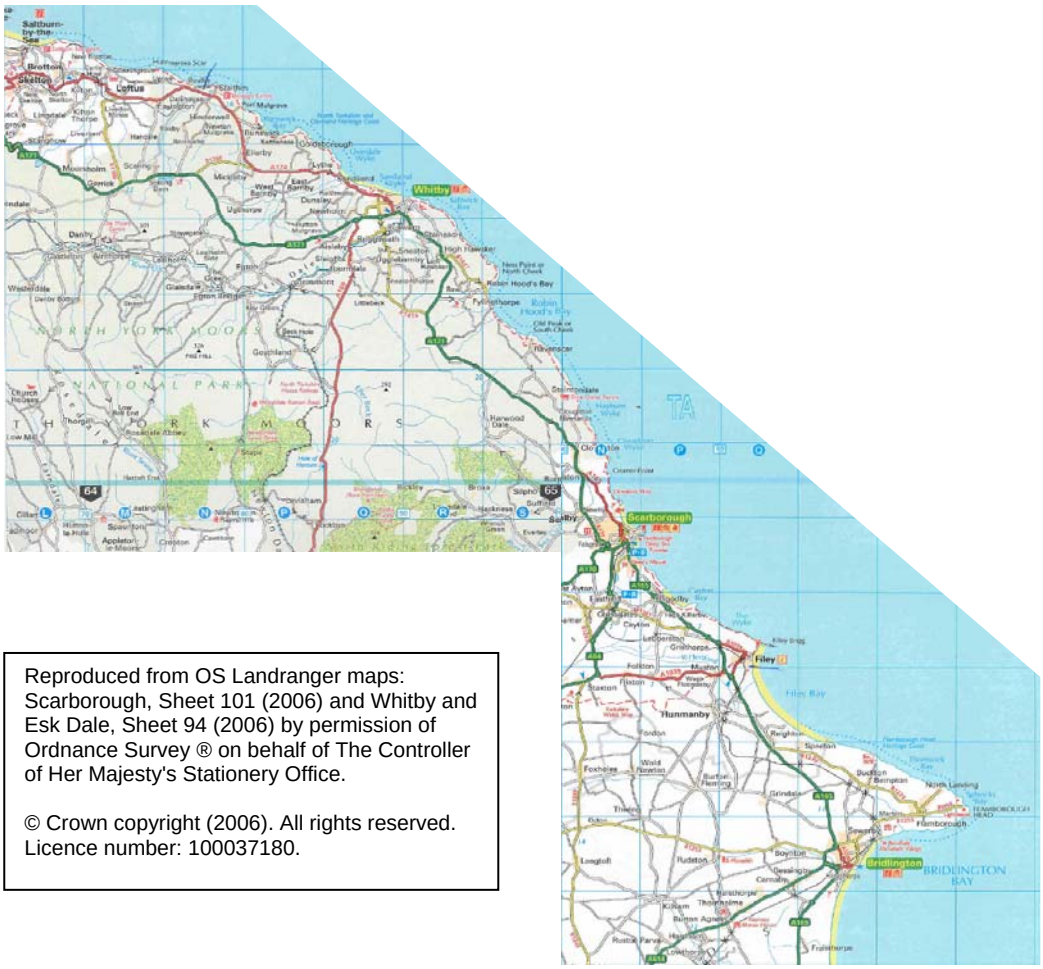
*** - Landslip along A165 in January 2010 is outside of monitoring area.**

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 experienced 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 landslip event. Instead a quantity of rainfall was determined that would be likely to produce a significant rise in groundwater levels that might trigger a landslip. 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 75th percentile was calculated as a determining threshold value. A rainfall value, for a specific day, at the 75th 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 75th 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 Nettledale 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 Nettledale Beck to the south.

Figure 2 Site Location - Runswick Bay

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^{o} 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 2011 indicate that no ground movements have occurred within inclinometers installed in boreholes A001, A003 and A004. Data from A002 would indicate that -6 mm ground movement has occurred between approximately 17.0 and 15.5 metres below ground level. However, the readings are most likely to be due to an erroneous reading than actual movements of the ground. Data of December 2010 indicated ground movements in A001 due to a discrepancy in readings recorded from 22.0 to 20.0 metres depth. This was attributed to dirt within the tube tracks and present readings would confirm 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 16th June 2009 up to the present. A comparison of the groundwater readings of December 2010 and June 2011 shows reductions of 490 mm, 2440 mm, 910 mm and 520 mm in A001, A002, 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 in 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.

Current groundwater levels compared with those of December 2010 are depressed reflecting the dry period and lower than usual rainfall experienced in the region up to July 2011.

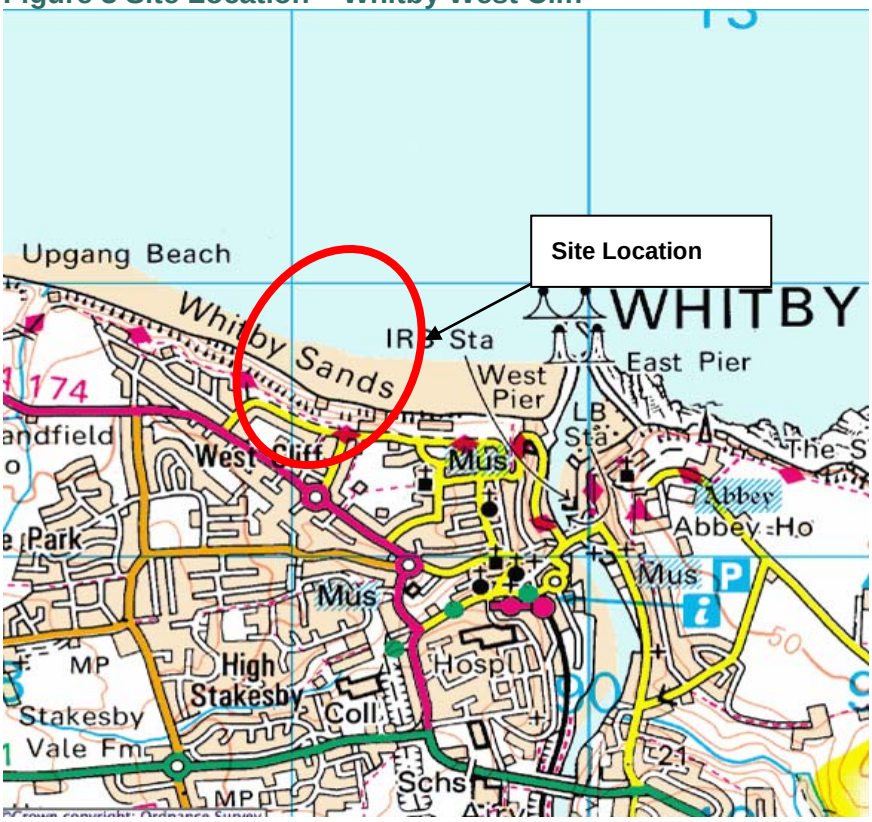
3 Whitby West Cliff

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



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 (16th June 2009) and the initial set of Ongoing monitoring readings (9th 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 latest reading of June 2011 recorded a decrease in groundwater level to 8.35 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 December 2010 and showed that over a distance of 49 metres, 11 mm of surface movement had occurred during this period. The latest readings of June 2011 indicate that 1 mm of movement has occurred since December 2010 with a total of -4mm since July 2009. 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 was 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 July 2011, 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 know 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 2009, 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 -4 mm, measured from July 2009 to June 2011. 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 monitoring these features.

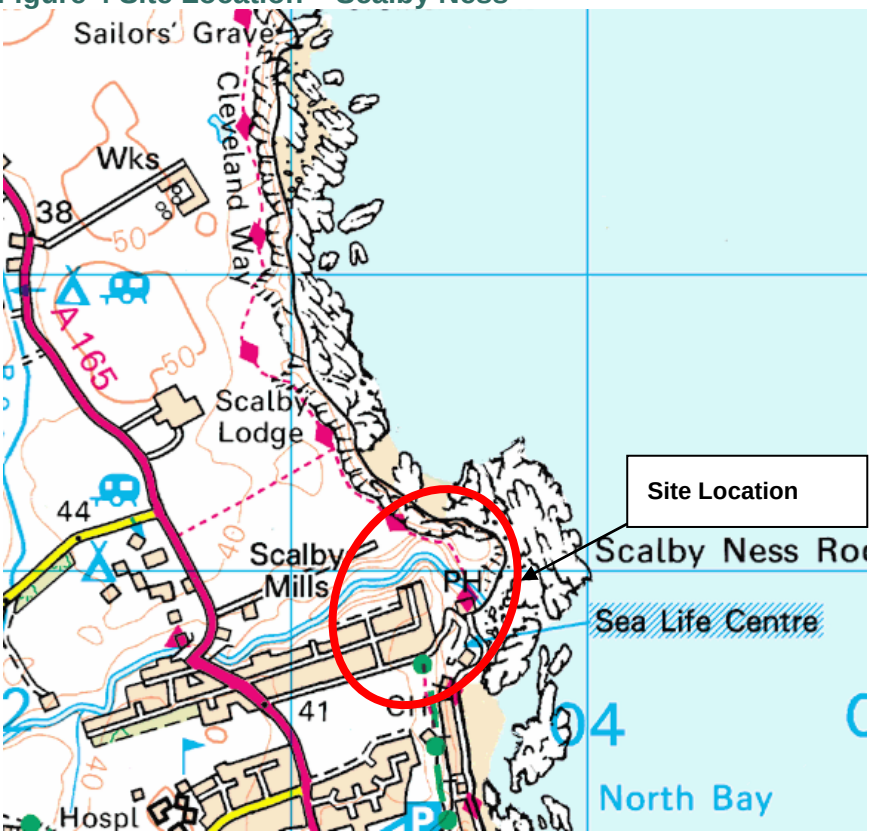
4 Scalby Ness

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



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 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 beck.

- 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 2 no. piezometers (B6 and B9) located within the inner headland of Scalby Ness (See Appendix A, drawing 3). Monitoring of installations BH114, Sn4, B1, B2, B3, B10 and B11 has not been undertaken as they are broken 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 16th July 2009.

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

Groundwater Readings

Groundwater levels have been recorded since the Initial Full Suite Survey (16th July 2009) up to June 2011. Groundwater levels recorded have reflected decreases in ground water across the site ranging from 1520 mm (WS4) to 100 mm (Sn2a); WS1, 2 and 3 recorded stable groundwater levels. Decreases in groundwater depths were also recorded within inclinometers I1 (1180 mm) and I3 (290 mm) compared to previous readings taken in December 2010.

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 29th June 2004 to 5th November 2009 and from 3rd February and 16th March 2010 to June 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 precipitation which have resulted in raised groundwater levels. 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 piezometers of P1, P2 and P3 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 piezometer has 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 will be monitored 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 a cliff recession rate of 10 mm was noted to have occurred between July and August 2009, though zero recession rates have been recorded from August 2009 onwards. Over the period December 2009 to June 2011 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 8th September and 22nd October 2010. However, a comparison of the baseline reading taken by Mouchel of February 2011 and follow up readings of June 2011 show that 17 mm of movement has occurred between 12.0 and 10.0 metres depth. 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 headscarps have remained intact without further recession so far evident.

An analysis of rainfall data illustrates that graphical peaks in groundwater levels were preceded by periods of 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 21st 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 2nd March and 21st April 2010.

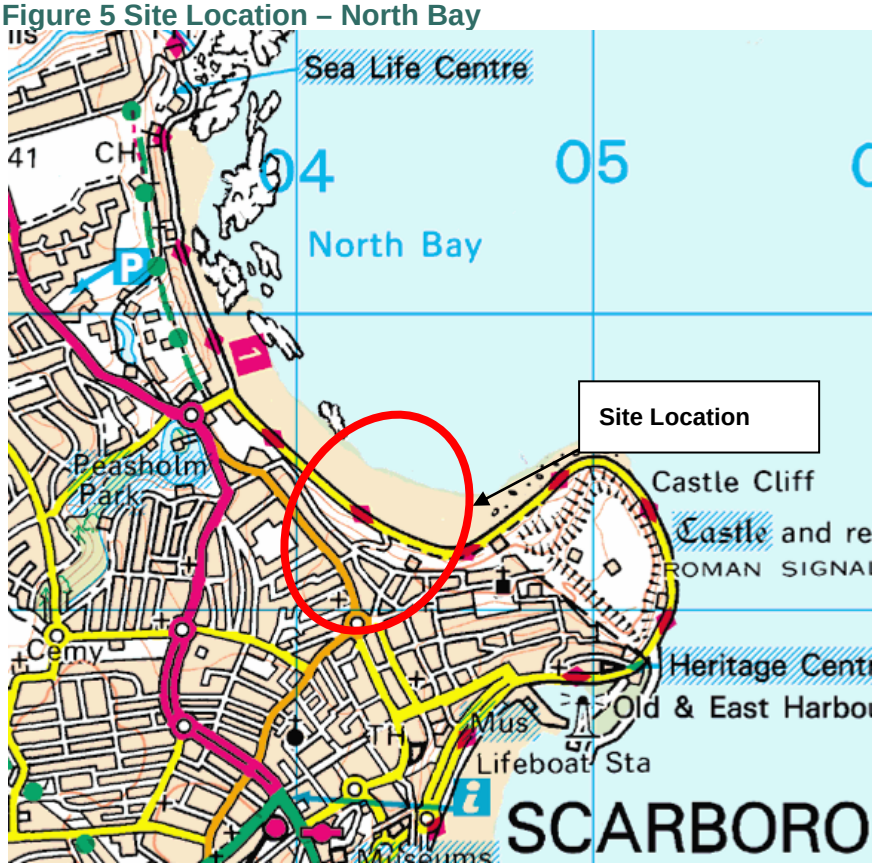
Observations (with recommendations on further monitoring) made at the time of a site visit in May 2010 are presented in a previously published Mouchel report (*Report No. 721229-002-GIR-009-Final, May 2010*).

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 – North Bay



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 of a deep-seated landslide which '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 (BH1I, 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 13th and 18th 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 8th September to 22nd October 2010 and separately, baseline readings recorded by Mouchel on 4th February and follow up readings of June 2011.

Groundwater Readings

Groundwater levels have been recorded from the Initial Full Suite Survey (15th July 2009) to the Fifth Full Suite Survey in June 2011. Groundwater levels recorded over this period show little fluctuation except for boreholes L11 and L12 which showed increases of 2750 and 660 mm, respectively. Variations of 30 mm and 200 mm in L1 (a & b) are attributed to changes in tidal levels. Piezometers installed above the Oasis Café indicate a reduction in groundwater levels of 400 mm (BH2P) although increases were recorded in piezometers located higher up the coastal slope in BH3P and 4P of 100mm and 450 mm, respectively over the same period.

Groundwater readings are presented in Appendix E and F.

5.6 Conclusions

The wide fluctuation of groundwater levels within L11 and L12 may be the result of surface water 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. Hence no meaningful conclusions can be reached regarding the groundwater regime at this site.

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 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 a reduction in groundwater levels of 400 mm (BH2P) although increases were recorded in piezometers located higher up the coastal slope in BH3P and 4P of 100mm and 450 mm, respectively.

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 has occurred between 13 and 10 metres depth since December 2010.

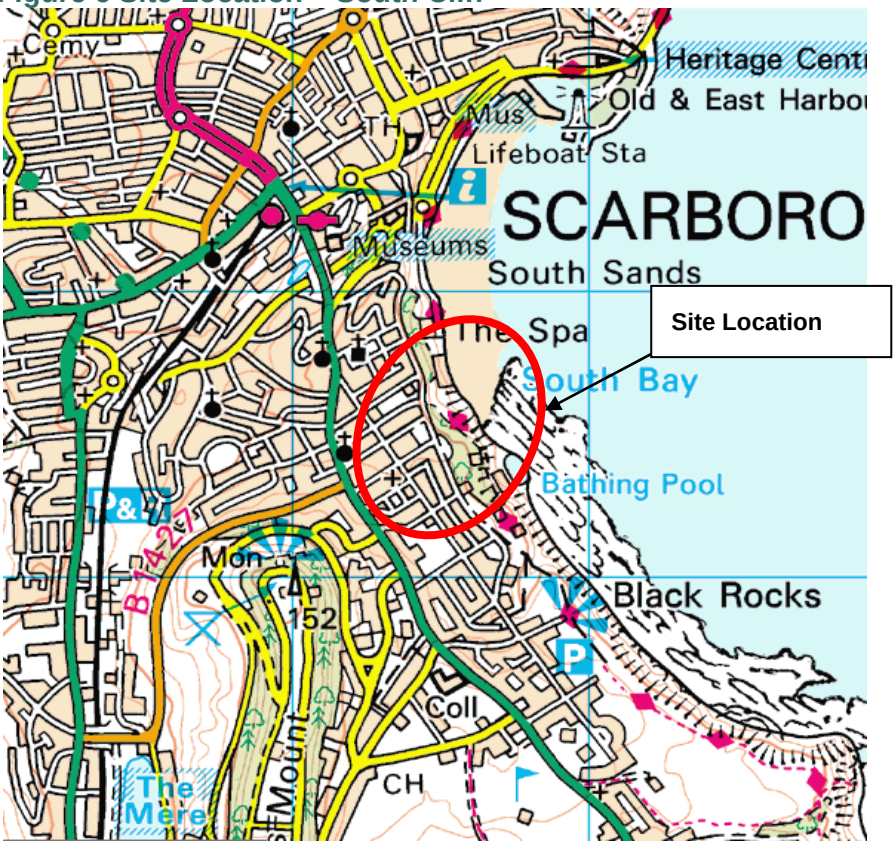
Groundwater data graphs for the two replacement instrumentation is yet to provide definite evidence of groundwater regimes around The Holms area. Due to the some what erratic groundwater readings from BH9, it is recommended that the piezometers in BH9 are flushed with clean water as they may be blocked 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 – South Cliff



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 27th 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 19th 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 / 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. The replacement inclinometer graphs consist of up to seven readings taken by the contractor during site works from 8th September to 22nd October 2010 and separately, baseline readings recorded by Mouchel on 2nd - 3rd February with follow up readings in June 2011.

Groundwater Readings

Groundwater levels have been recorded from the Initial Full Suite Survey (15th July 2009) up to the Fifth Full Suite monitoring of June 2011. 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 December 2009 to June 2011 shows that a maximum ground movement of +15 mm occurred over this period at borehole E3. Along the other two survey sections +9 mm was recorded at H4 and -3 mm difference was recorded at BH2.

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 Fifth 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 4 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. Apparent movements indicated in AA07 at 12.5 m depth are possibly caused by an uneven or a disturbed joint in the inclinometer tubing. 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 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-slope further south.

Inclinometer data graphs for the majority of the replacement instrumentation have shown that no ground movements have occurred since monitoring began in late 2010 to February 2011. However, BH12 indicates that up to 20 mm of movement has occurred at depths of between 40 m to 31 mbgl since February 2011. Also, in BH14 less than 5 mm ground movements are indicated from the base at 55 m to 30 mbgl. Both instruments 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.

Such failures are unpredictable and it is recommended to increase the frequency of monitoring of these selected instruments. Additional monitoring events should be undertaken in August and October, reverting back to the original monitoring regime in December 2011.

Instruments located around The Spa (BH1 SPA and Piezometers 1 to 5) have showed an increase in water levels ranging from 90 mm to 5620 mm, although boreholes SPA1, G1a and G3 have displayed a decrease in water levels up to 1230 mm. Elsewhere along South Cliff gardens piezometric levels have shown a similar pattern of depressed groundwater levels apart from I2, north of The Spa, which may be influenced by the tidal regime and, within BH3b (above South Bay Pool) installed at depth (45.40 mBGL) in sandy mudstone. This instrument may be reacting to the water regime within a deeper watertable that is unaffected by short-term rainfall patterns. In general the groundwater monitoring results collated to-date reflect fluctuations in the prevailing groundwater regime within the various horizons in which piezometers have been installed. Groundwater levels recorded in piezometers have in general displayed an overall decline in response to the lower than average monthly rainfall experienced during Spring and early Summer 2011. Groundwater levels recorded within water well installations behind The Spa show significant rises of up to 5620 mm, these may be due to the wells being blocked with silt and may need flushing and cleaning 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 December 2009 to June 2011 shows that a maximum ground movement of +15 mm occurred over this period at borehole E3. Along the other two survey sections +9 mm was recorded at H4 and -3 mm difference was recorded at BH2.

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

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 4th 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 Appendix A, Drawing 9. 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 26th 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 as 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 22, 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 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 up to 5 metres of the headland being lost to recession since December 2010.

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 worsen ground movement and potential failure of Knipe Point headlands. However, since December 2010 groundwater levels are recorded as reduced by up to 310 mm in piezometers at the base of the cliffs complex and, 150 mm in BH 01 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. Since the start of monitoring in March 2010, this section of cliff headscarp has shown a cessation in cliff recession rates along this 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. Currently a lesser loss of land was recorded at H07, this section of the headland has previously displayed surface tension cracking with potential block detachment that is reported in National Trust (Halcrow) Report No. 10, (SBC records, issued 18th 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 landslip. While there are no longer any structures threatened by cliff recession, the unstable and unpredictable condition of these cliffs still pose 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 (Plate 11, Appendix J). 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 lead to block detachment and localised cliff recession. It is considered that this immediate area is unstable and unsafe to walk near.

Further along this headscarp cliff recession rates, particularly at H11 which has shown high recession rates, have reduced between December 2010 and June 2011. Recession rates at this locale had coincided with groundwater seepages in the early part of 2010, which were present approximately 5 metres below cliff crest level (Plates 12 to 17, Appendix J); these lead to the development of mudslides and headscarp recession. However, since the previous monitoring event of December 2010, recession rates at H11 have shown no further recession evident along this scarp. H11 appears to have become less active from October 2010 up to June 2011. This condition has reflected the drier Spring and early Summer months of 2011.

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 landslip 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.

In view of the amount of land lost to cliff recession at various points around Knipe Point, it is recommended that monitoring of coastal headscarps should be increased to two monthly intervals. Additional monitoring events should be undertaken in August and October, reverting back to the original monitoring regime in December 2011.

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

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 27th 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. Inclinometers 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 (10th December 2009), the base of BH03 was found to be dipping at a reduced depth of 18.35 mBGL. Further investigation carried out on 11th 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 (8th July 2009) up to the June 2011. A comparison of readings taken in December 2010 and the latest recorded in June 2011 indicate that groundwater levels across the site have decreased by up to 7420 mm (BH04). Water levels within BH05B and 06 have decreased by 230 mm and 530 mm respectively and BH01 water levels have also fallen by 100 mm. The largest change in water levels of 7420 mm was recorded in BH04. The piezometer in BH01 reflects 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 continue to remain fairly static with the only significant change of 7420 mm apparent in borehole BH06 probably reflecting a reduced watertable in response to lower rainfall. BH05B reflects 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.

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

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 landslip (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

A comparison of the latest groundwater readings with those recorded of December 2010 indicate groundwater levels within boreholes have reduced by 8880 mm (D1), 2550 mm (A3) and 2800 mm (B1). Borehole BB01 (D2) has been recorded as dry on each previous monitoring occasion, having failed at 14.20 m depth. Groundwater readings are presented in Appendix E.

9.6 Conclusions

Monitoring data from the inclinometer BB02 (A2) has illustrated very little or no ground movement occurring within the vicinity of this borehole. A deviation of 15mm is indicated at near surface from the latest inclinometer readings of June 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. To-date the monitoring data indicates that no ground movements have taken place within the location of inclinometer A2.

The single inclinometer offers very limited coverage of the site of 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.

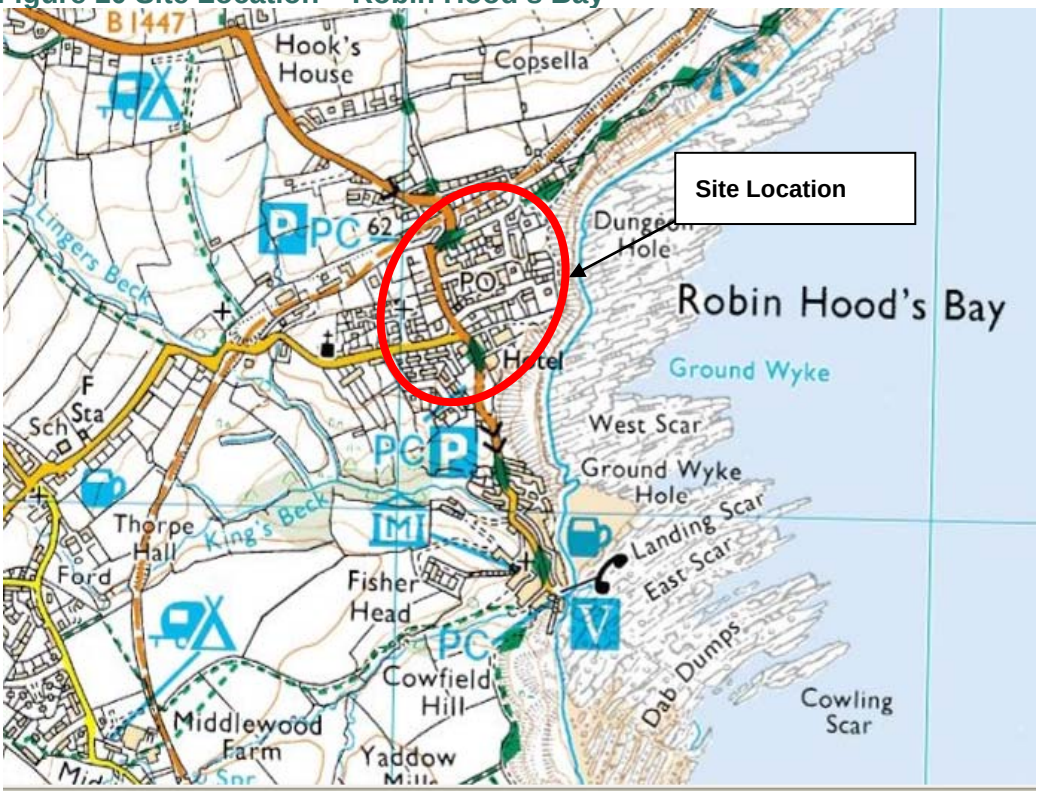
Groundwater levels across the site have tended to reflect the relatively dry period and general reduced levels of rainfall experienced from Spring to early Summer 2011, with depressed water levels recorded in the piezometers.

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



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 is to consist 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 August 2010 shows groundwater levels within BH3A and B remaining reasonably static except BH1A which indicated a rise in groundwater of 2.72 m, the deeper piezometer 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 mbgl. 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.

During the most recent monitoring event of June 2011 BH 2 inclinometer tube could only be read to 21.5 metres depth (inclinometer installed to 41.0m) 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.

In view of the continuing ground movements indicated from the latest monitoring data it is recommended that the monitoring frequency at this site is increased from six monthly intervals to two monthly intervals. Additional monitoring events should be undertaken in August and October, reverting back to the original monitoring regime in December 2011.

11 References

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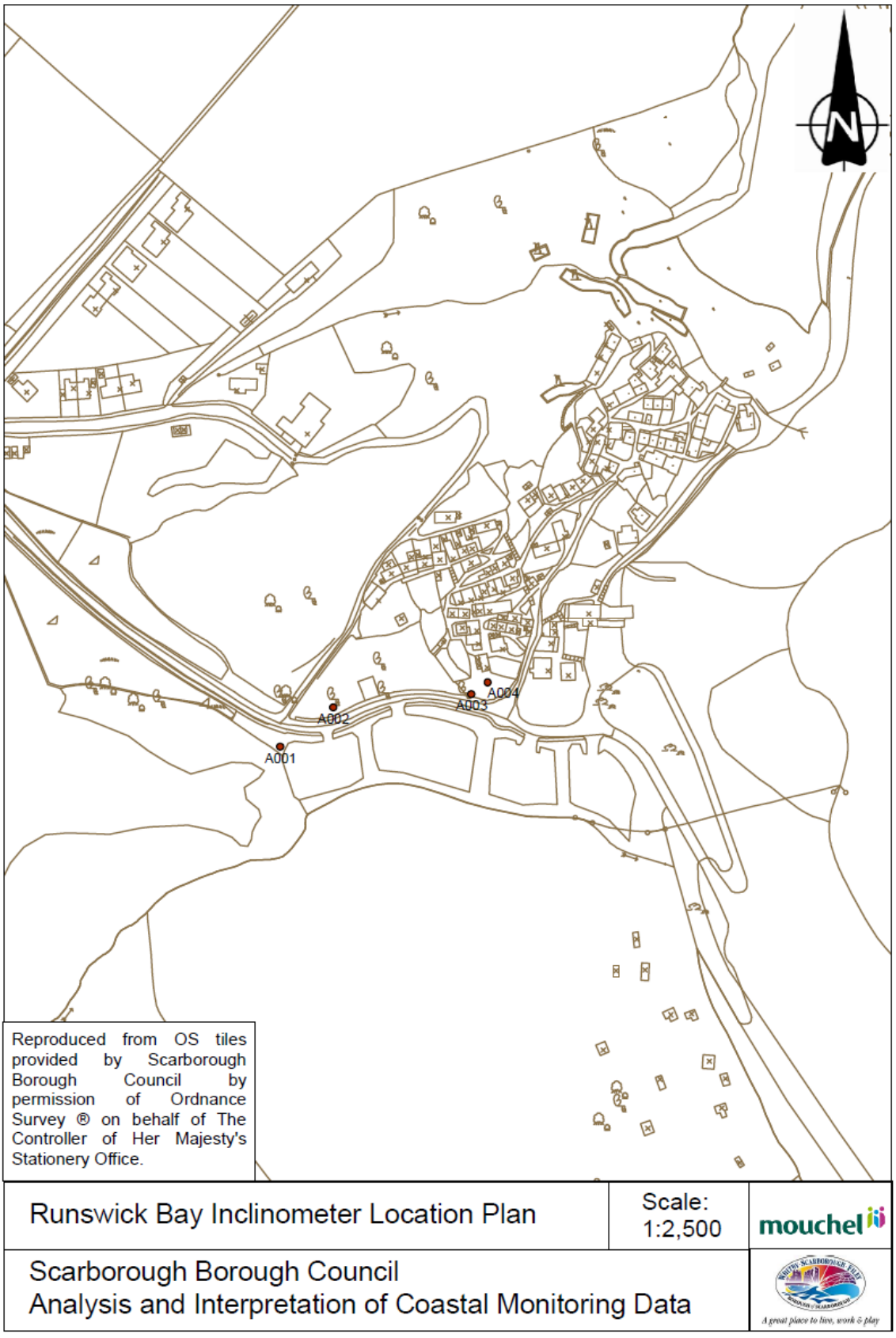
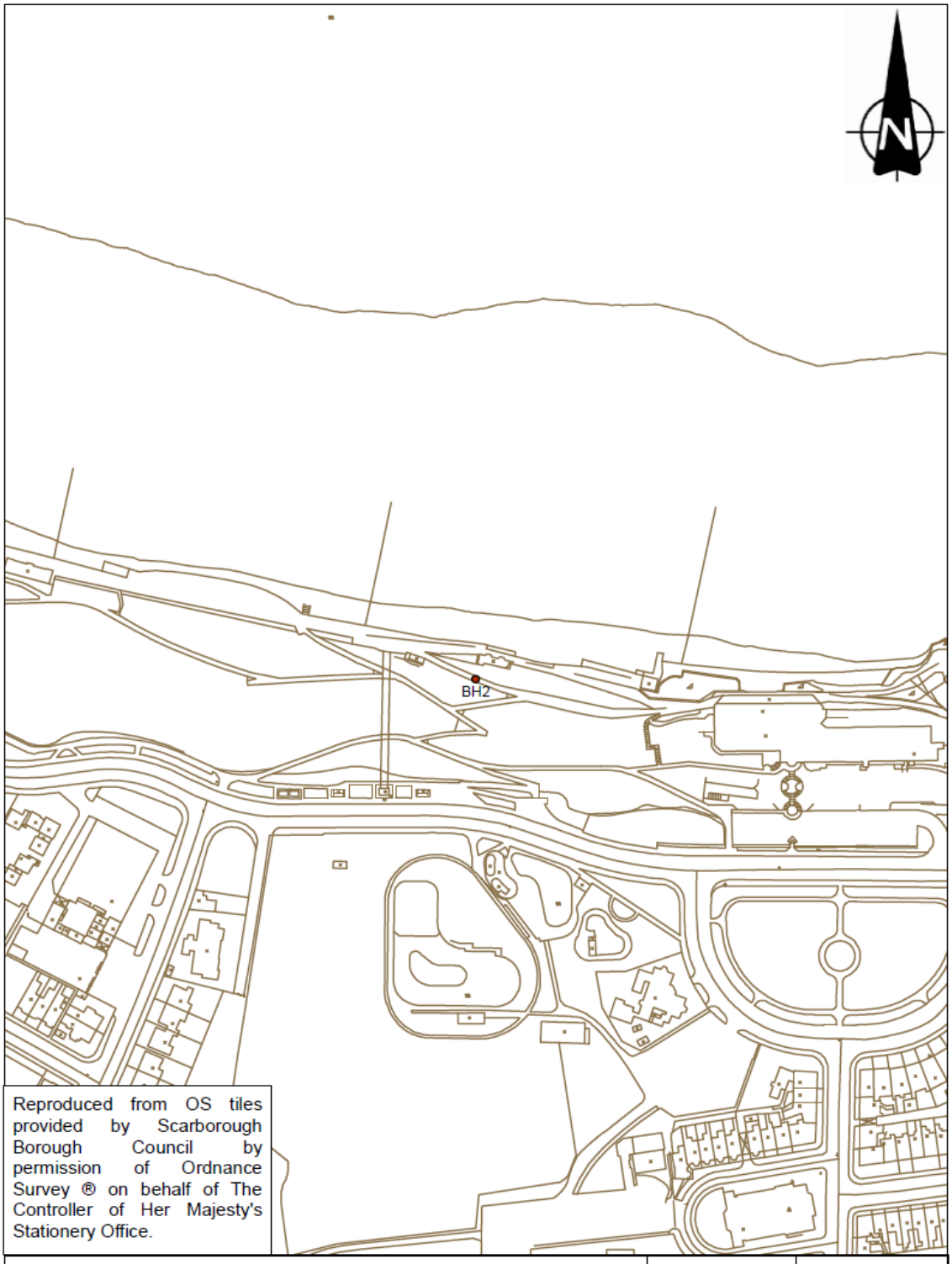
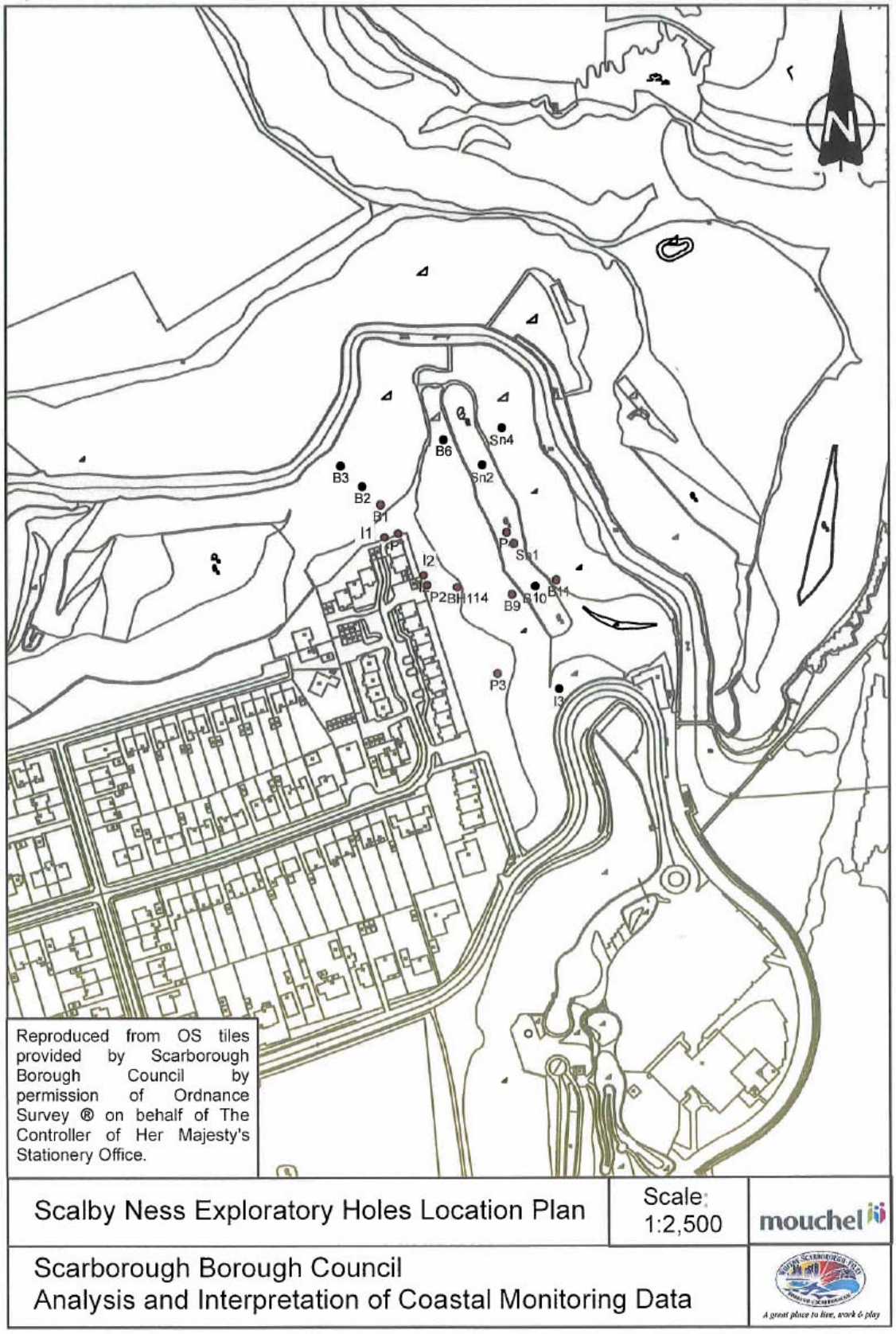
Appendix A Exploratory Holes Location Plans



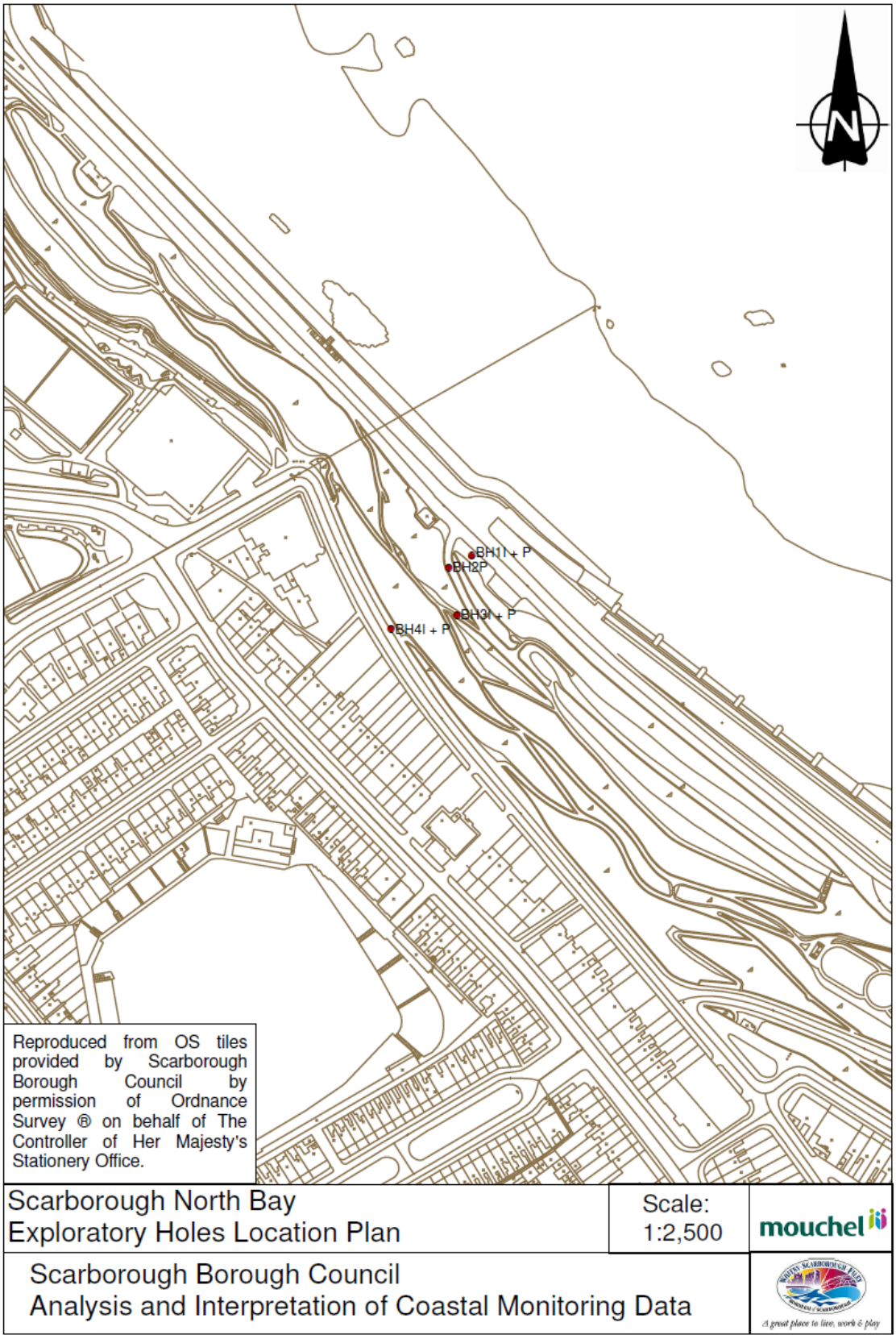
Drawing No. 1 Location Plan of Runswick Bay



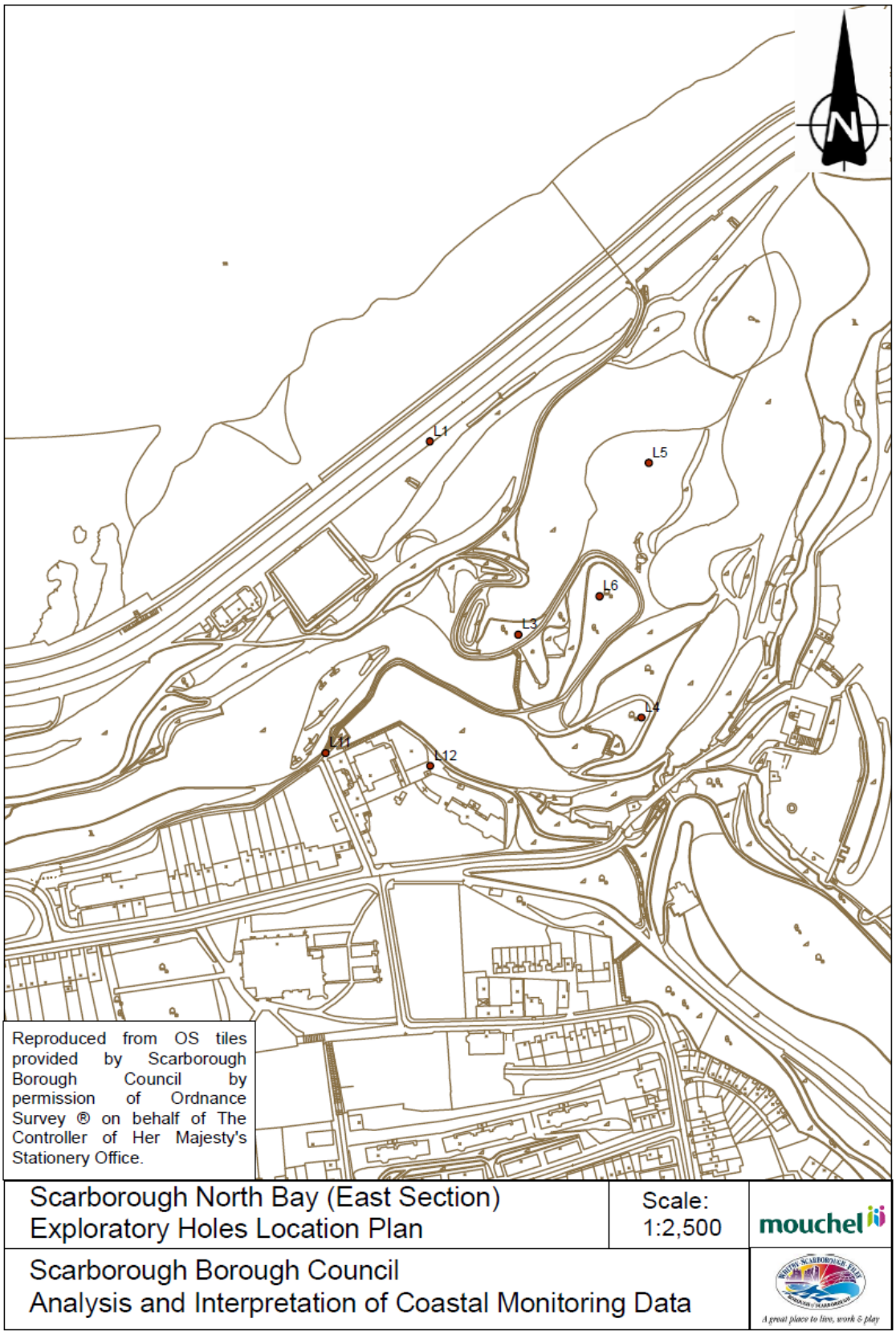
Drawing No. 2 Location Plan of Whitby West Cliff



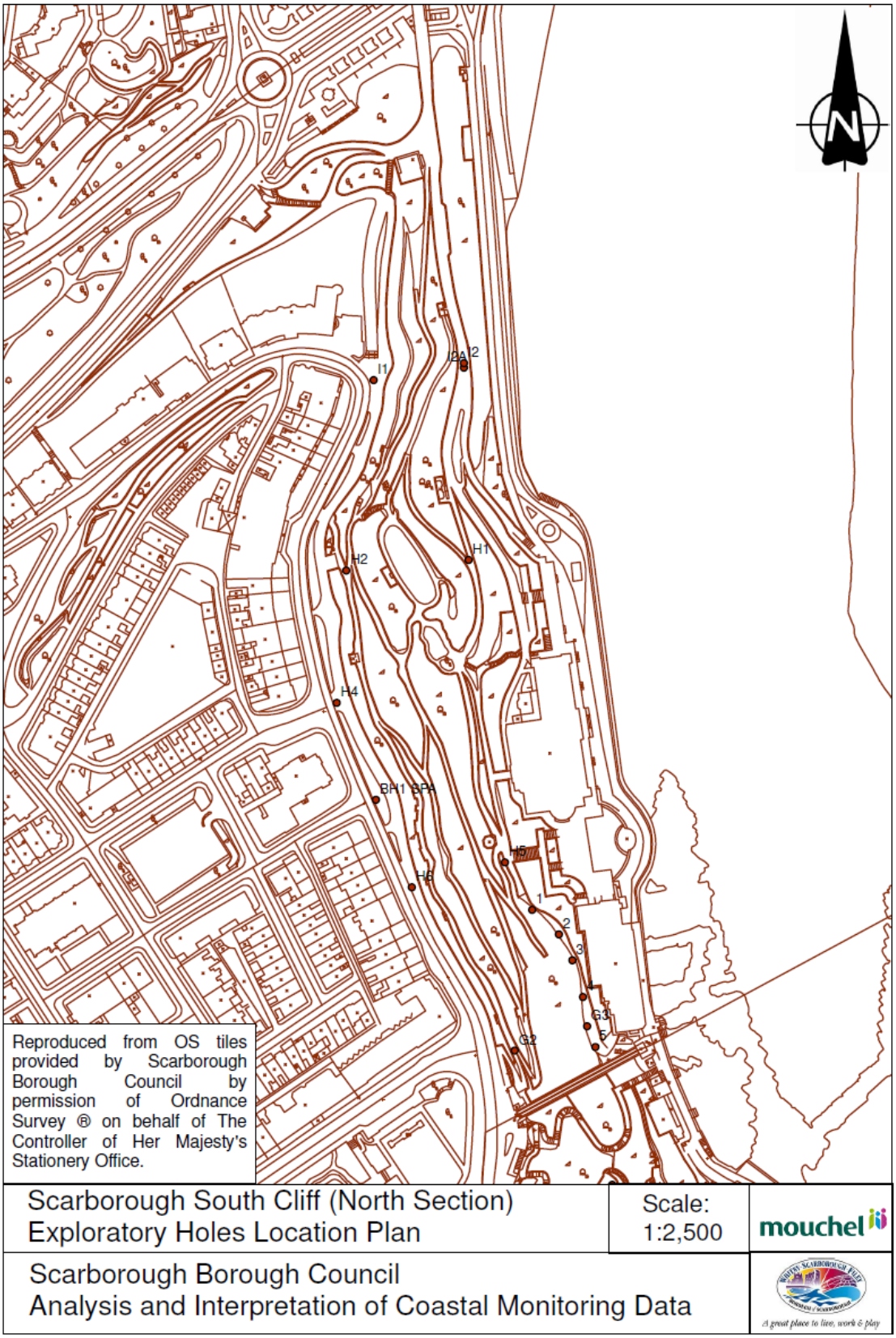
Drawing No. 3 Location Plan of Scalby Ness



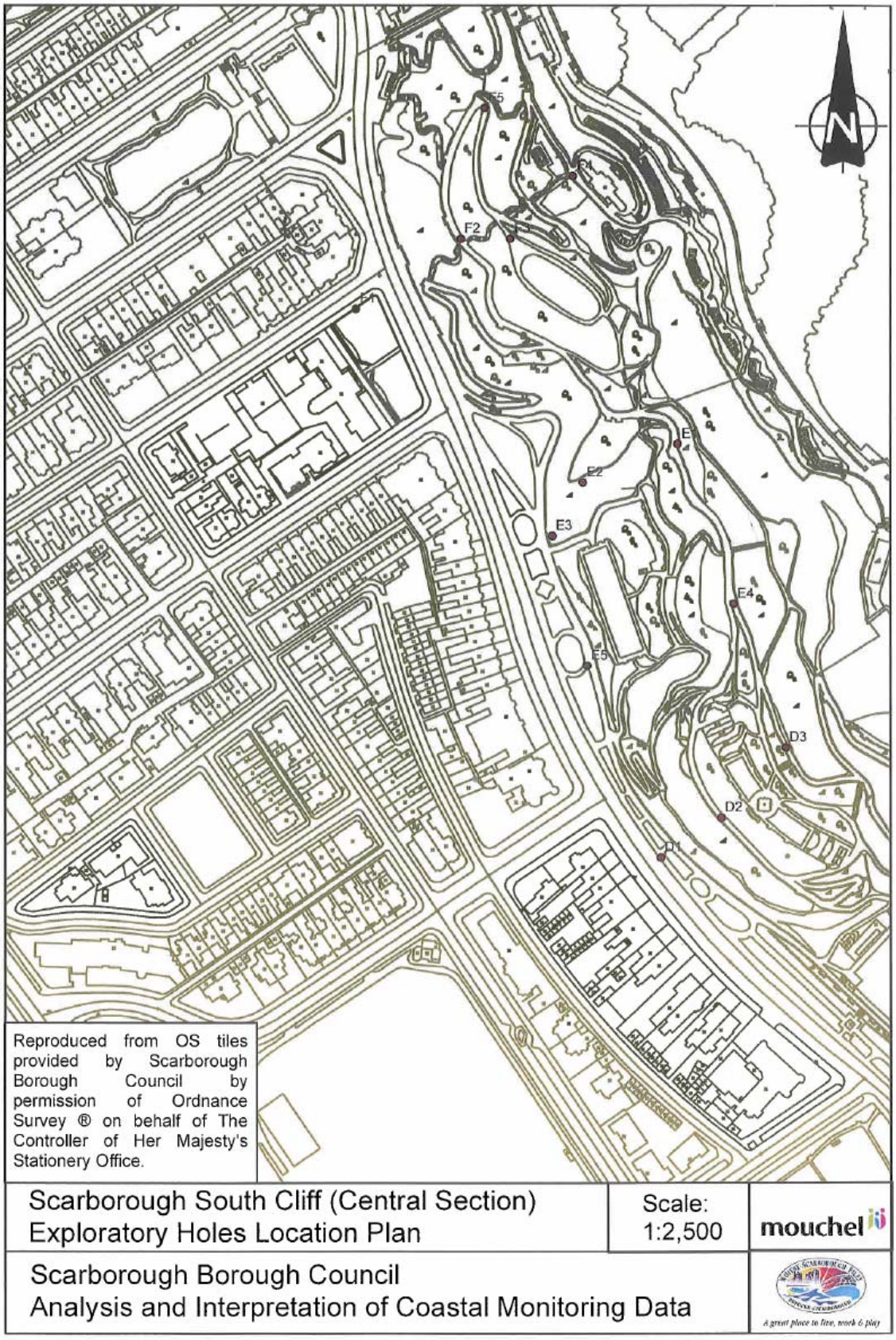
Drawing No. 4 Location Plan of Scarborough North Bay (Oasis Cafe)



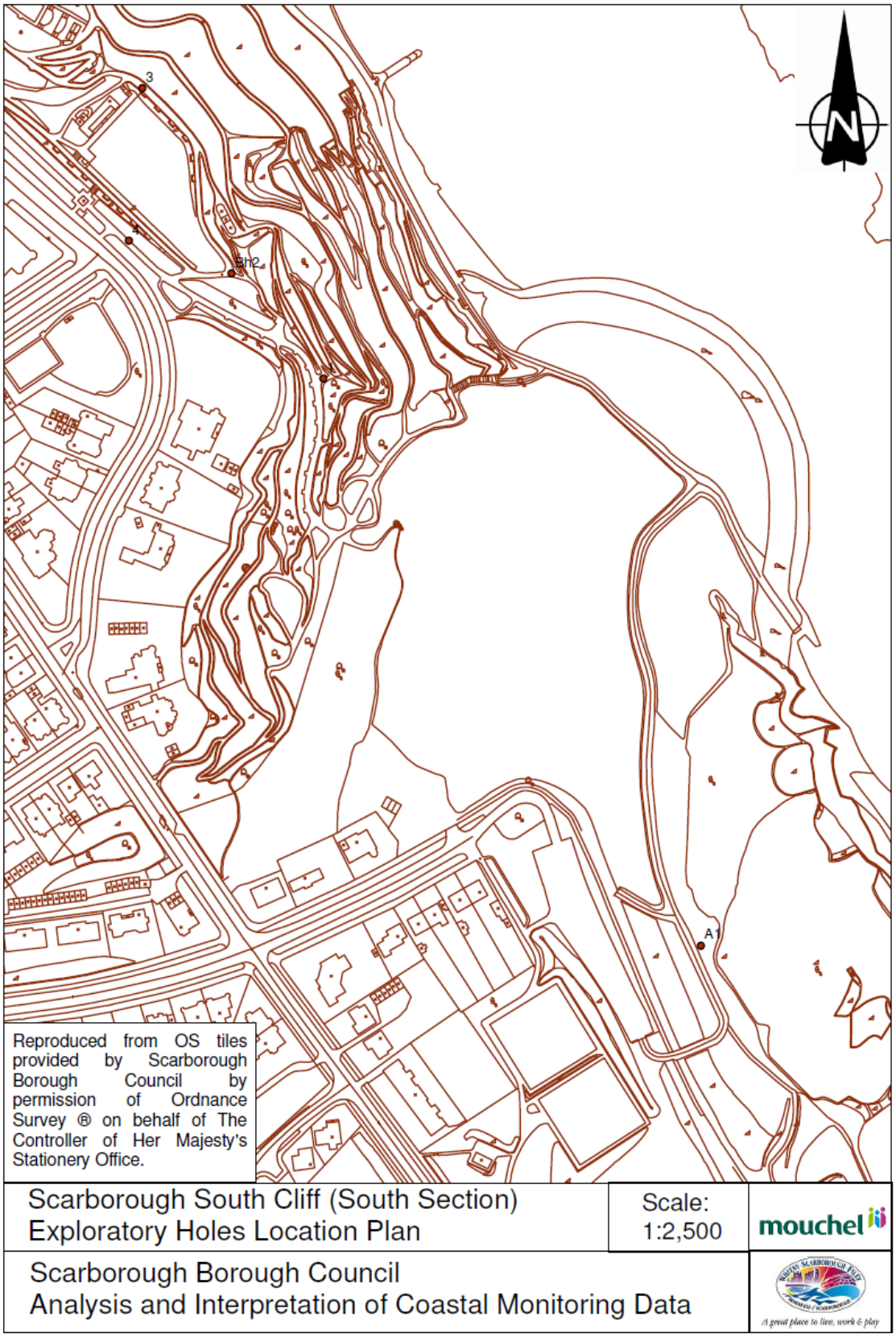
Drawing No. 5 Location Plan of Scarborough North Bay (East)



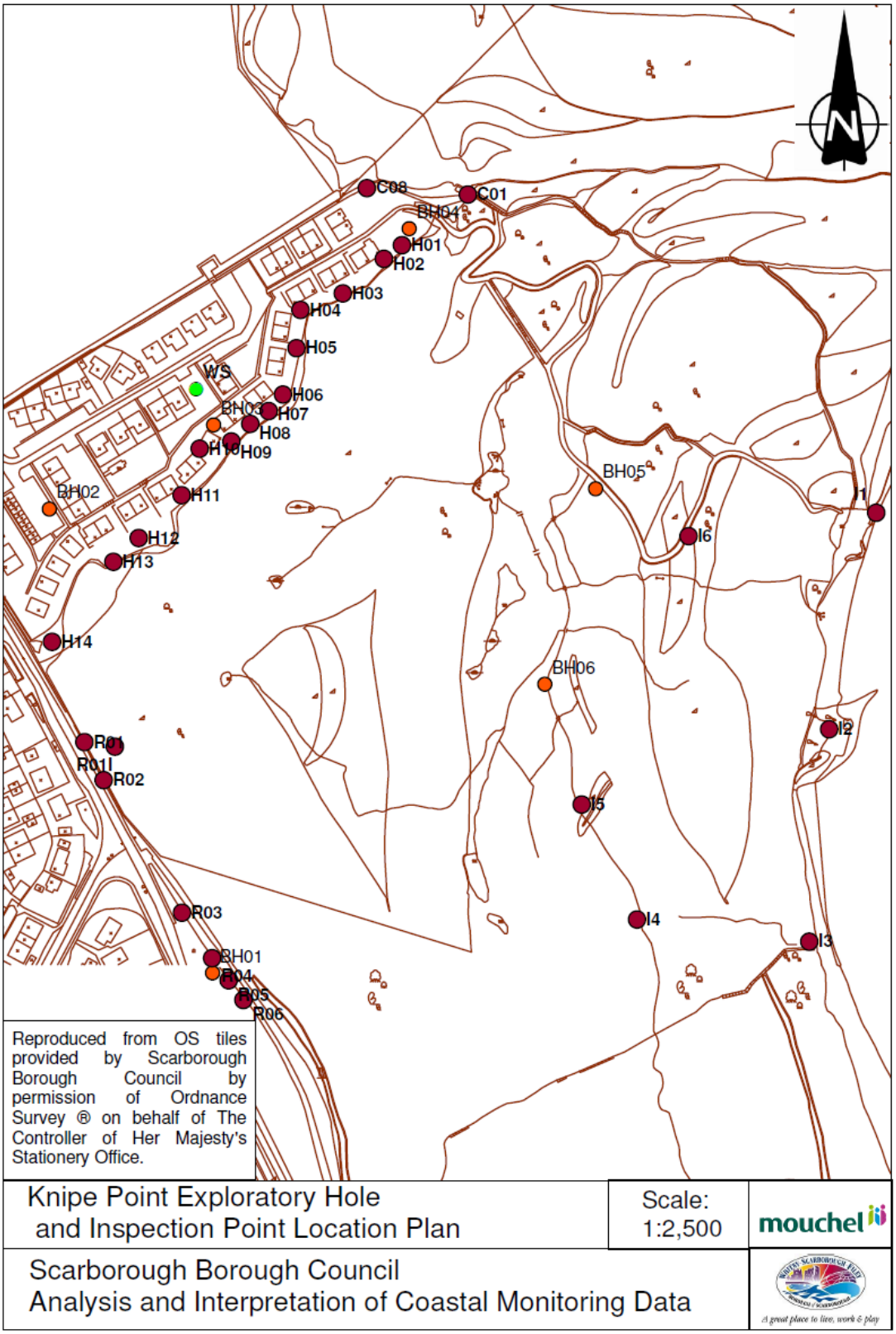
Drawing No. 6 Location Plan of Scarborough South Cliff (North)



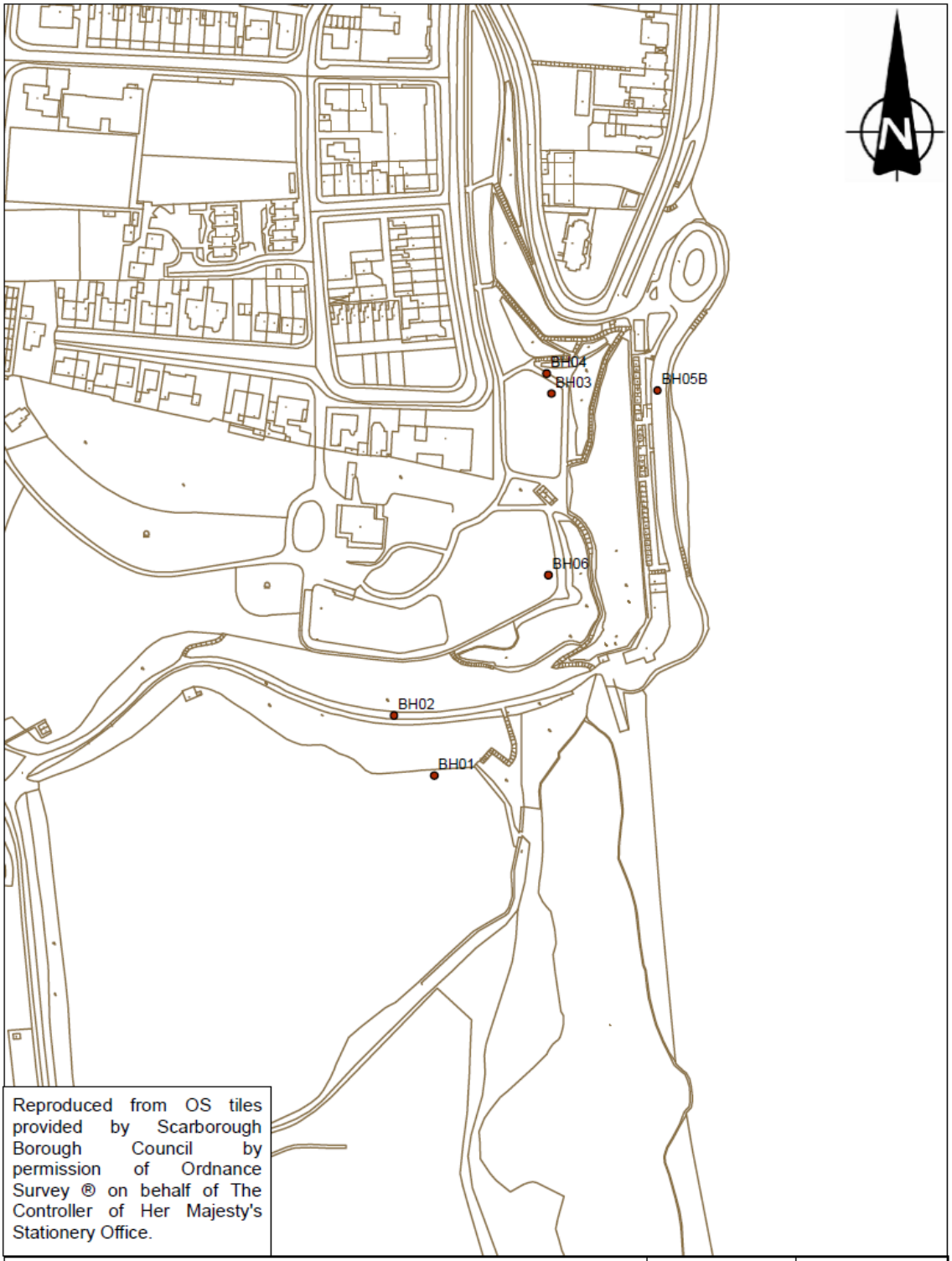
Drawing No. 7 Location Plan of Scarborough South Cliff (Central)



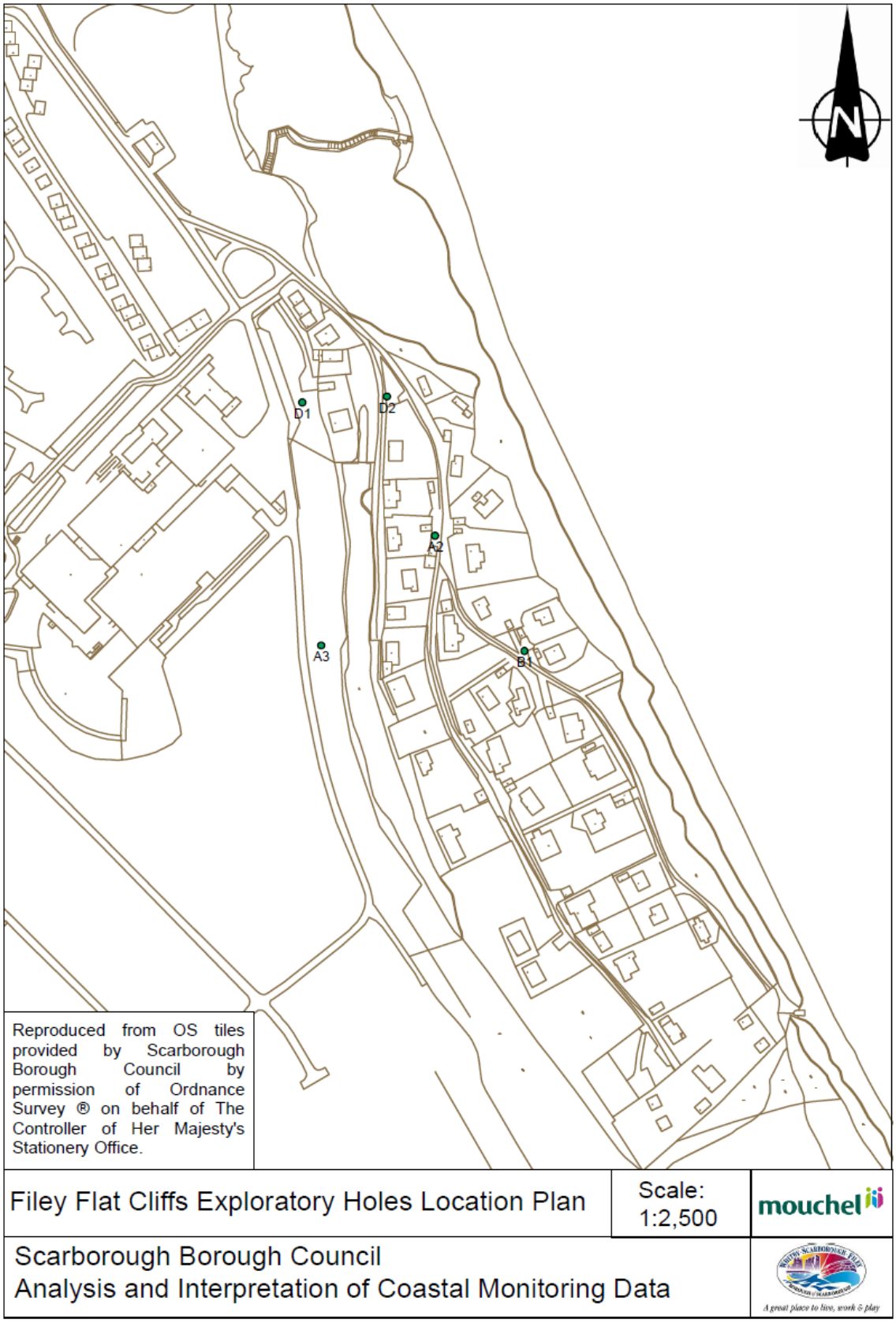
Drawing No. 8 Location Plan of Scarborough South Cliff (South)



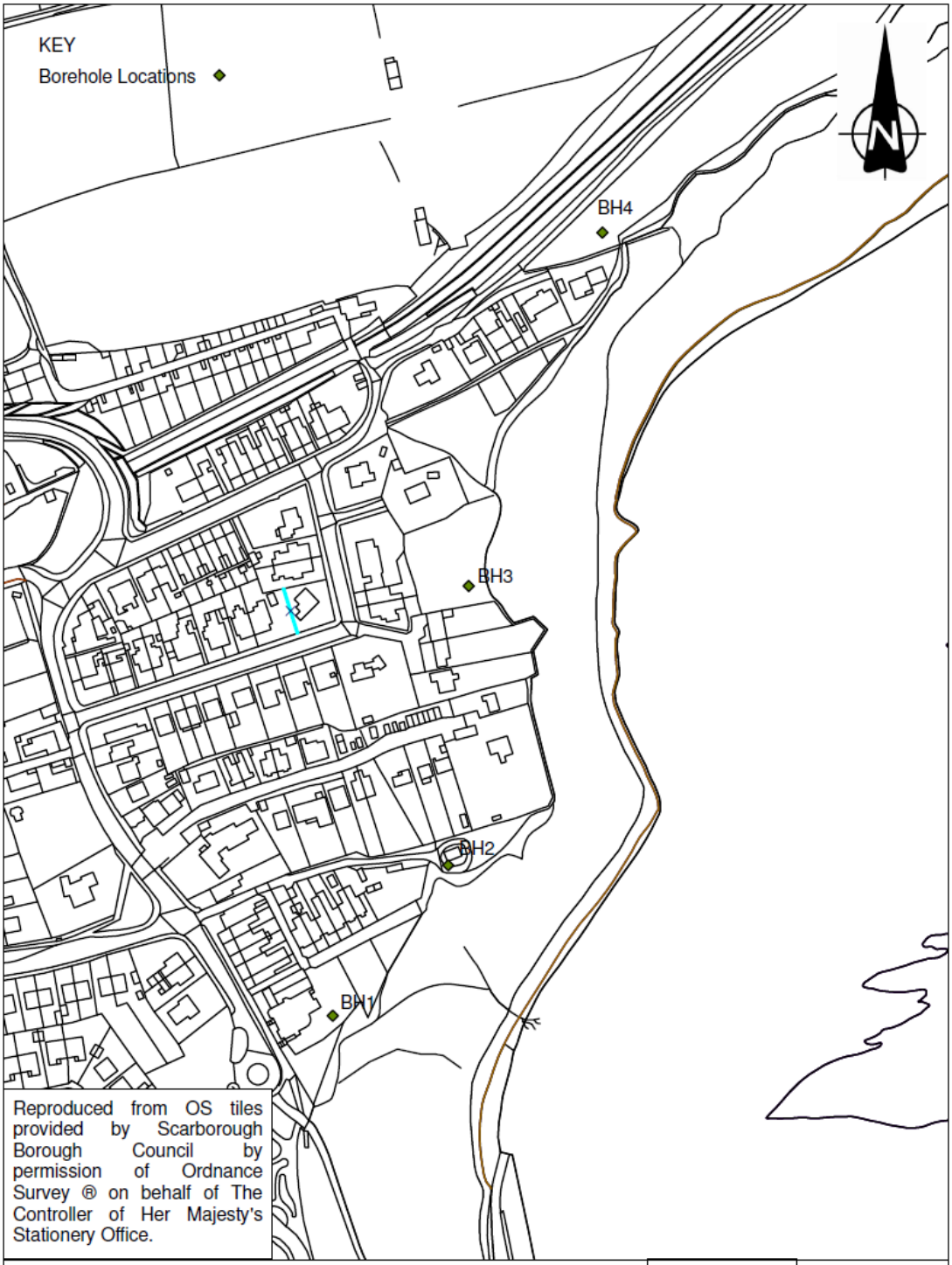
Drawing No. 9 Location Plan of Knipe Point



Drawing No. 10 Location Plan of Filey Town

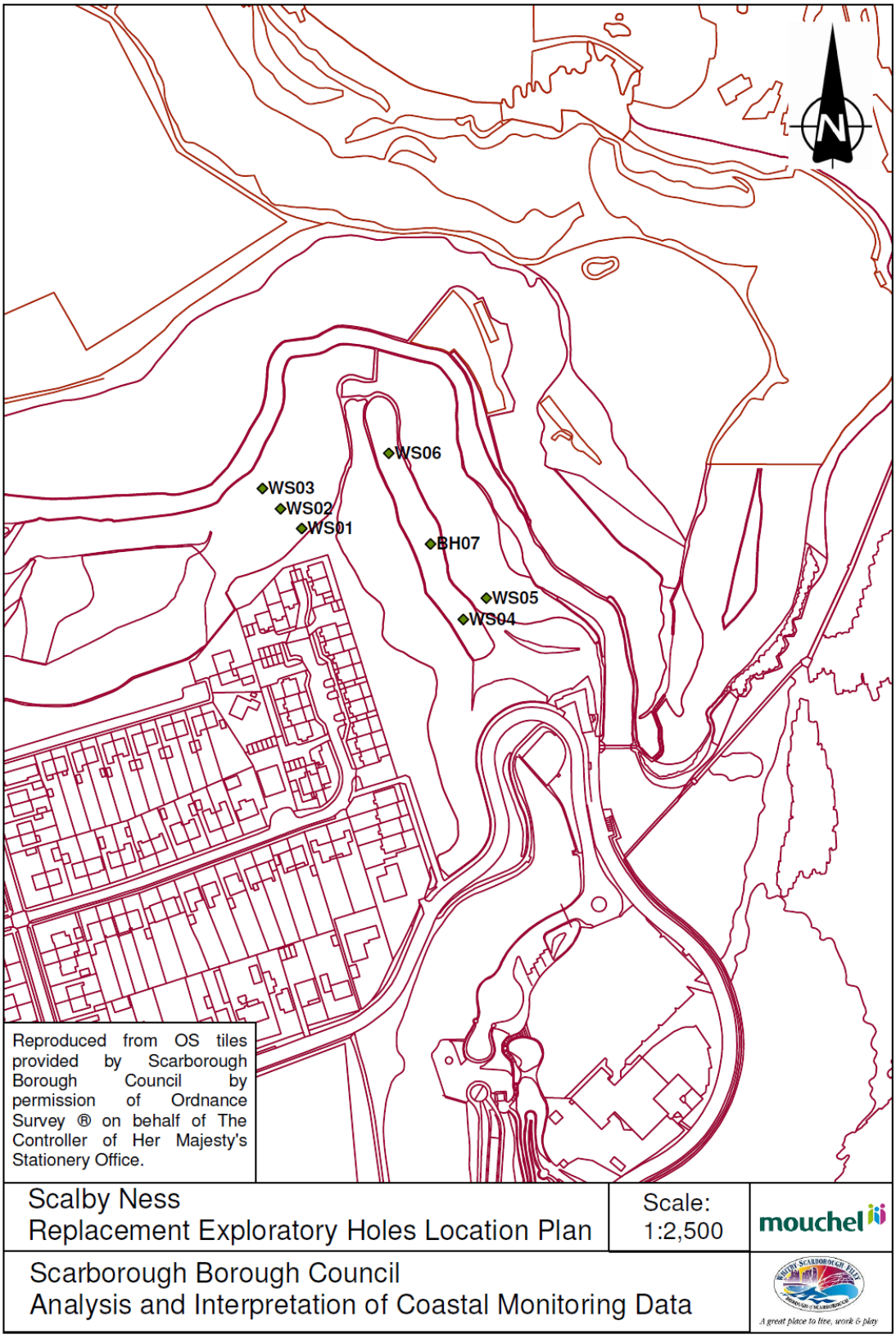


Drawing No. 11 Location Plan of Filey Flat Cliffs

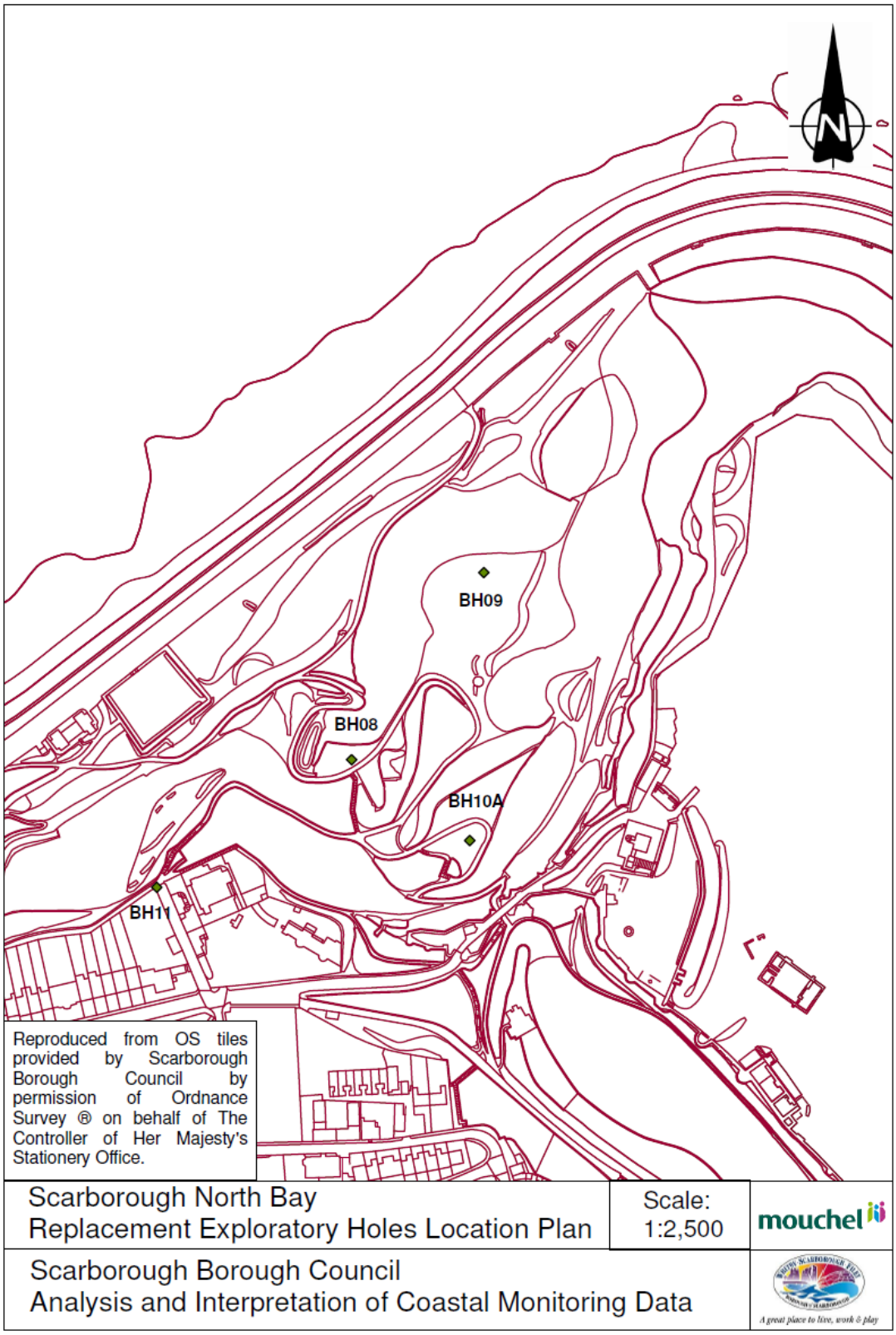


Drawing No. 12 Location Plan of Robin Hood's Bay

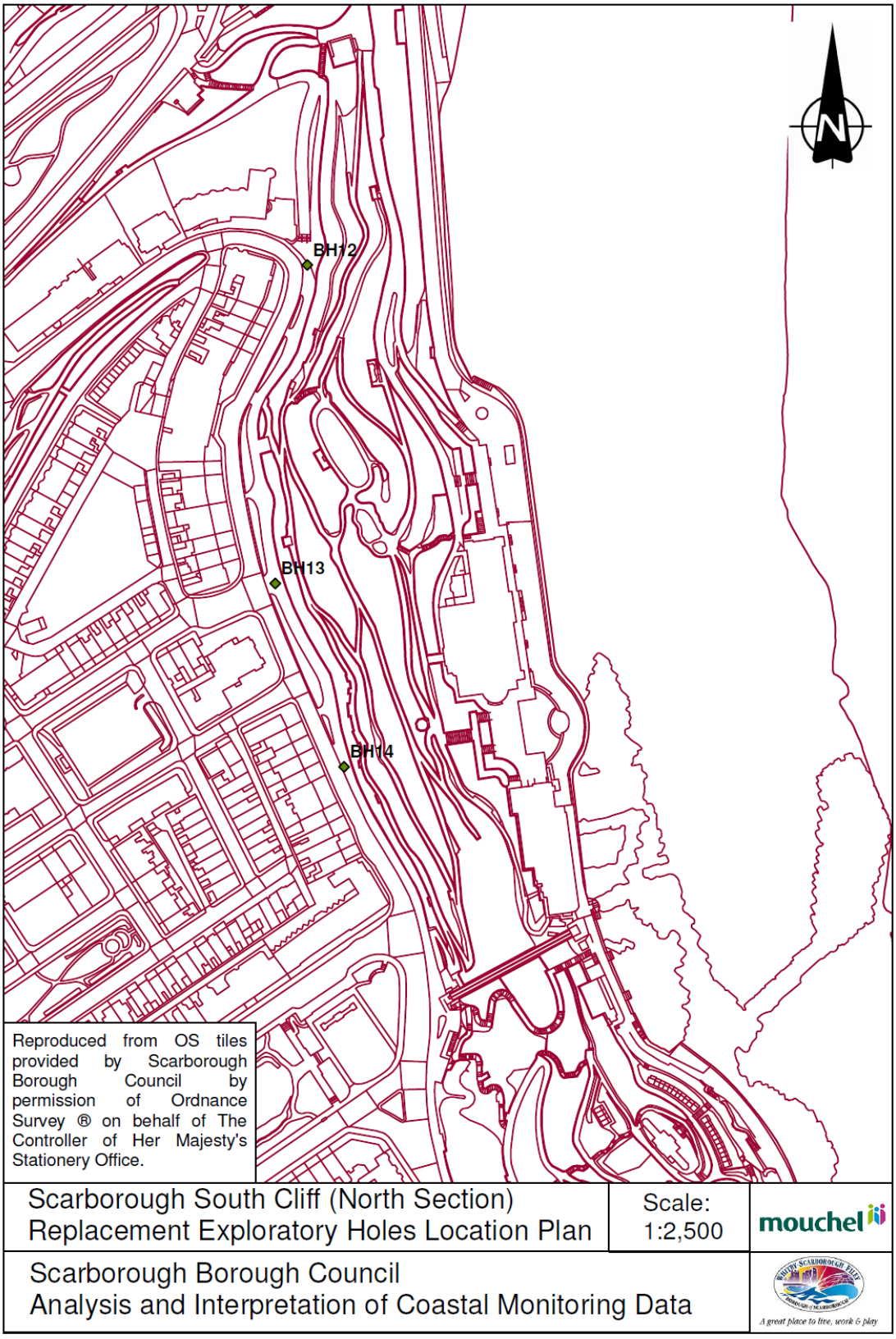
Appendix B Replacement Installation Location Plans



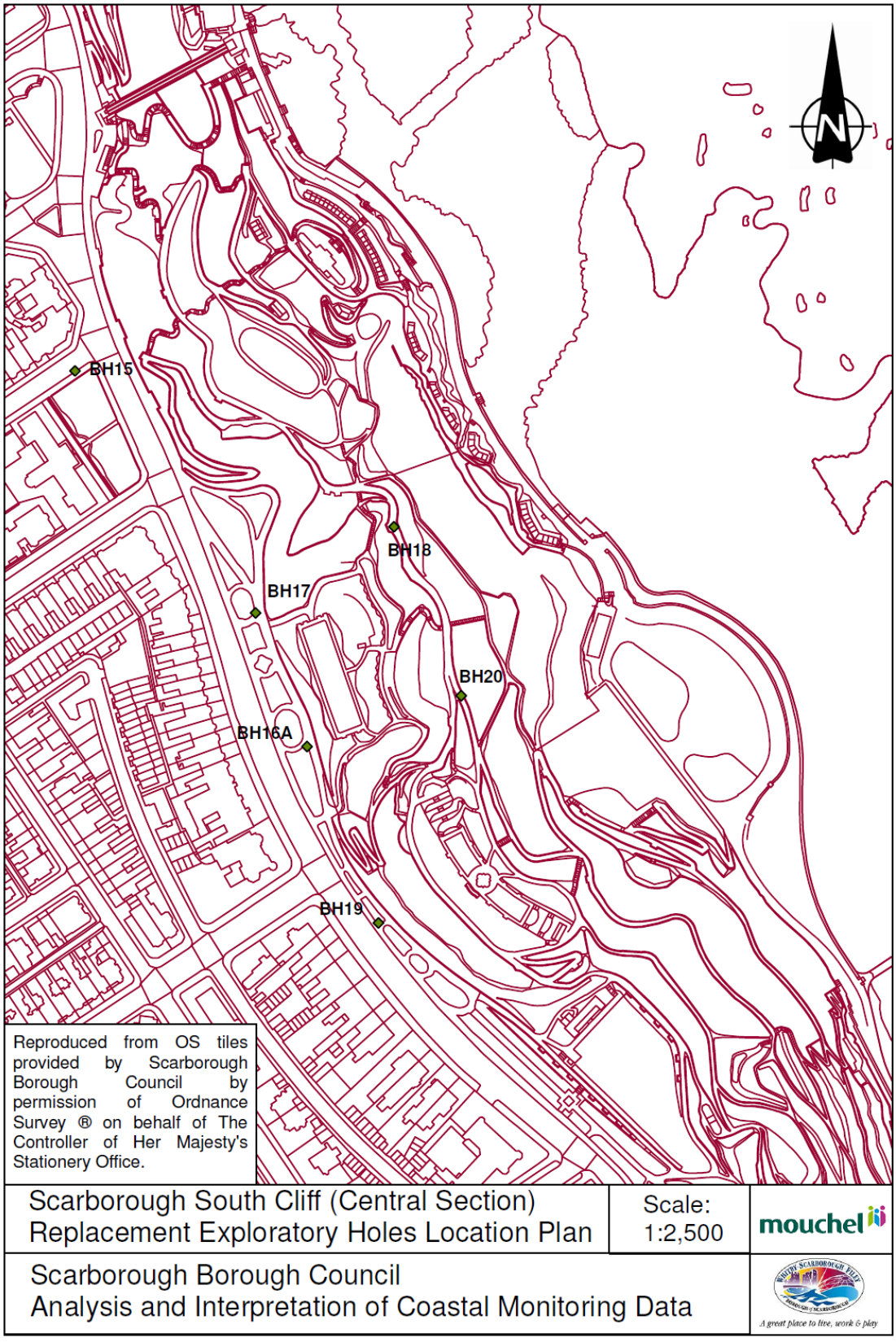
Drawing No. 1 Location Plan of Scalby Ness



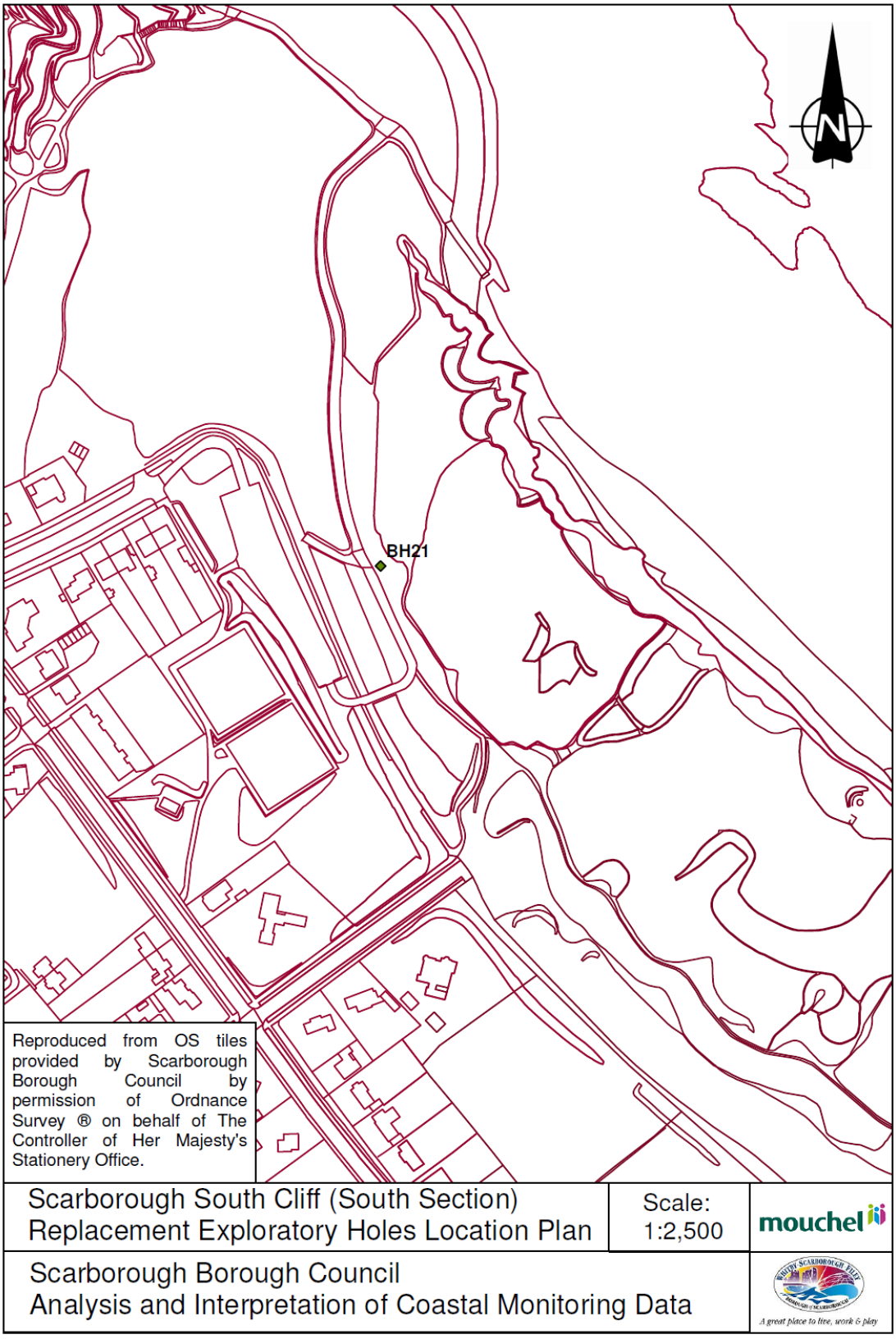
Drawing No. 2 Location Plan of The Holms, Scarborough North Bay



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

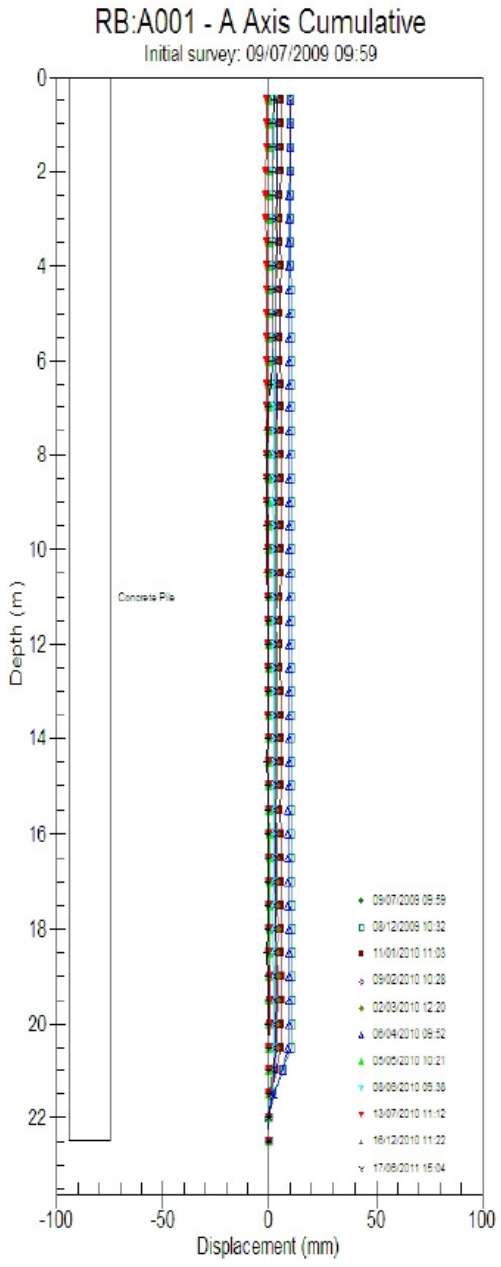


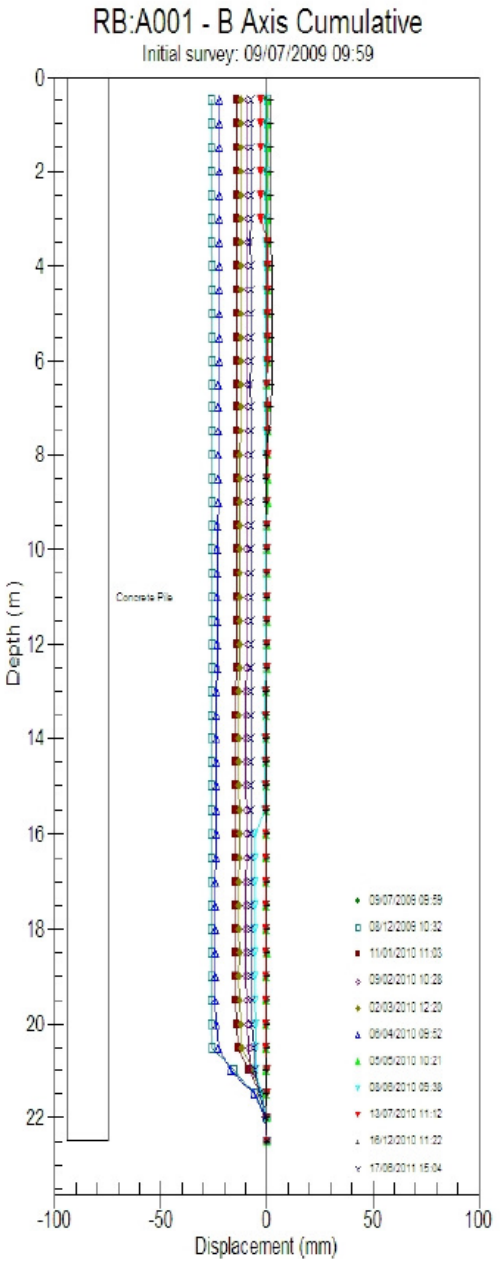
Drawing No. 4 Location Plan of Scarborough South Cliff (Central Section)



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

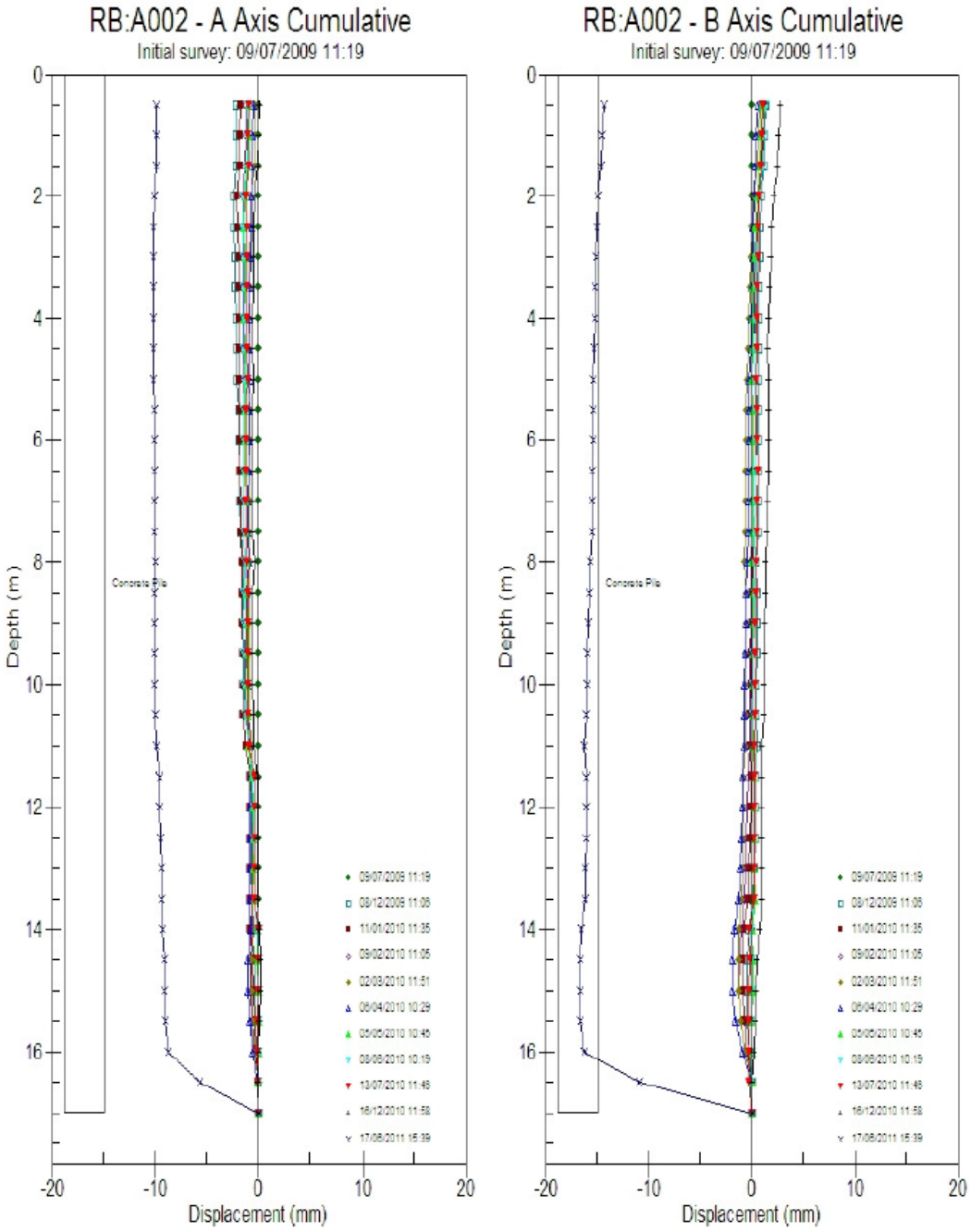
Appendix C Inclinometer Graphs





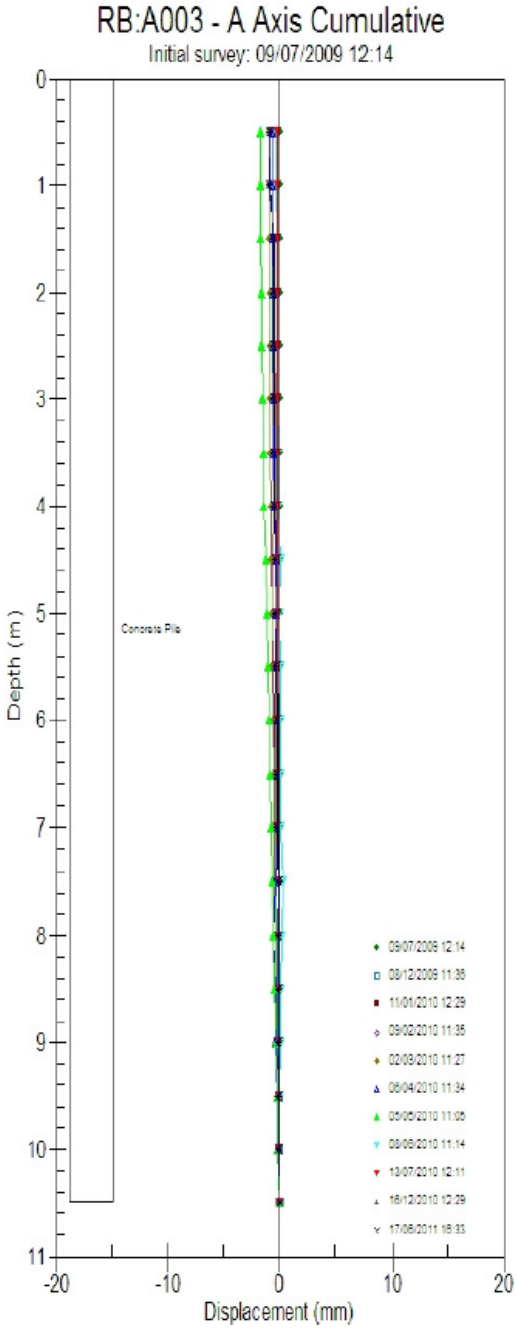
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A001
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

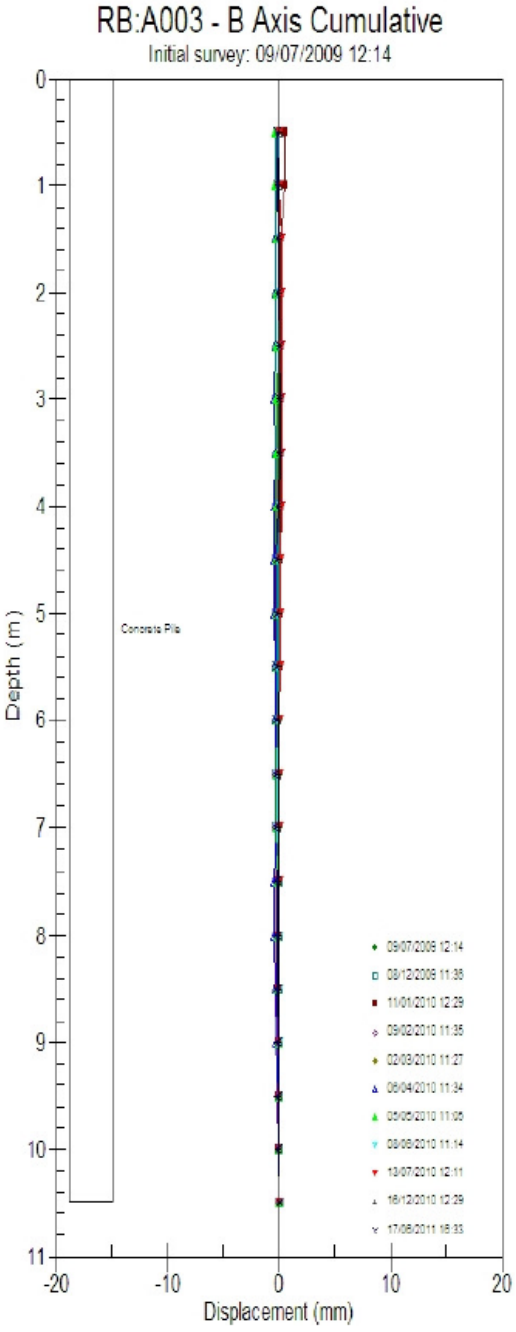
NOTE: A0 direction: East



PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A002
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

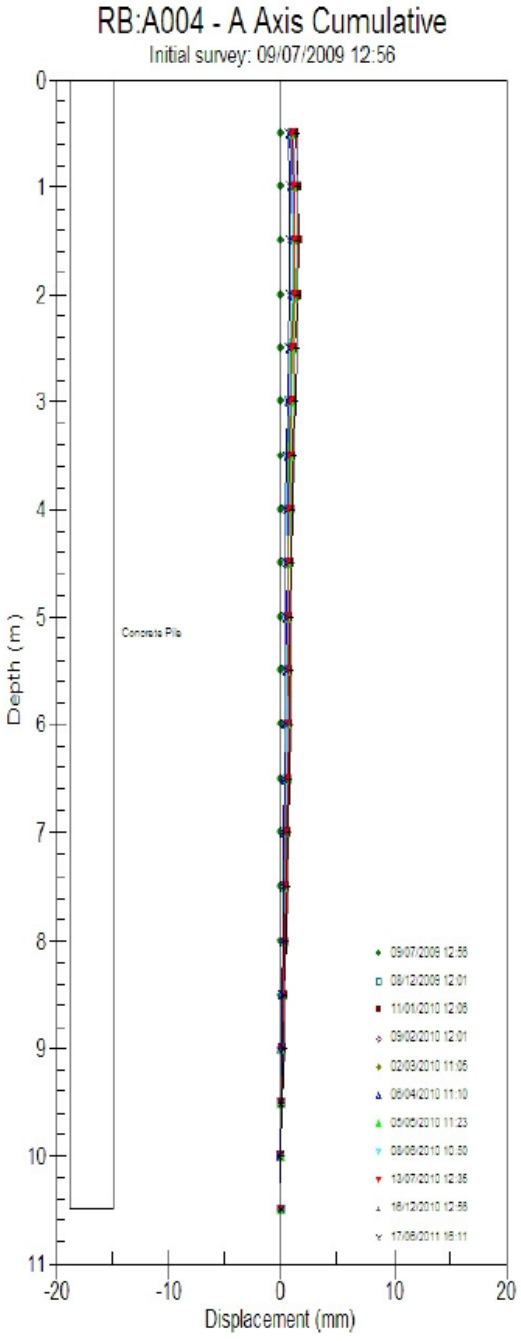
NOTE: A0 direction: East

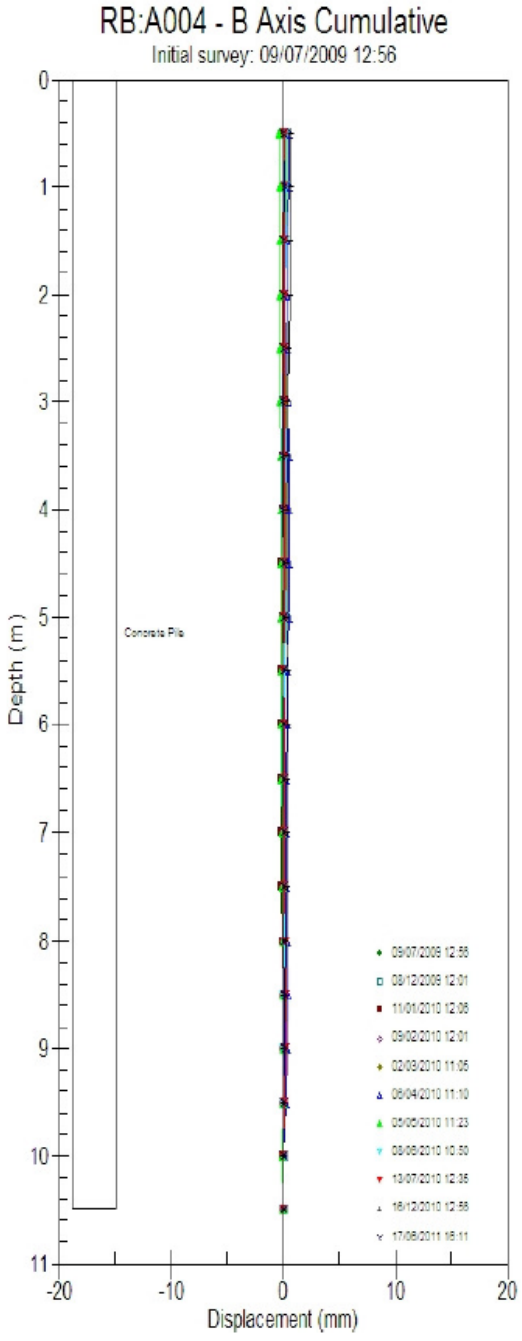




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A003
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

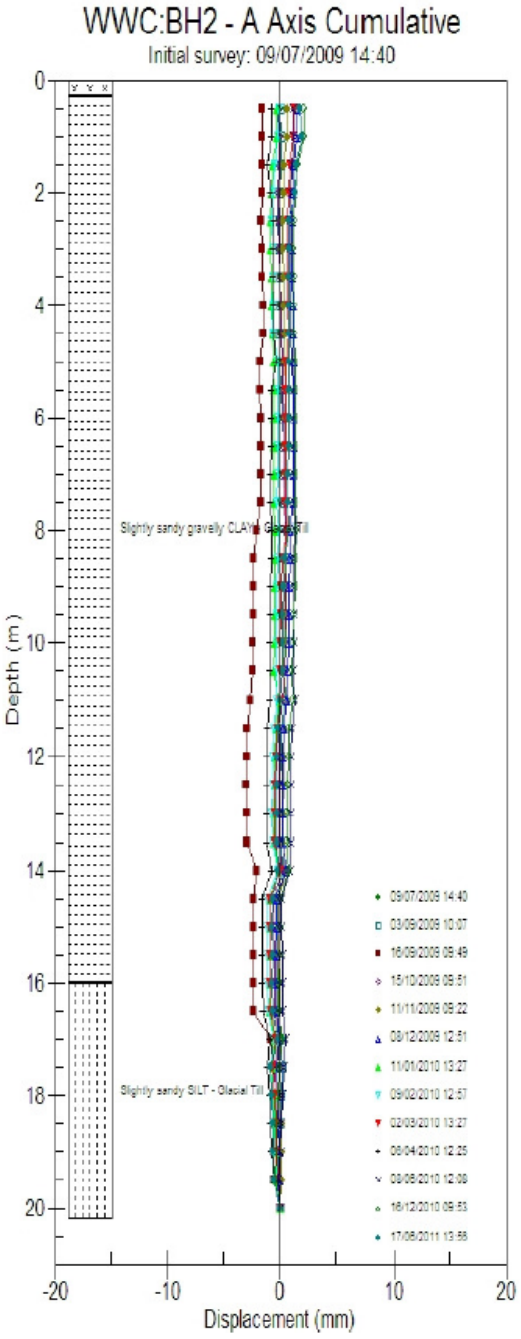
NOTE: A0 direction: South East

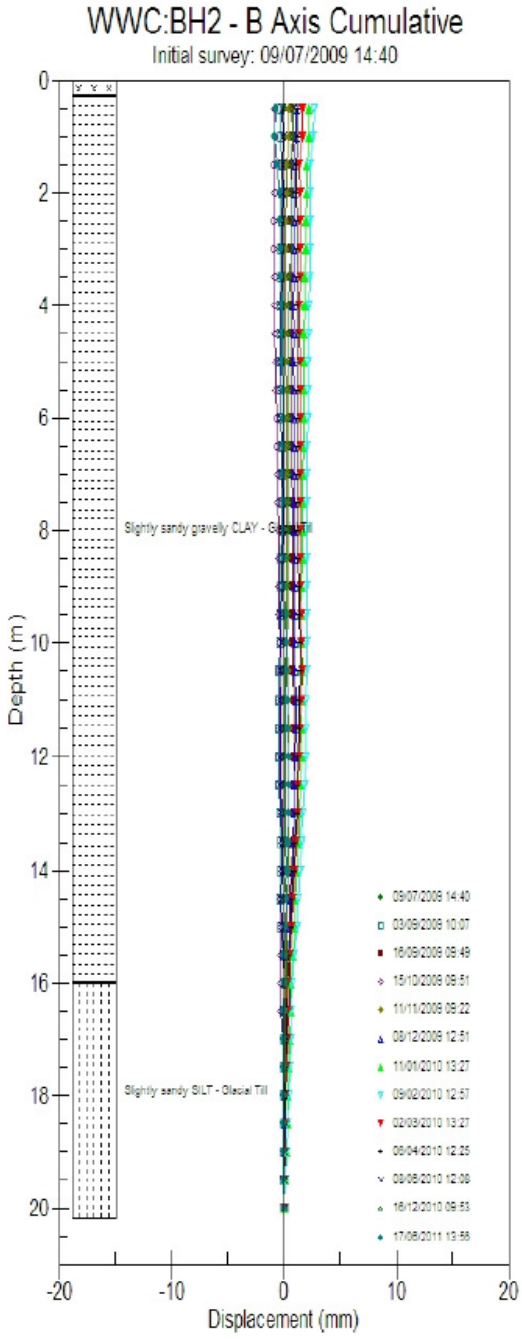




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A004
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

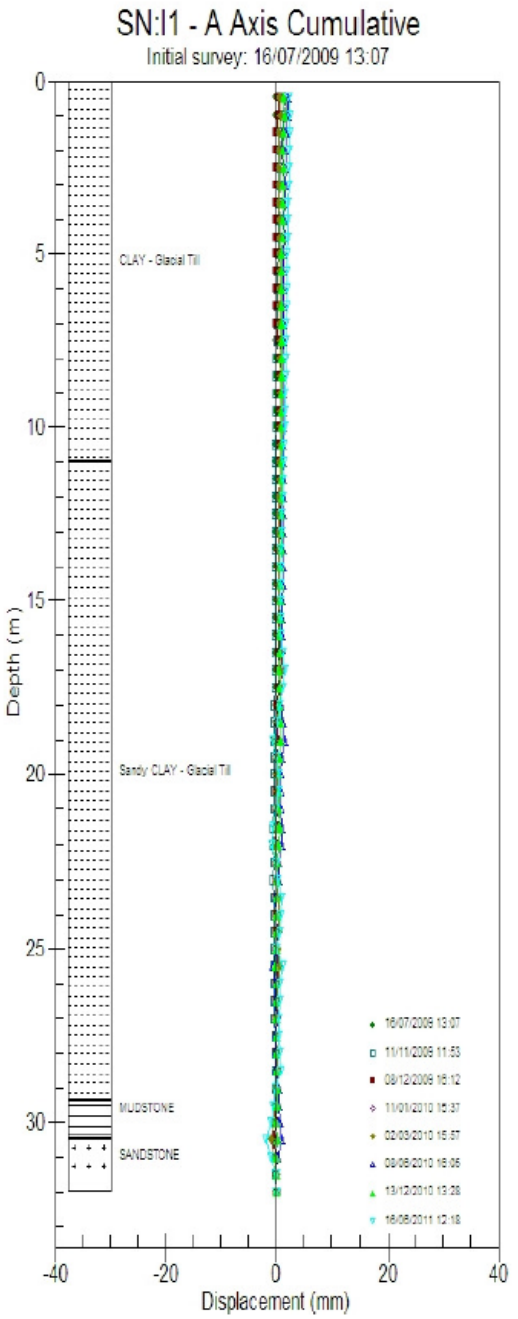
NOTE: A0 direction: East

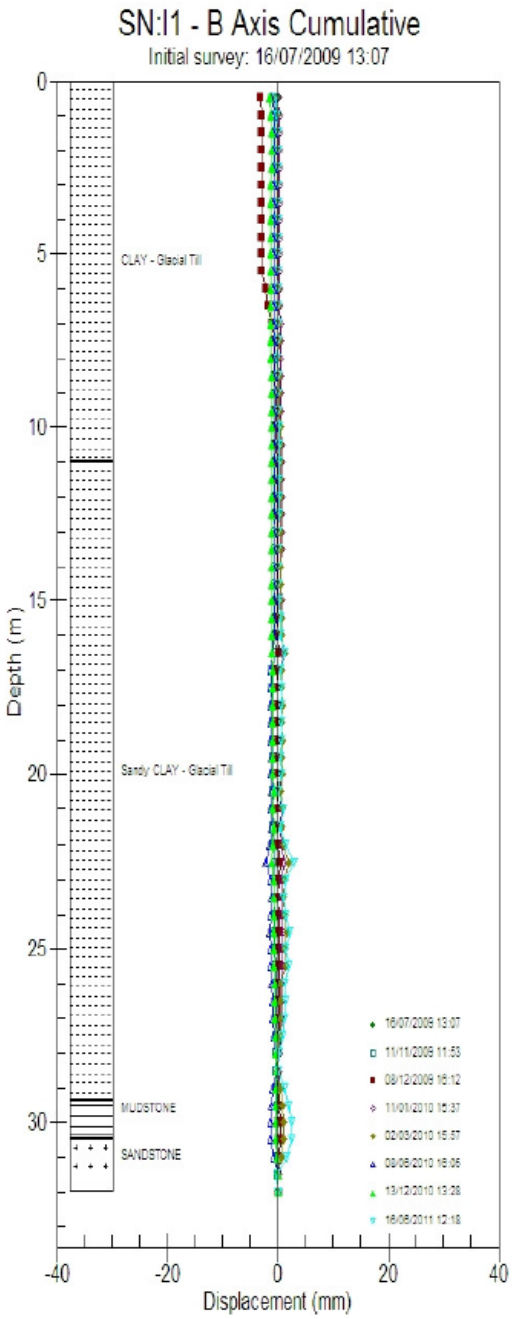




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Whitby West Cliff
INSTALLATION: BH2
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

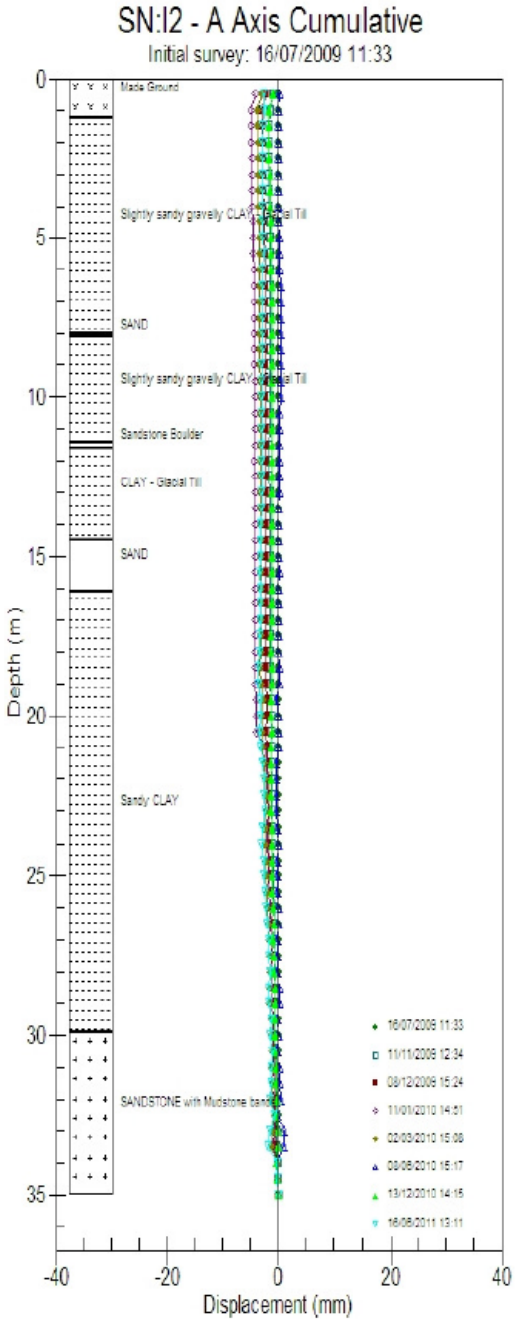
NOTE: A0 direction: North

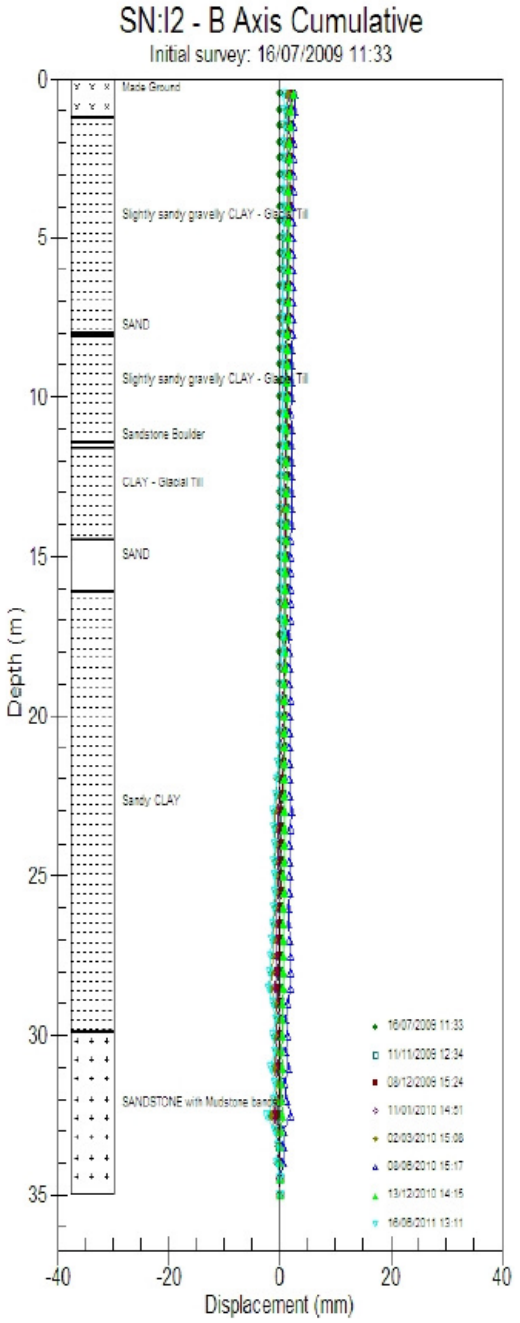




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scalby Ness
INSTALLATION: I1
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

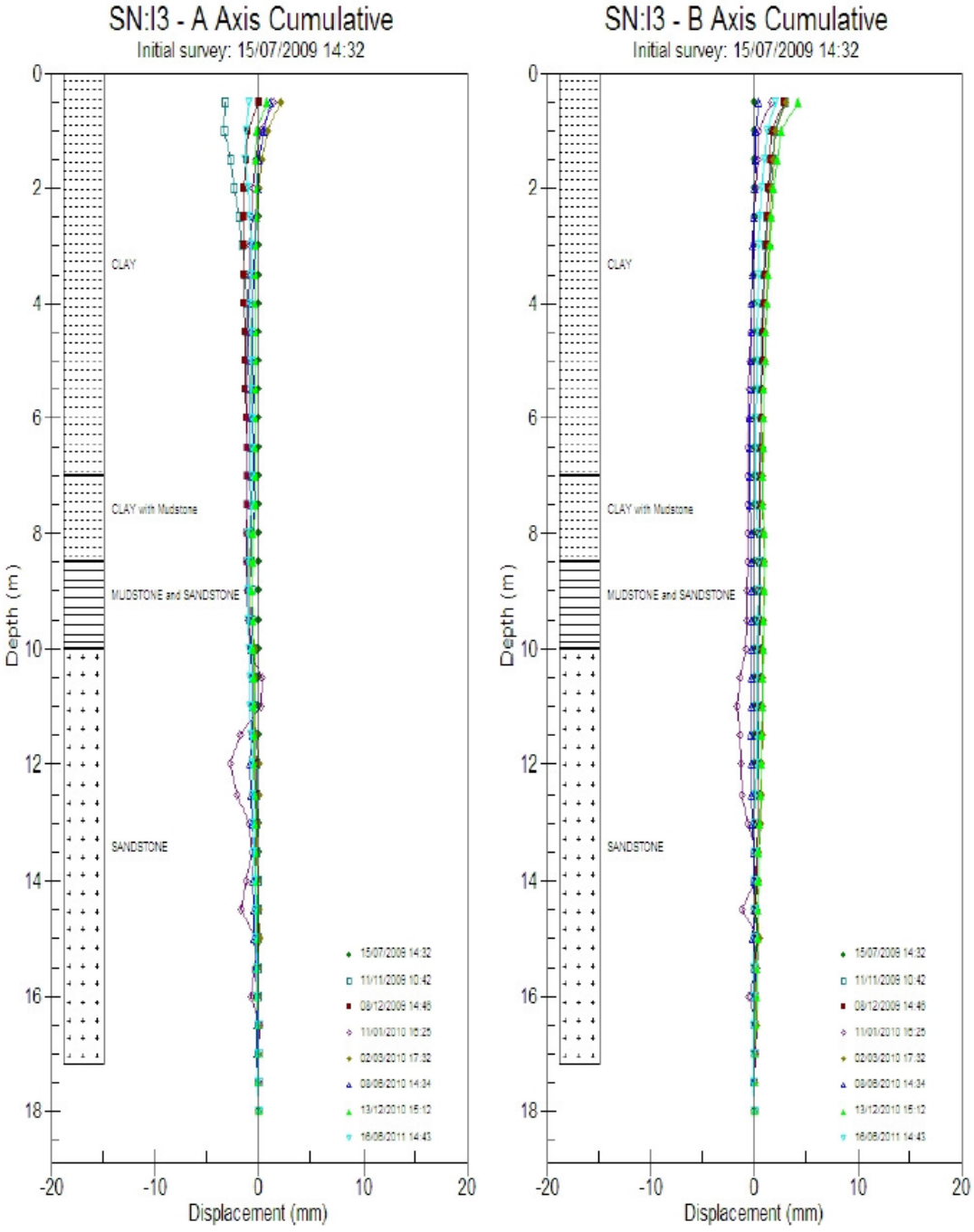
NOTE: A0 direction: North





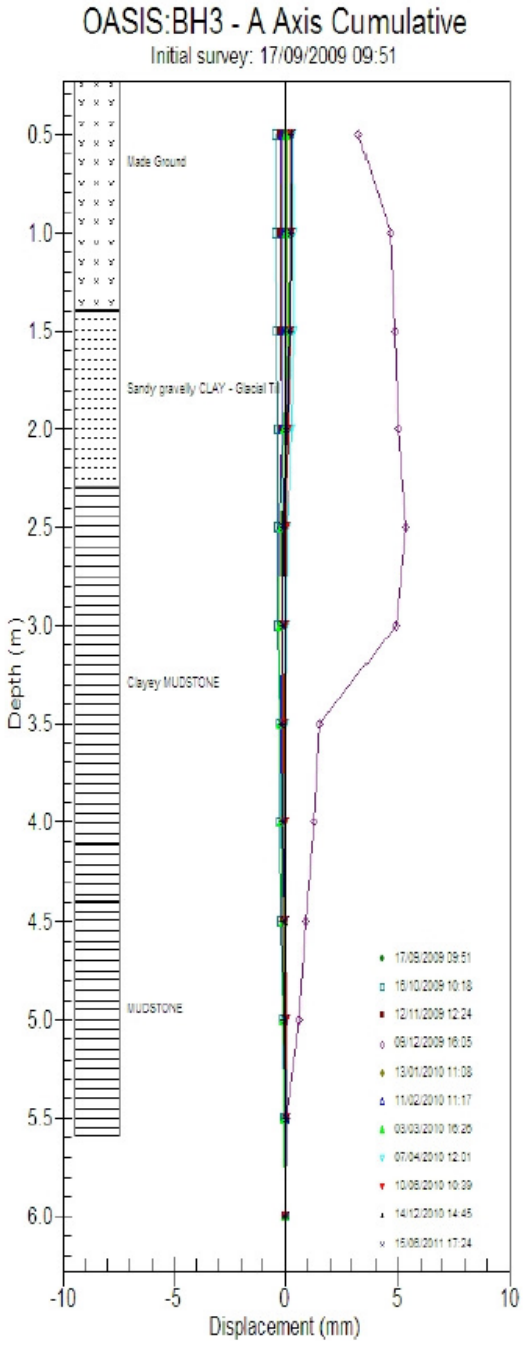
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scalby Ness
INSTALLATION: I2
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

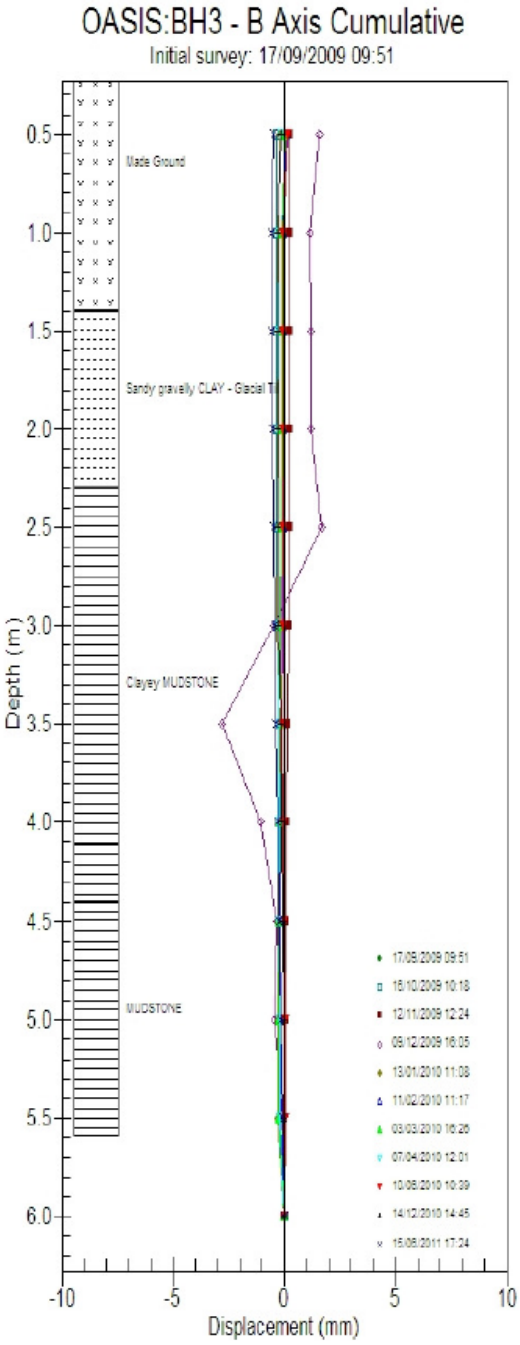
NOTE: A0 direction: North East



PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scalby Ness
INSTALLATION: I3
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

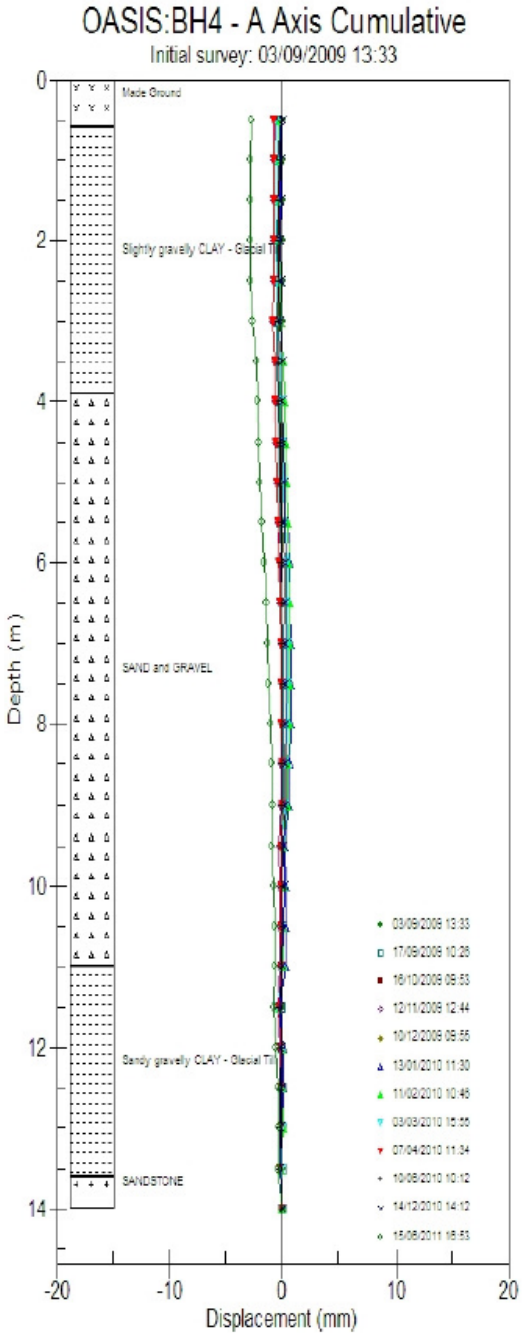
NOTE: A0 direction: East

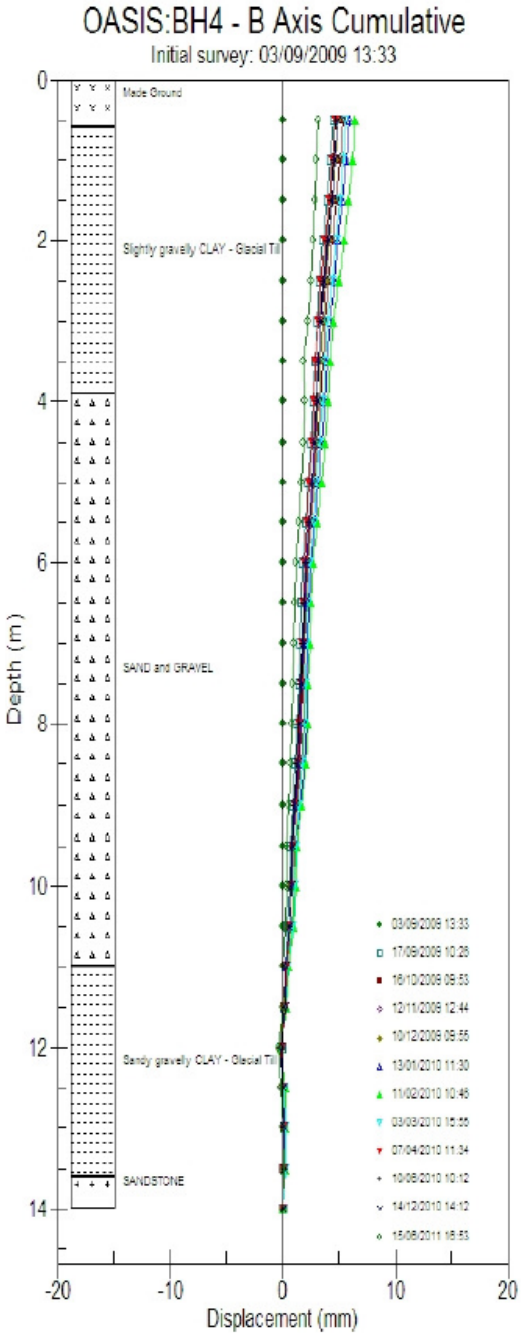




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Oasis North Bay
INSTALLATION: BH3
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

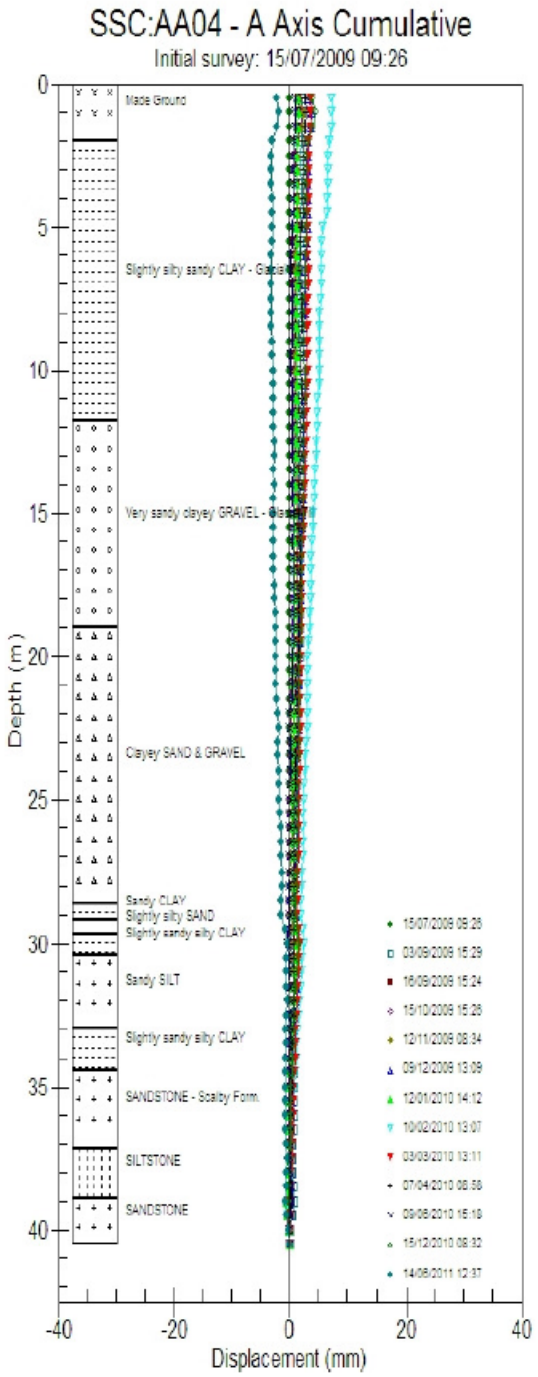
NOTE: A0 direction: East

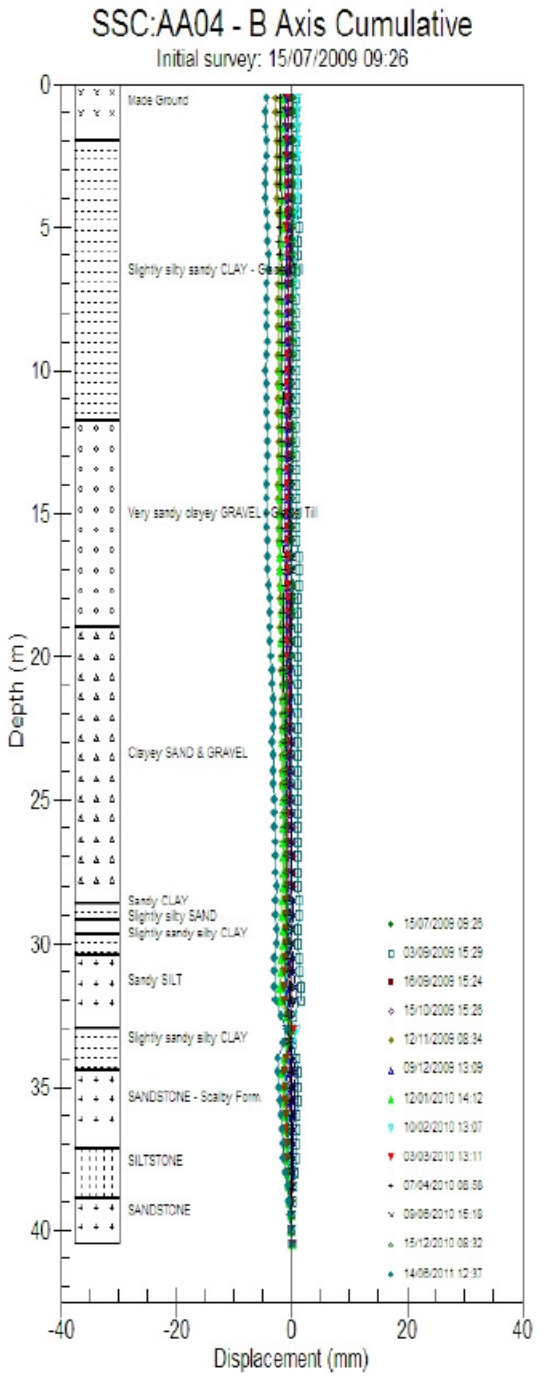




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Oasis North Bay
INSTALLATION: BH4
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

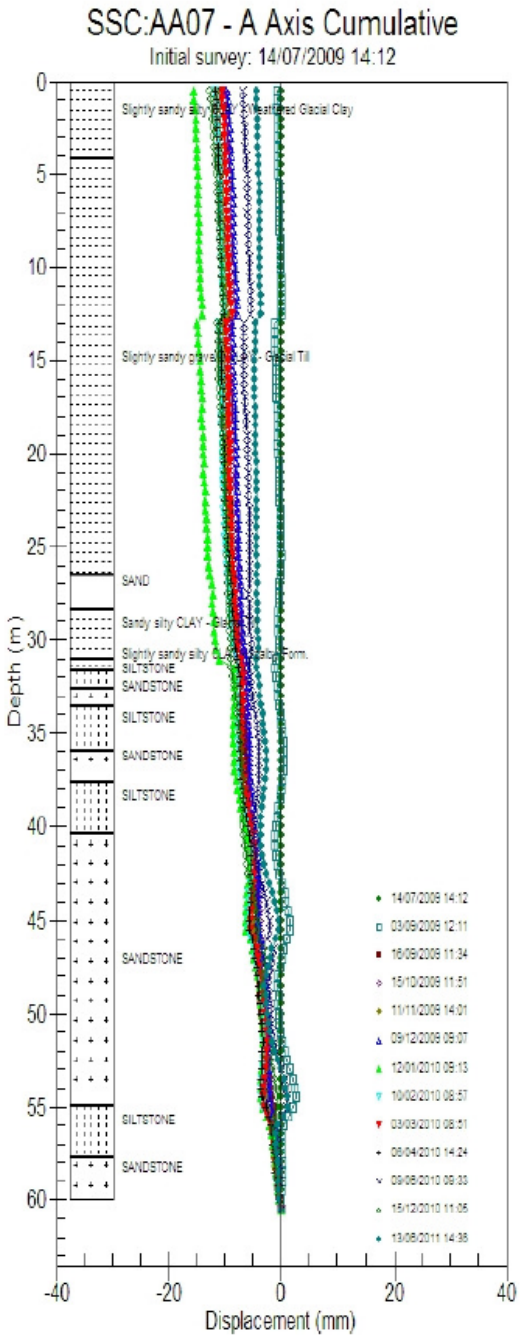
NOTE: A0 direction: East

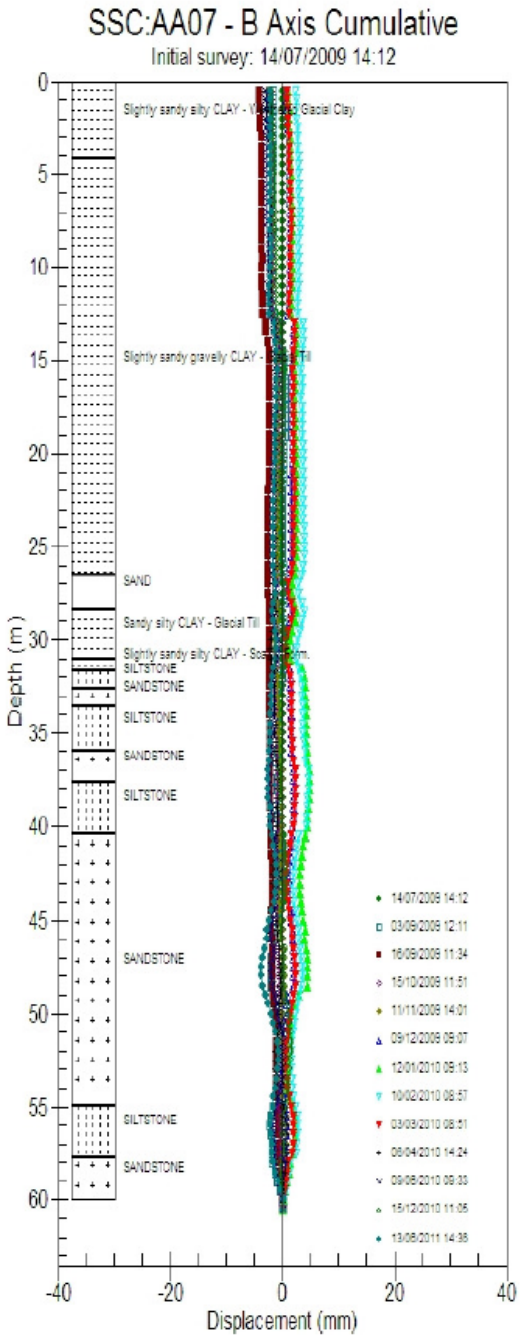




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scarborough South Cliff
INSTALLATION: AA04 (G2)
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

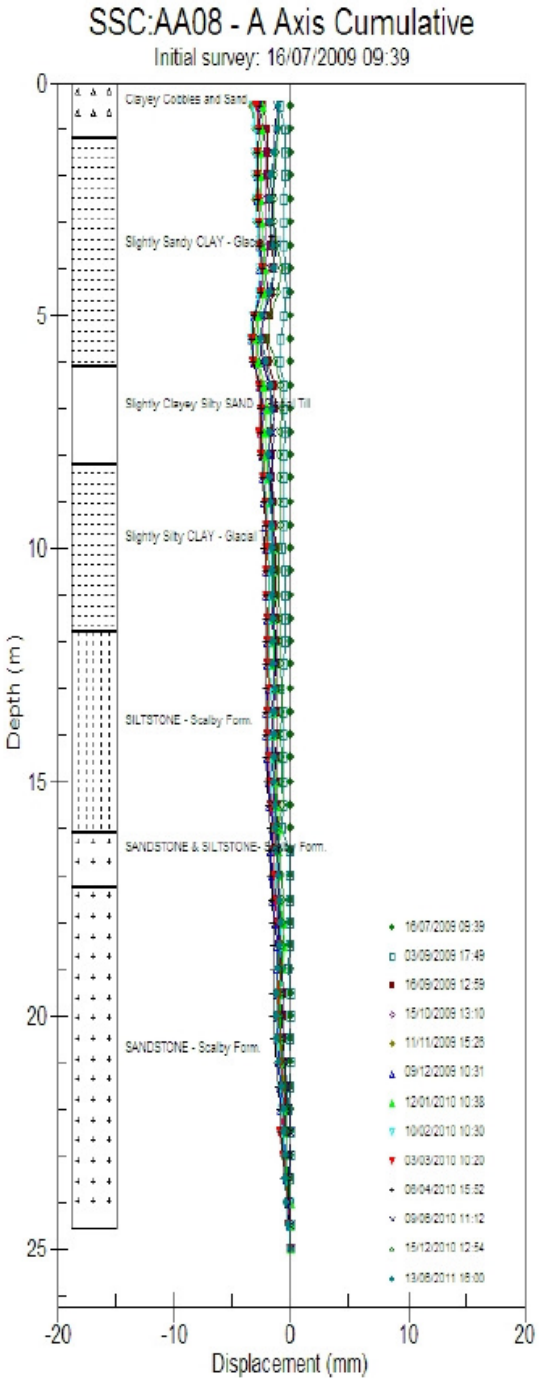
NOTE: A0 direction: North East

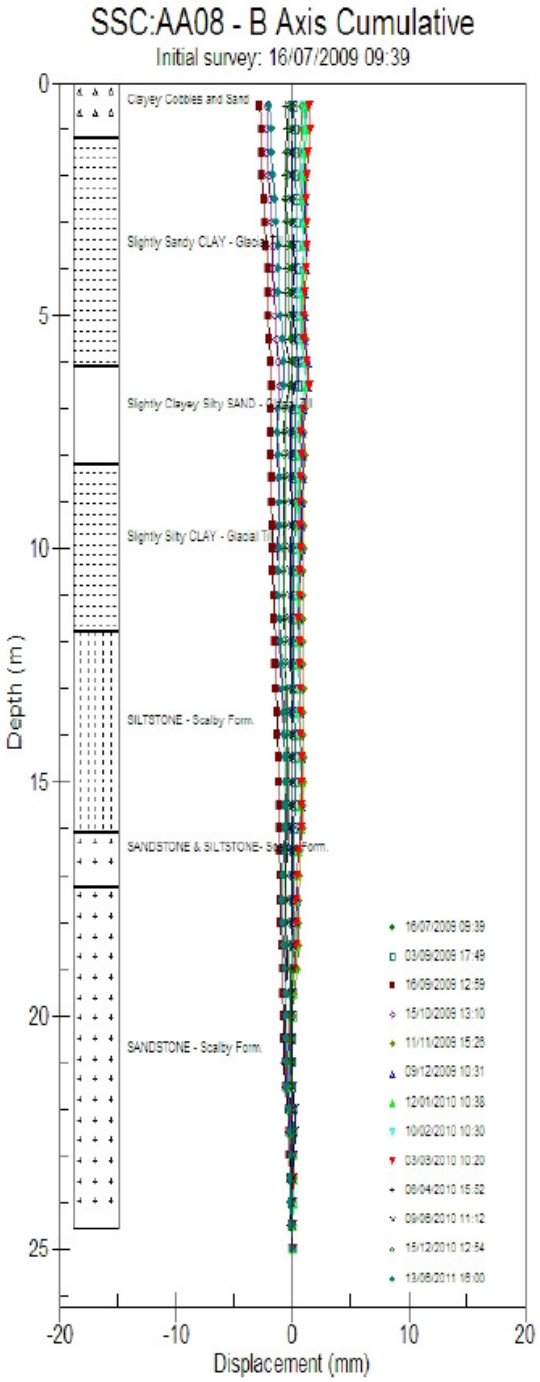




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scarborough South Cliff
INSTALLATION: AA07 (BH2)
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

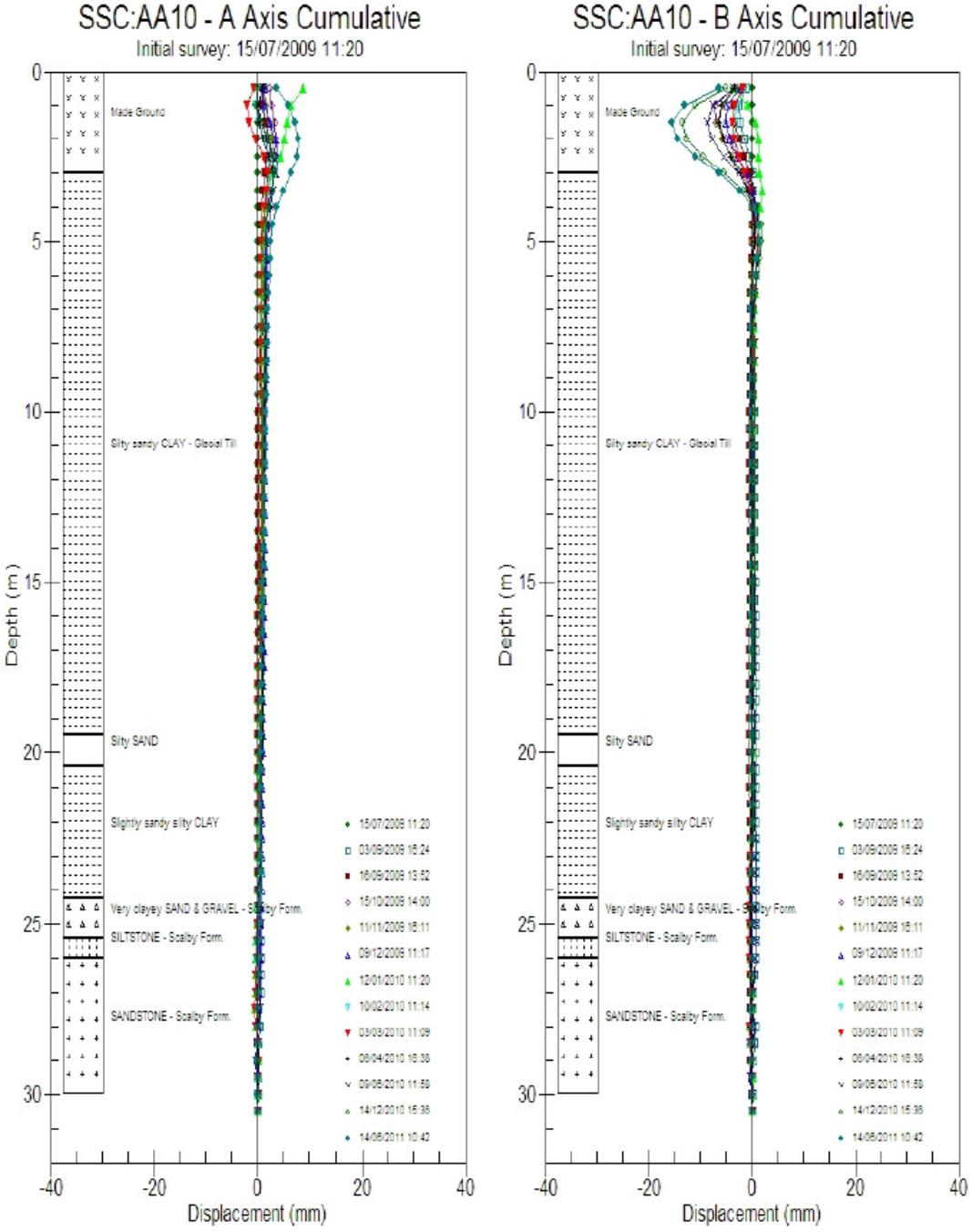
NOTE: A0 direction: North East





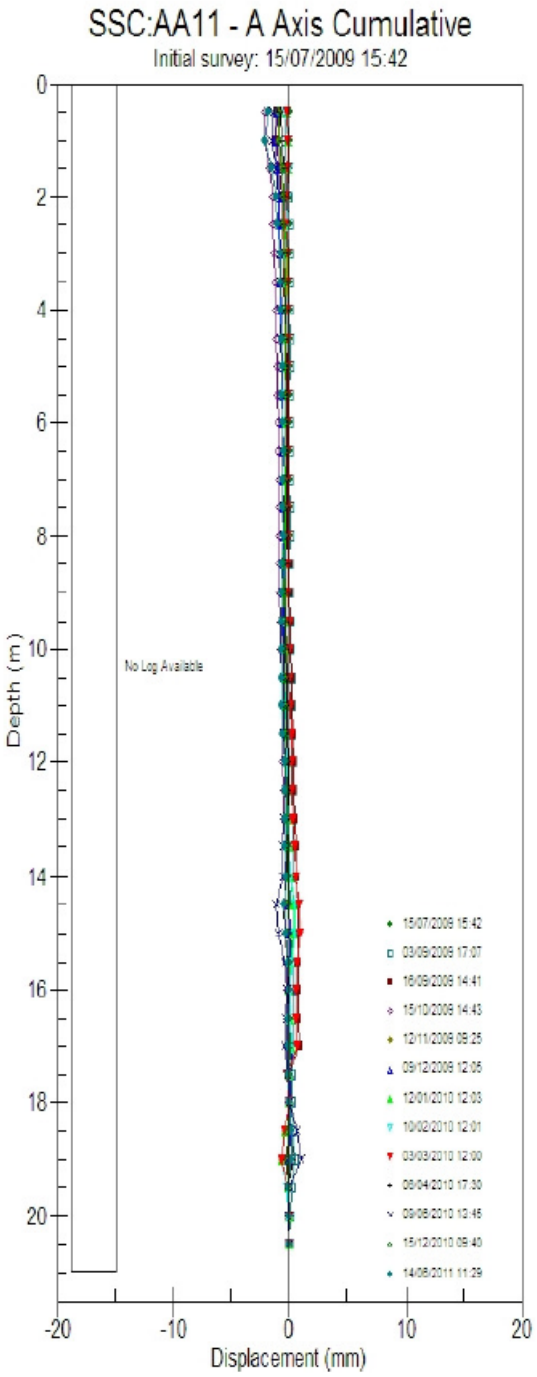
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scarborough South Cliff
INSTALLATION: AA08 (D3)
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

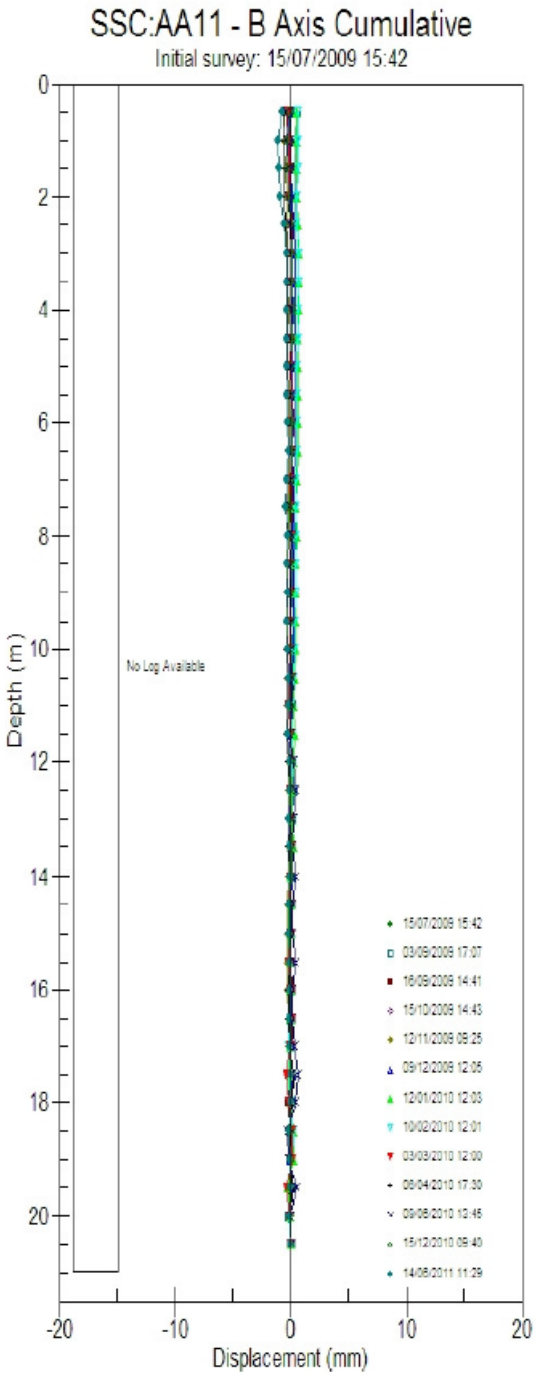
NOTE: A0 direction: East



PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scarborough South Cliff
INSTALLATION: AA10 (F2)
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

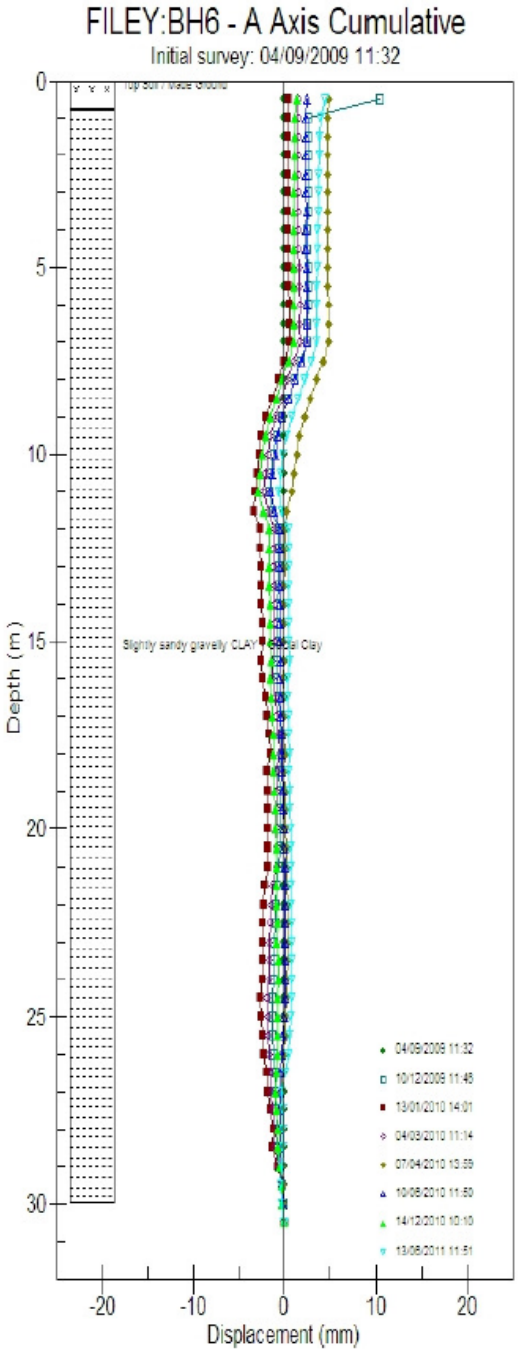
NOTE: A0 direction: North East

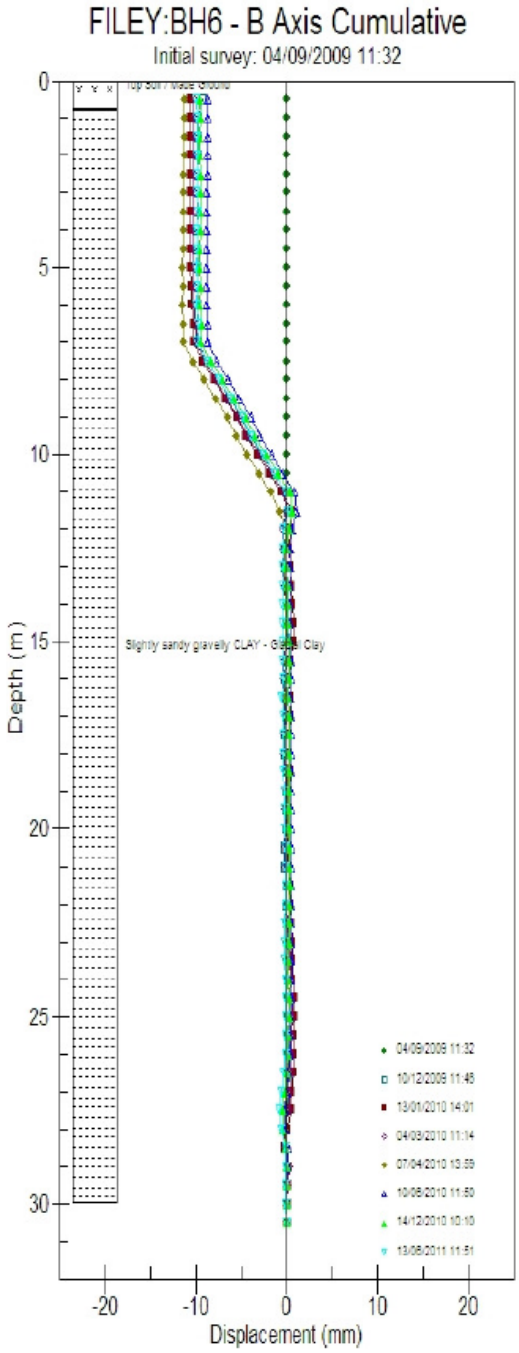




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scarborough South Cliff
INSTALLATION: AA11 (F4)
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

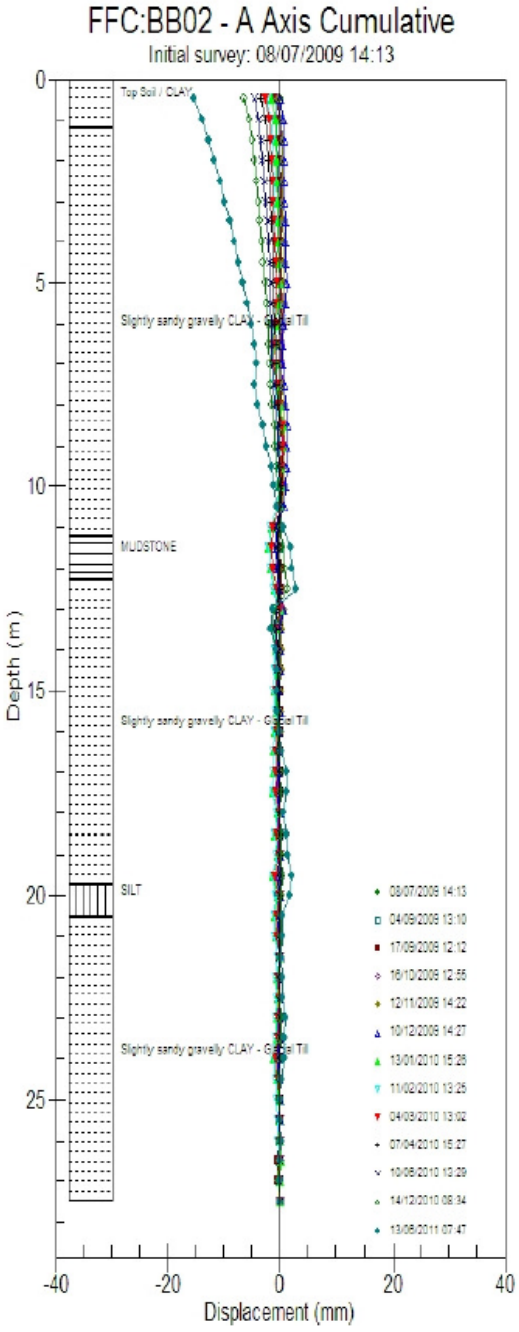
NOTE: A0 direction: North East

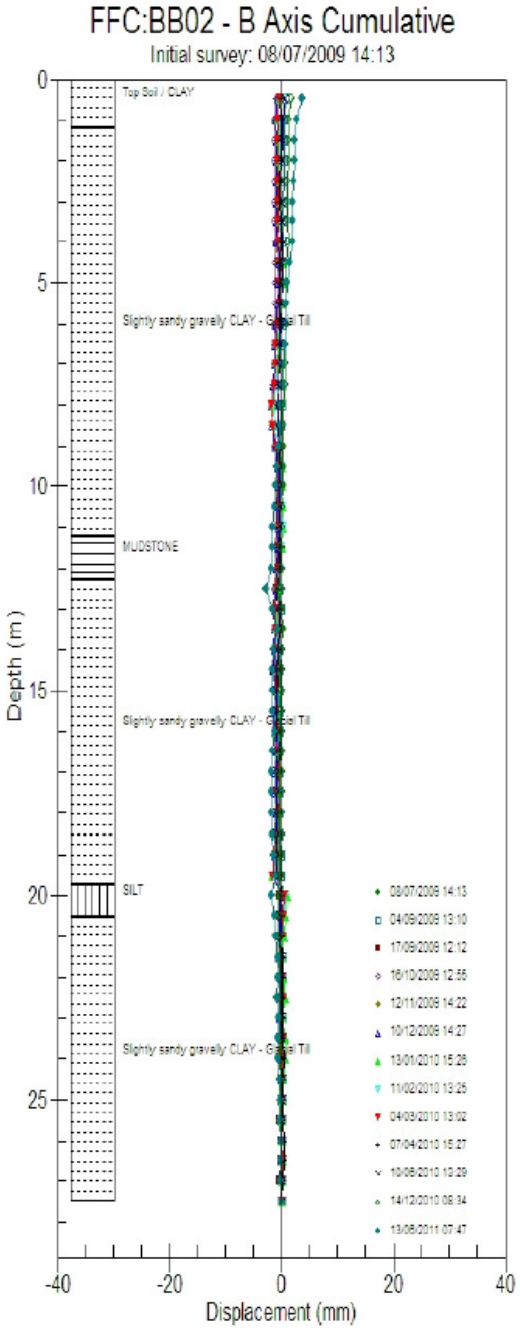




PROJECT: Ongoing Analysis of Coastal Monitoring Data
SITE: Filey Town
INSTALLATION: BH6
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

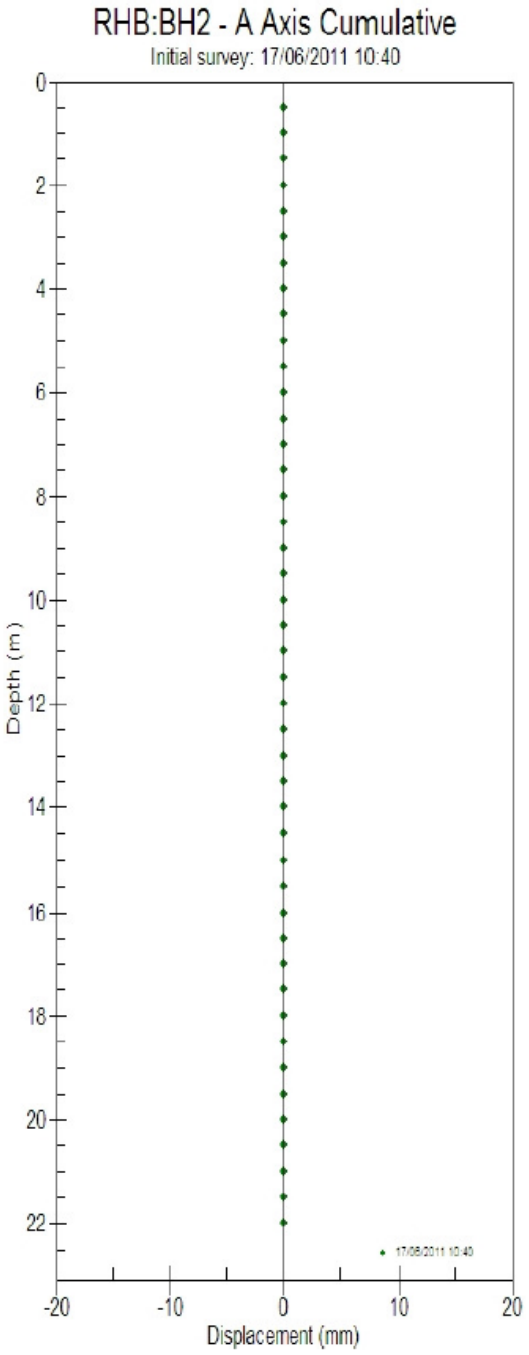
NOTE: A0 direction: North East

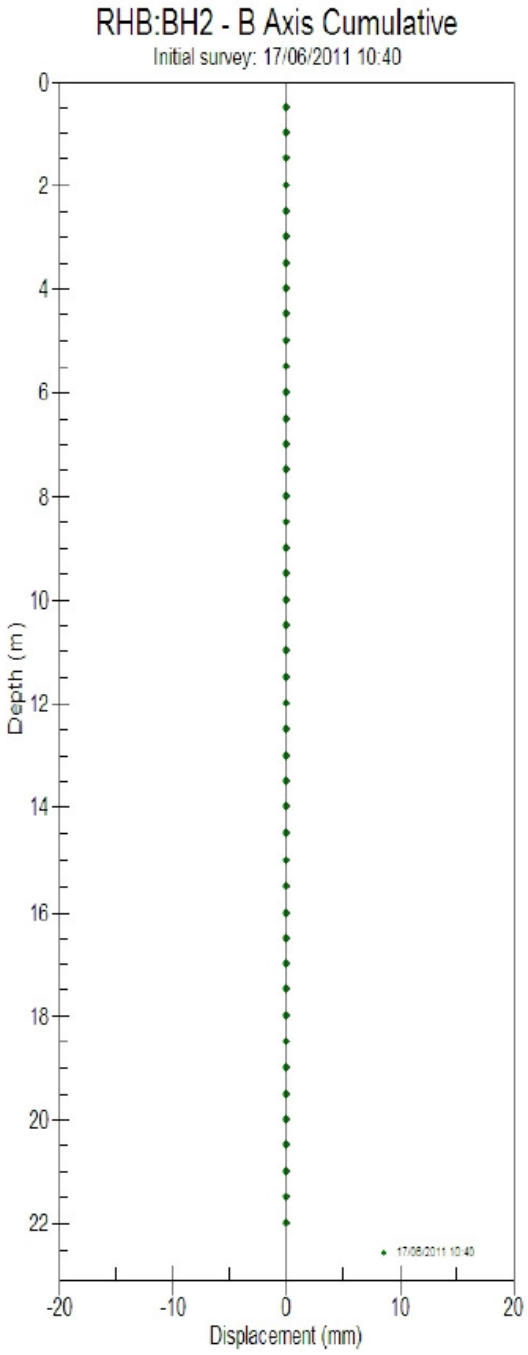




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Filey Flat Cliffs
INSTALLATION: BB02
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

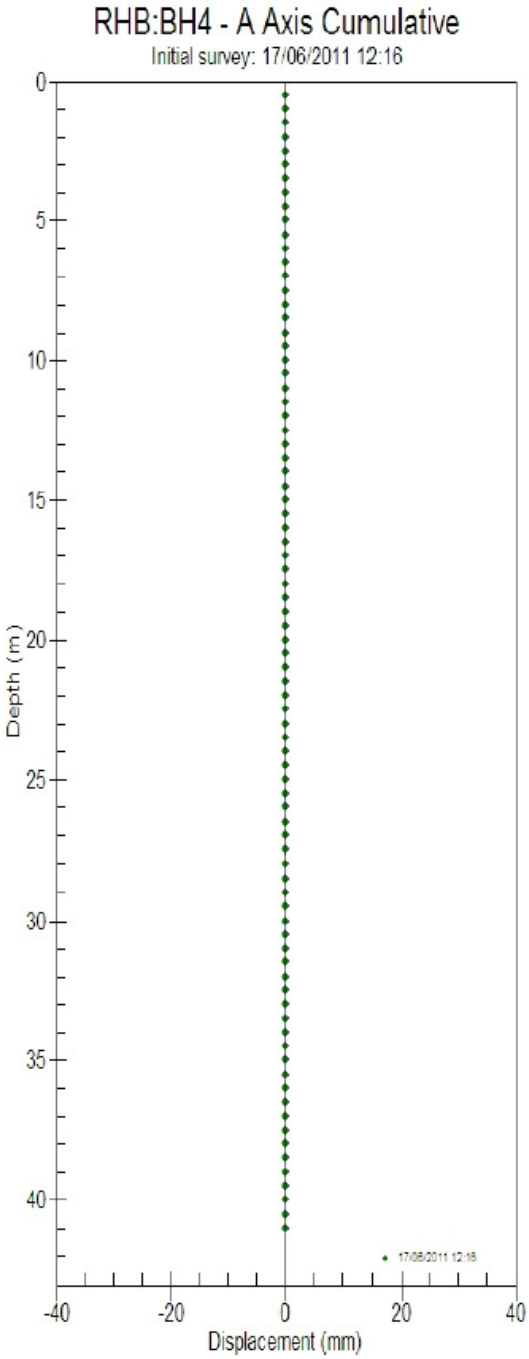
NOTE: A0 direction: East

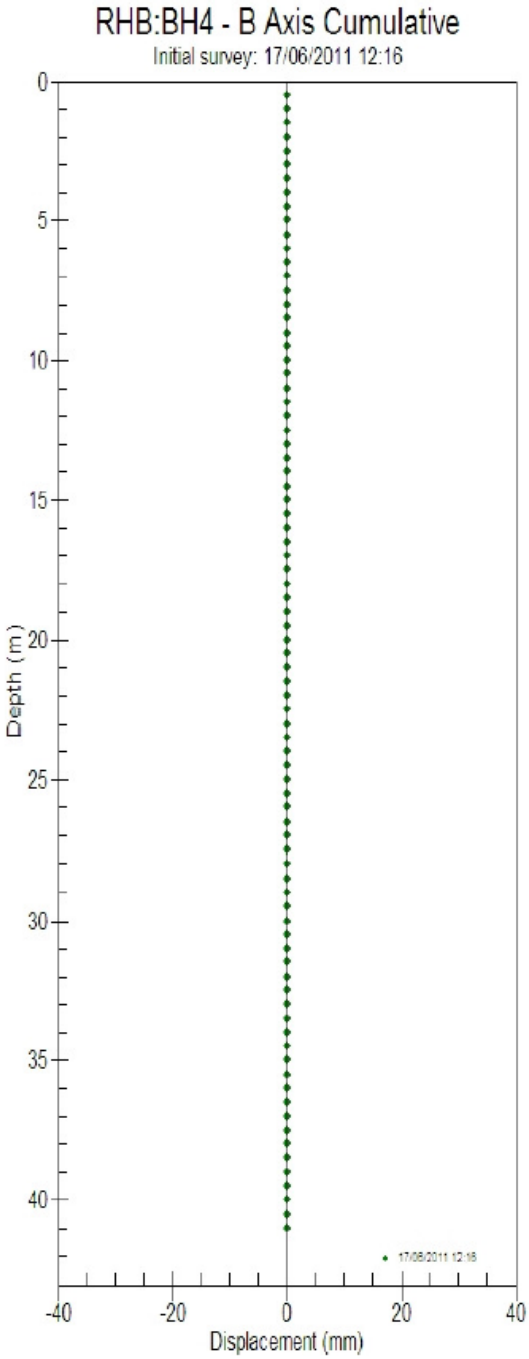




PROJECT:
SITE: RHB
INSTALLATION: BH2
COMPANY:
CLIENT:

NOTE:

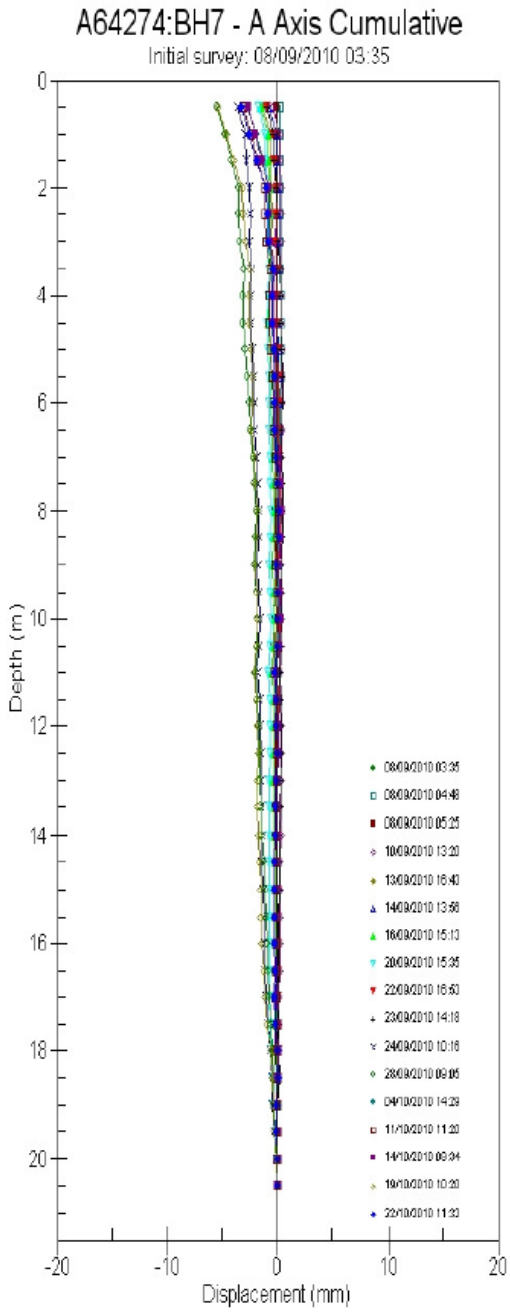


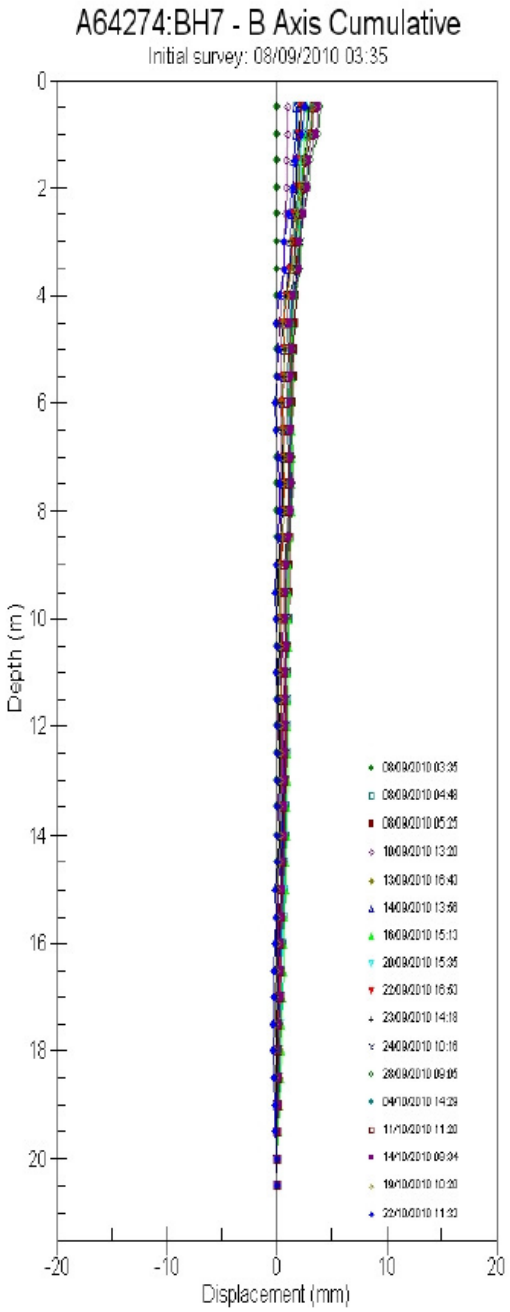


PROJECT:
SITE: RHB
INSTALLATION: BH4
COMPANY:
CLIENT:

NOTE:

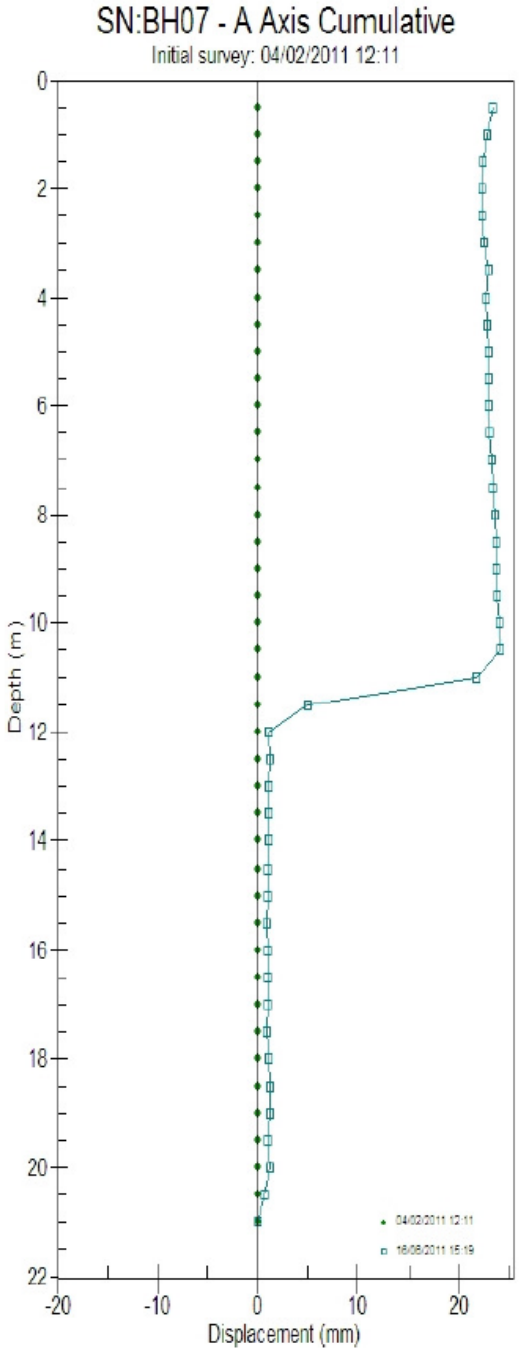
Appendix D Replacement Installation Inclinometer Graphs

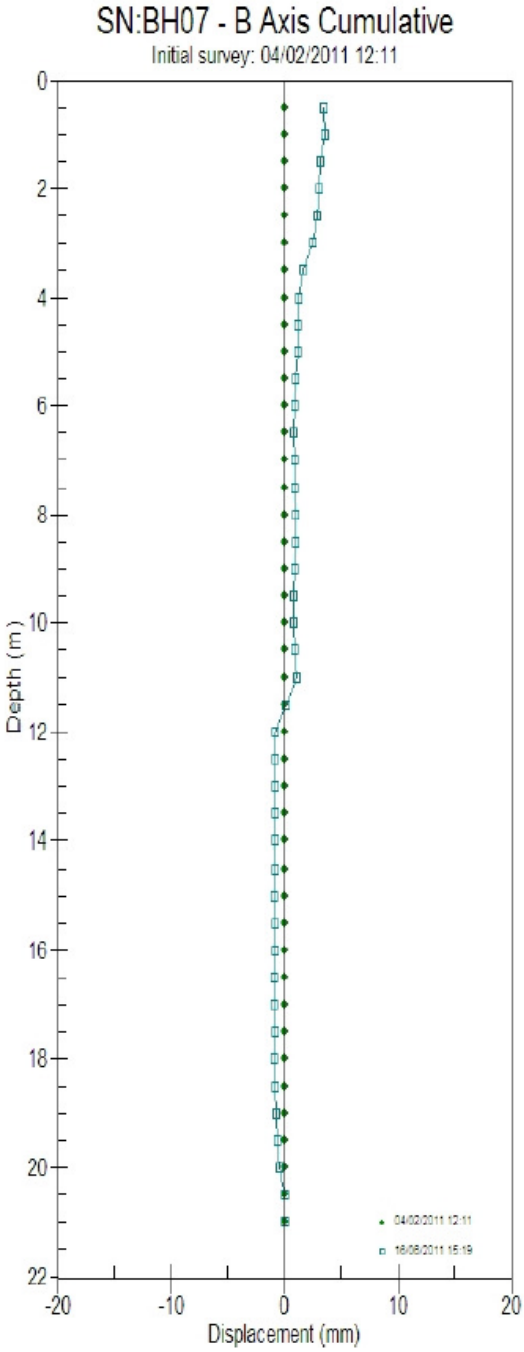




PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME
SITE: A64274
INSTALLATION: BH7
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

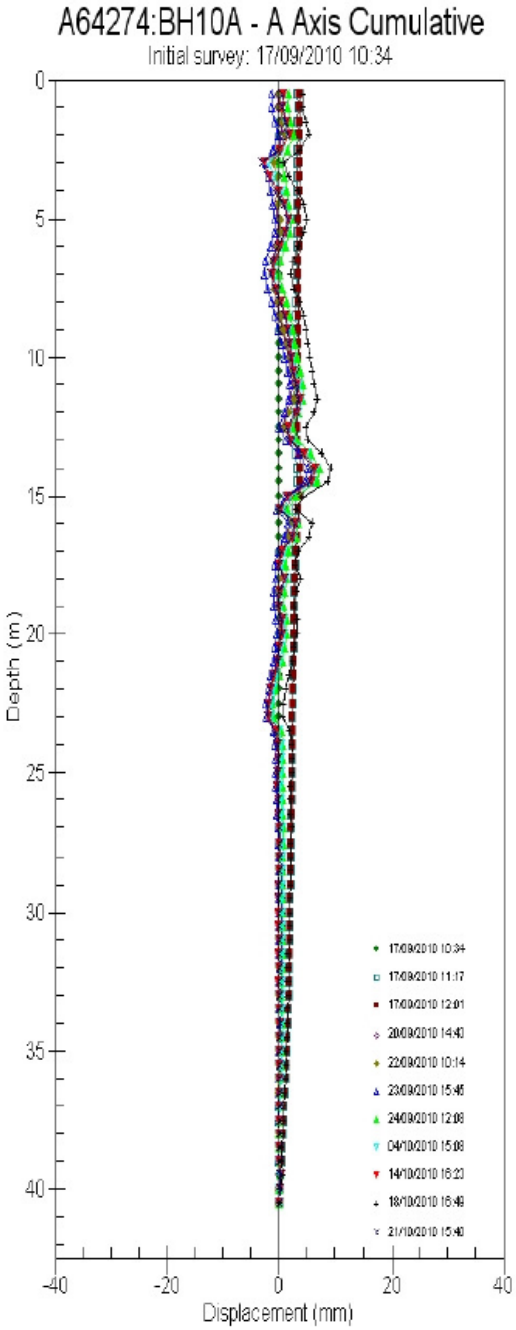
NOTE:

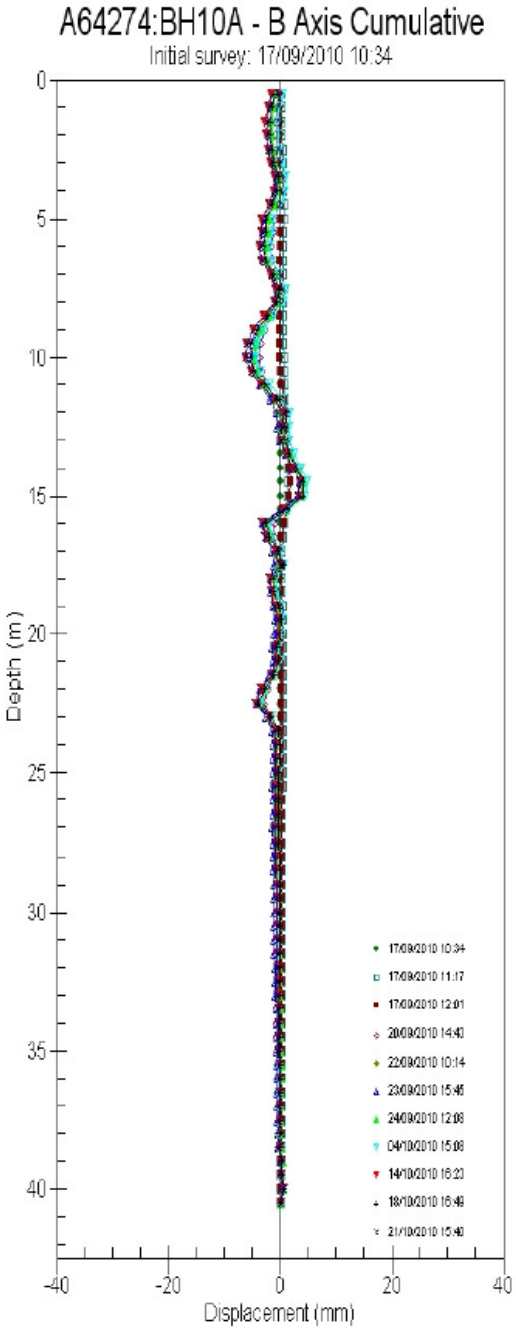




PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data. Replacement Installations.
SITE: Scalby Ness
INSTALLATION: BH7
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

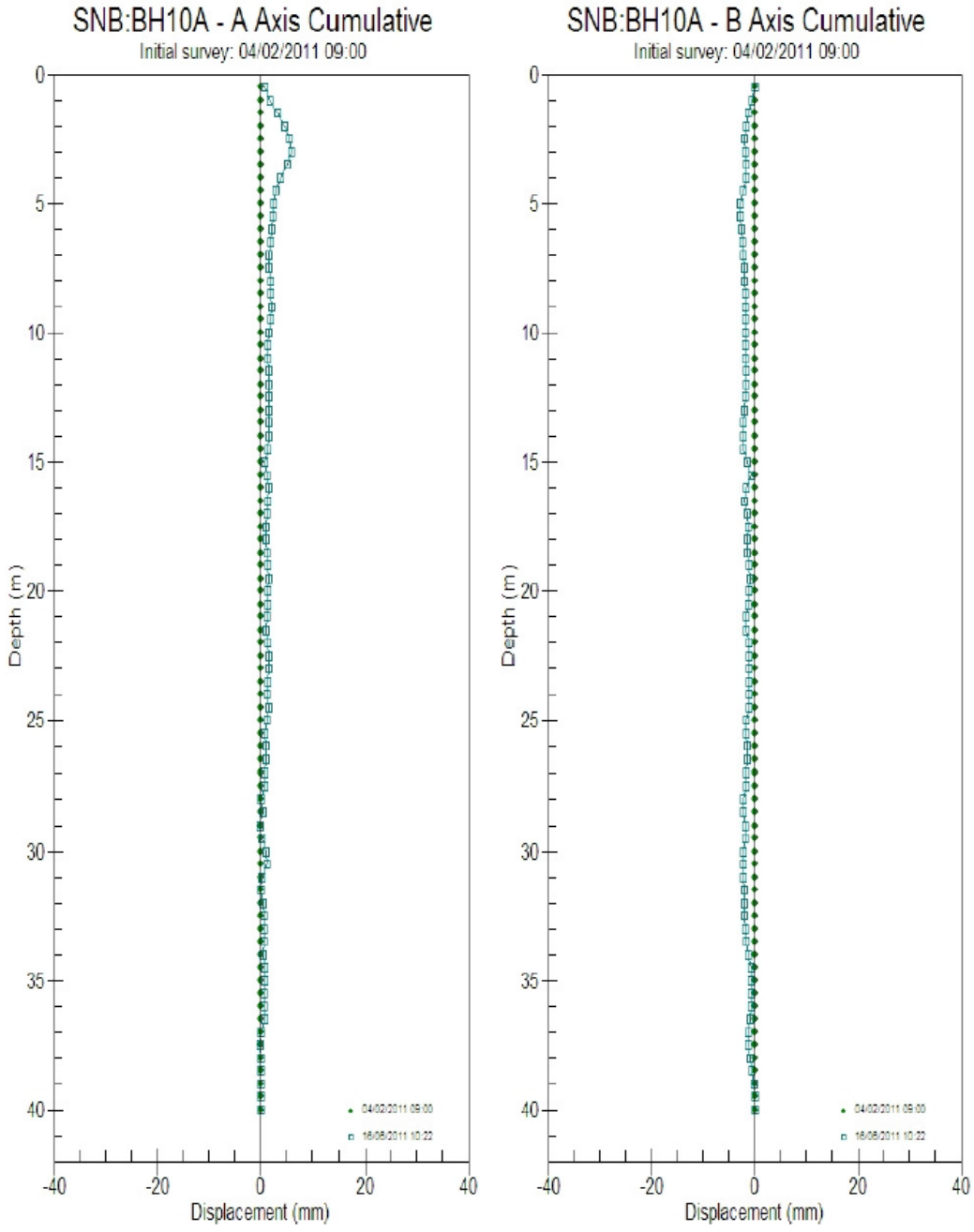
mouchel





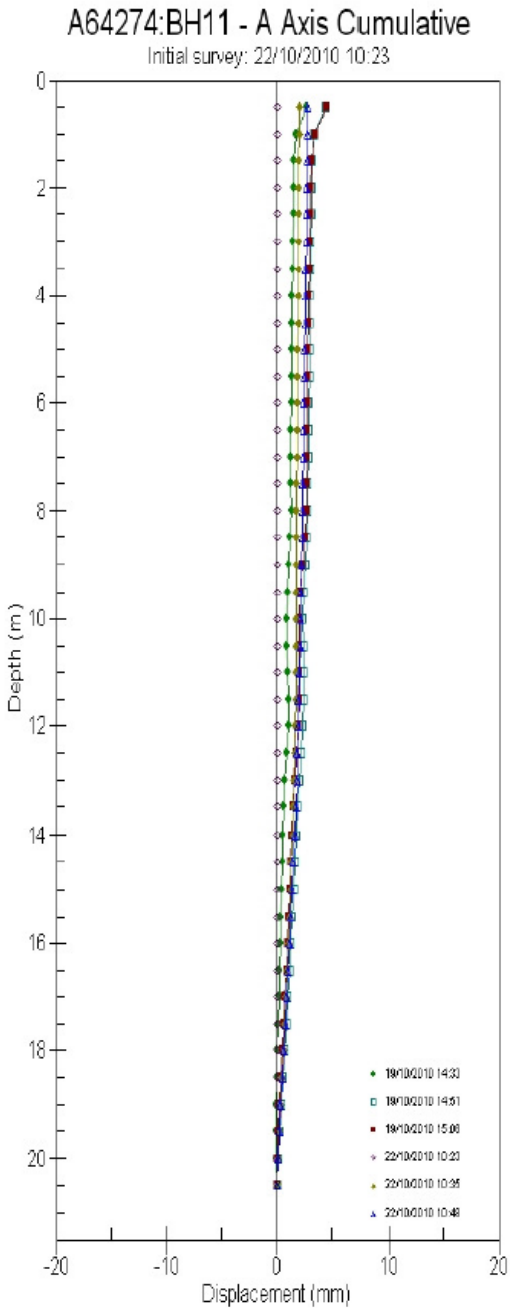
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT SCHEME
SITE: A64274
INSTALLATION: BH10A
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

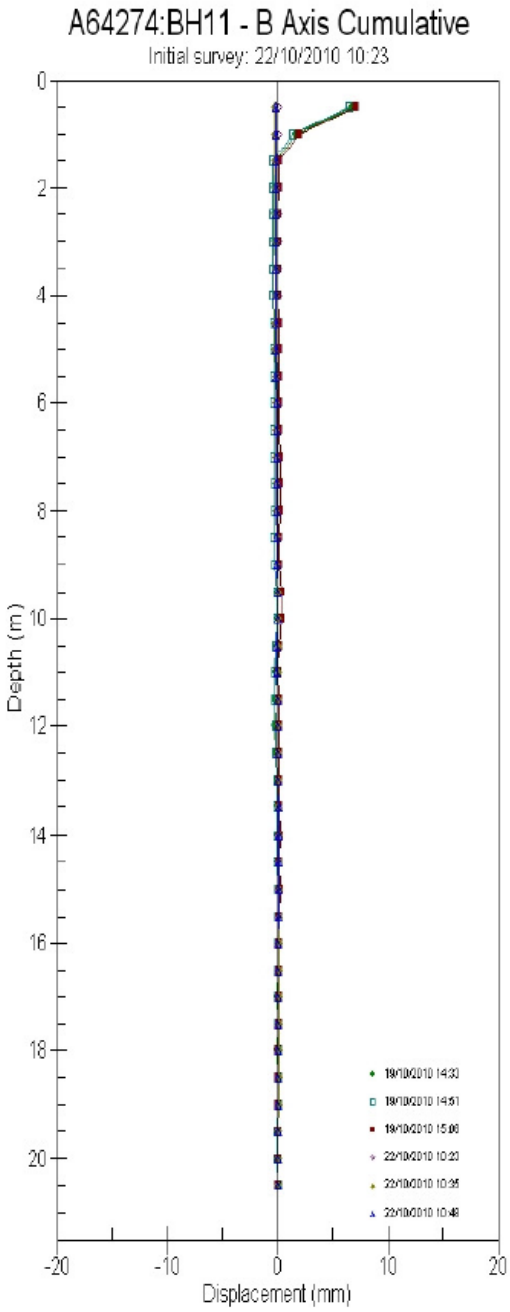
NOTE:



PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data. Replacement Installations.
SITE: The Holmes, Scarborough
INSTALLATION: BH10A
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: Northeast

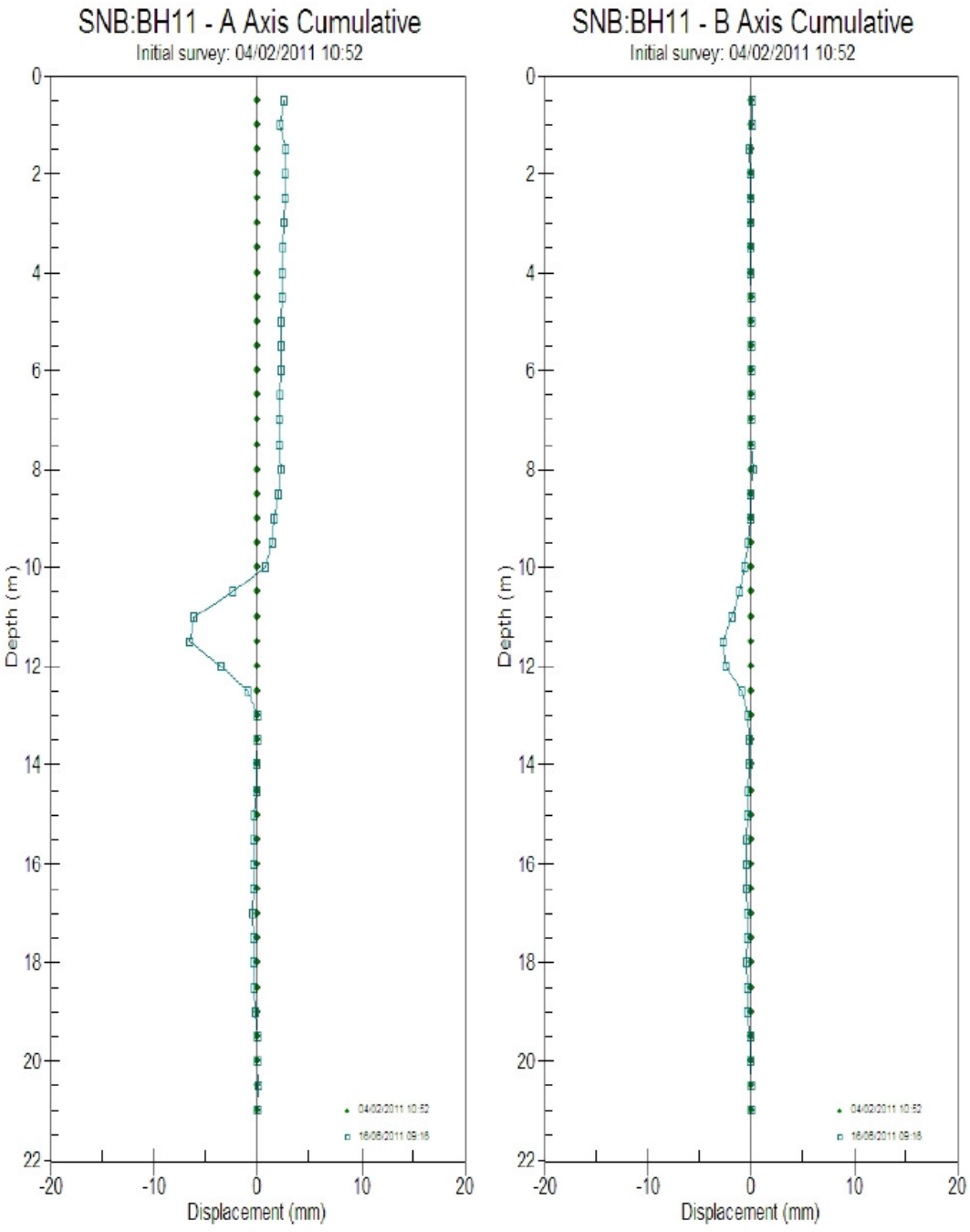
mouchel





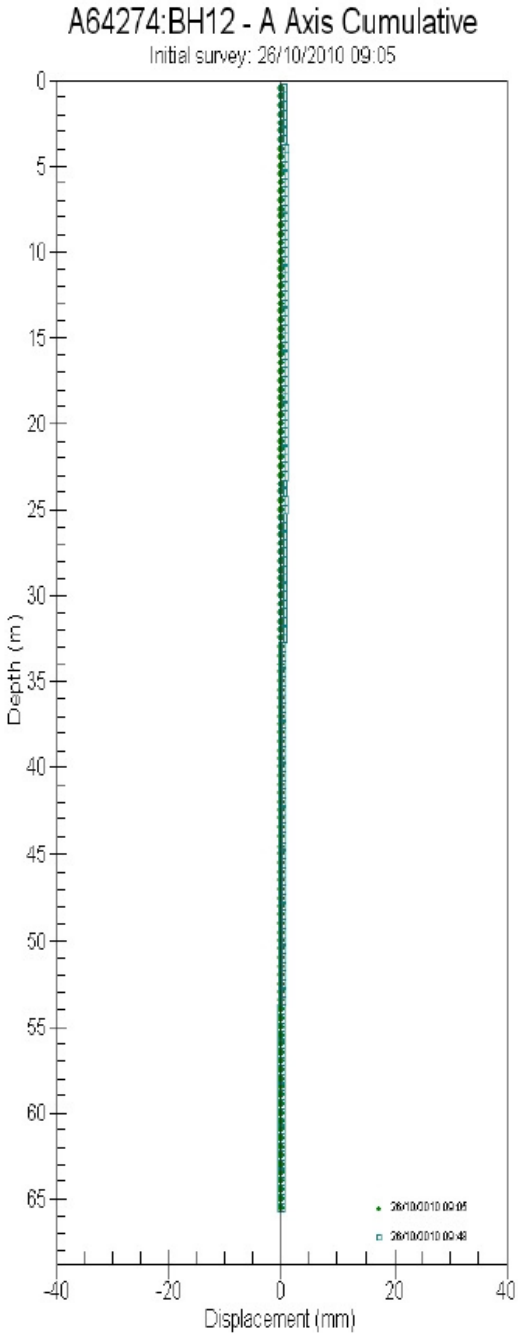
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT
SITE: A64274
INSTALLATION: BH11
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

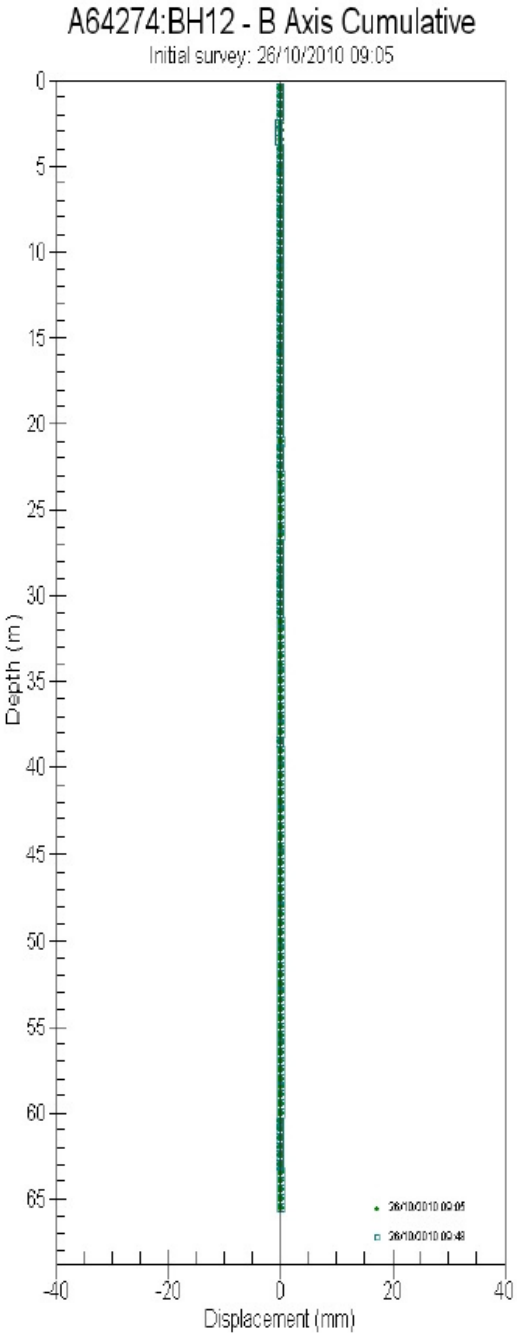
NOTE:



PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data. Replacement Installations.
SITE: The Holmes, Scarborough
INSTALLATION: BH11
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: North

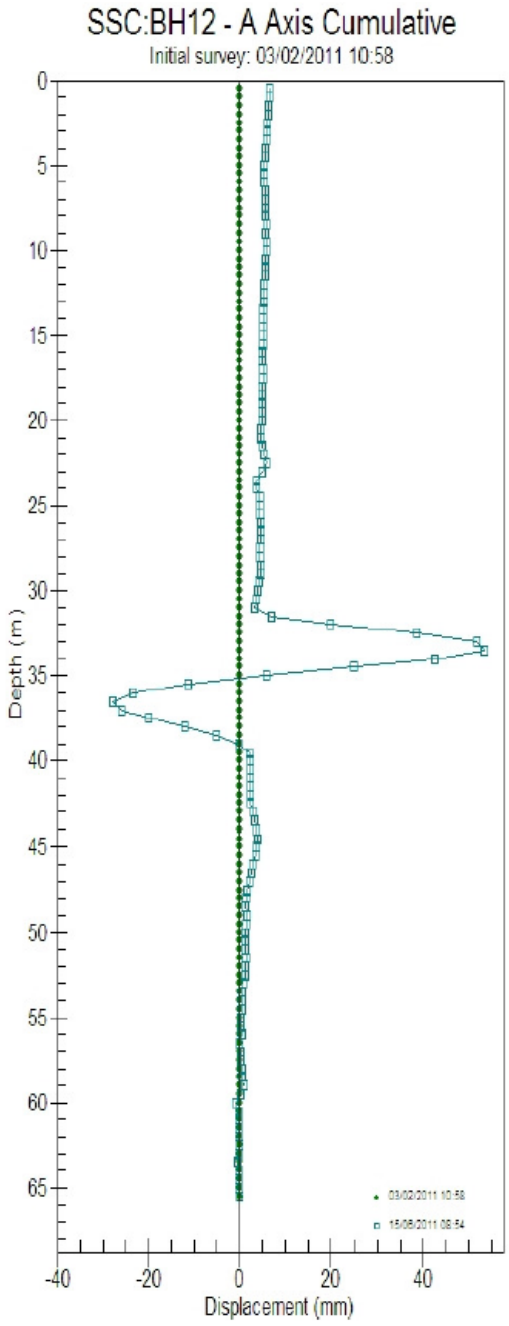
mouchel

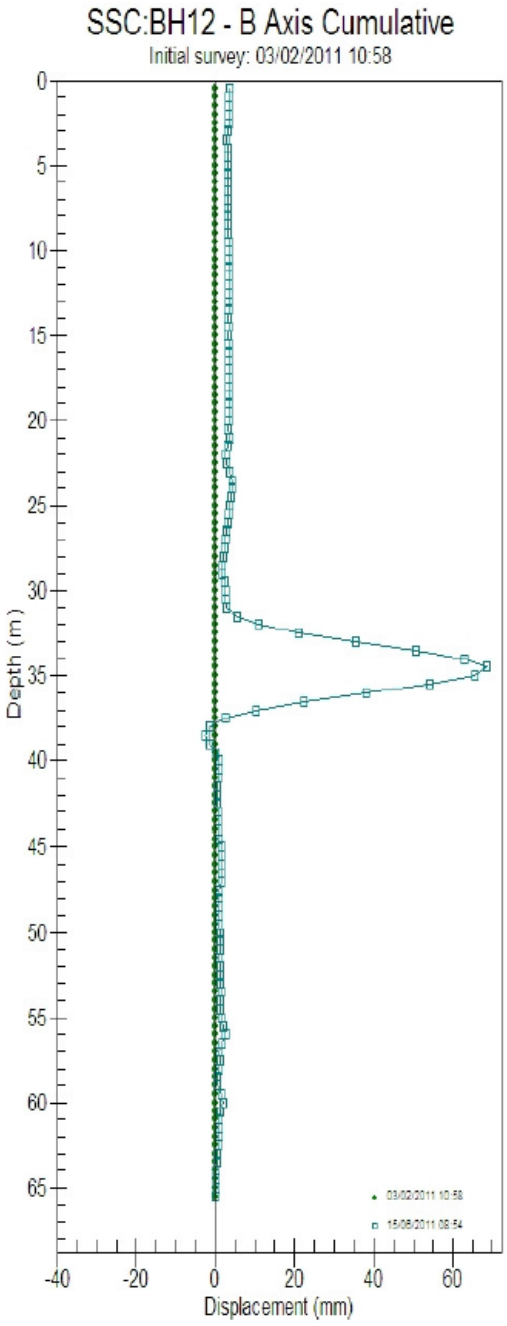




PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT
SITE: A64274
INSTALLATION: BH12
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

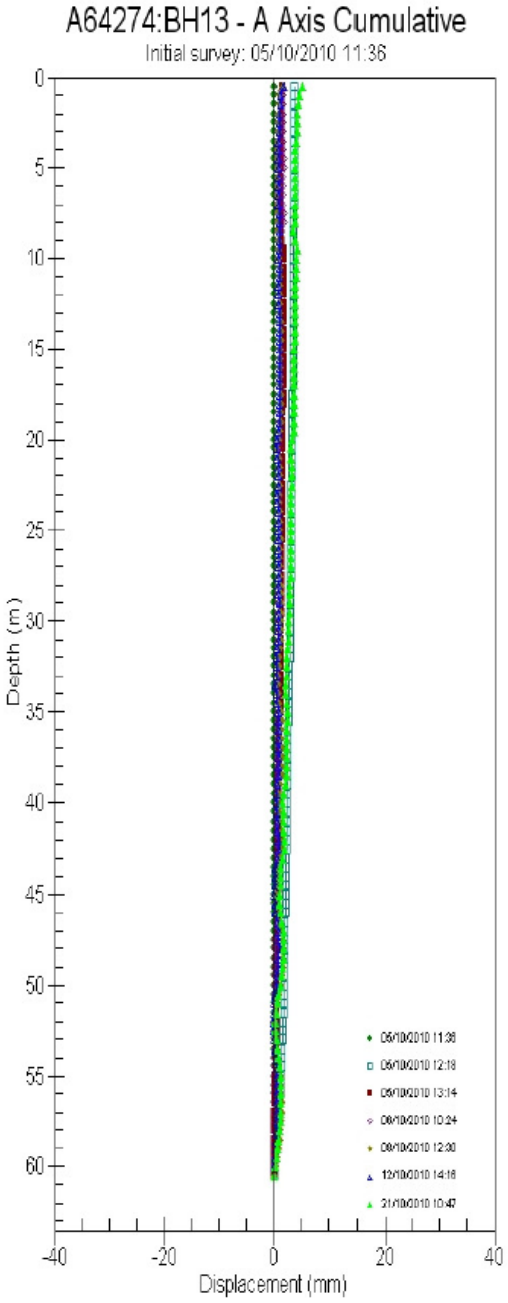
NOTE:

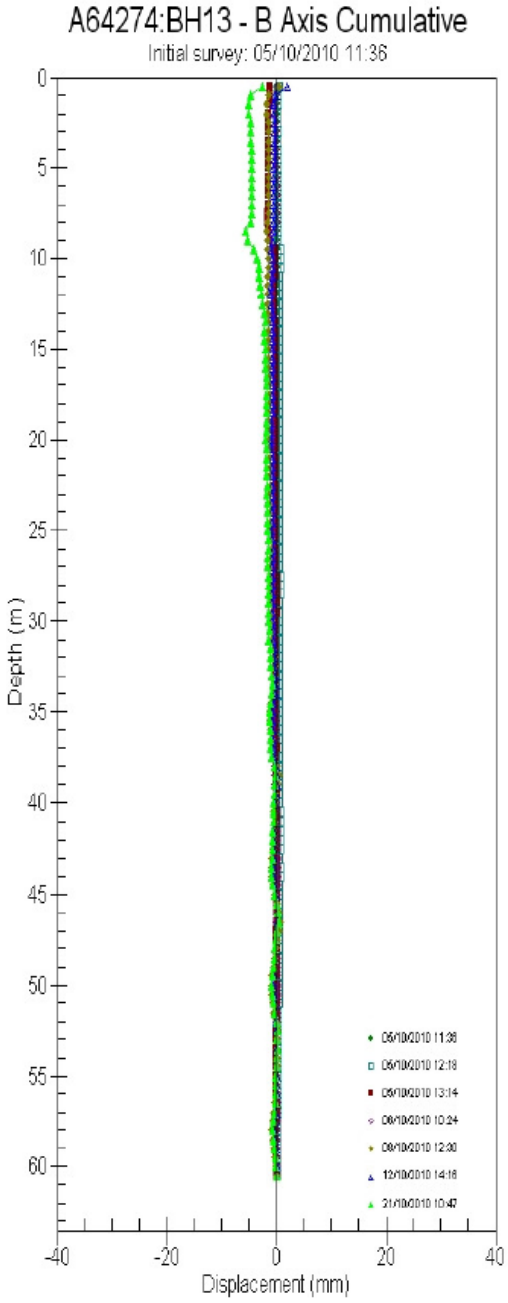




PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data.
Replacement Installations.
SITE: Scarborough South Cliff
INSTALLATION: BH12
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

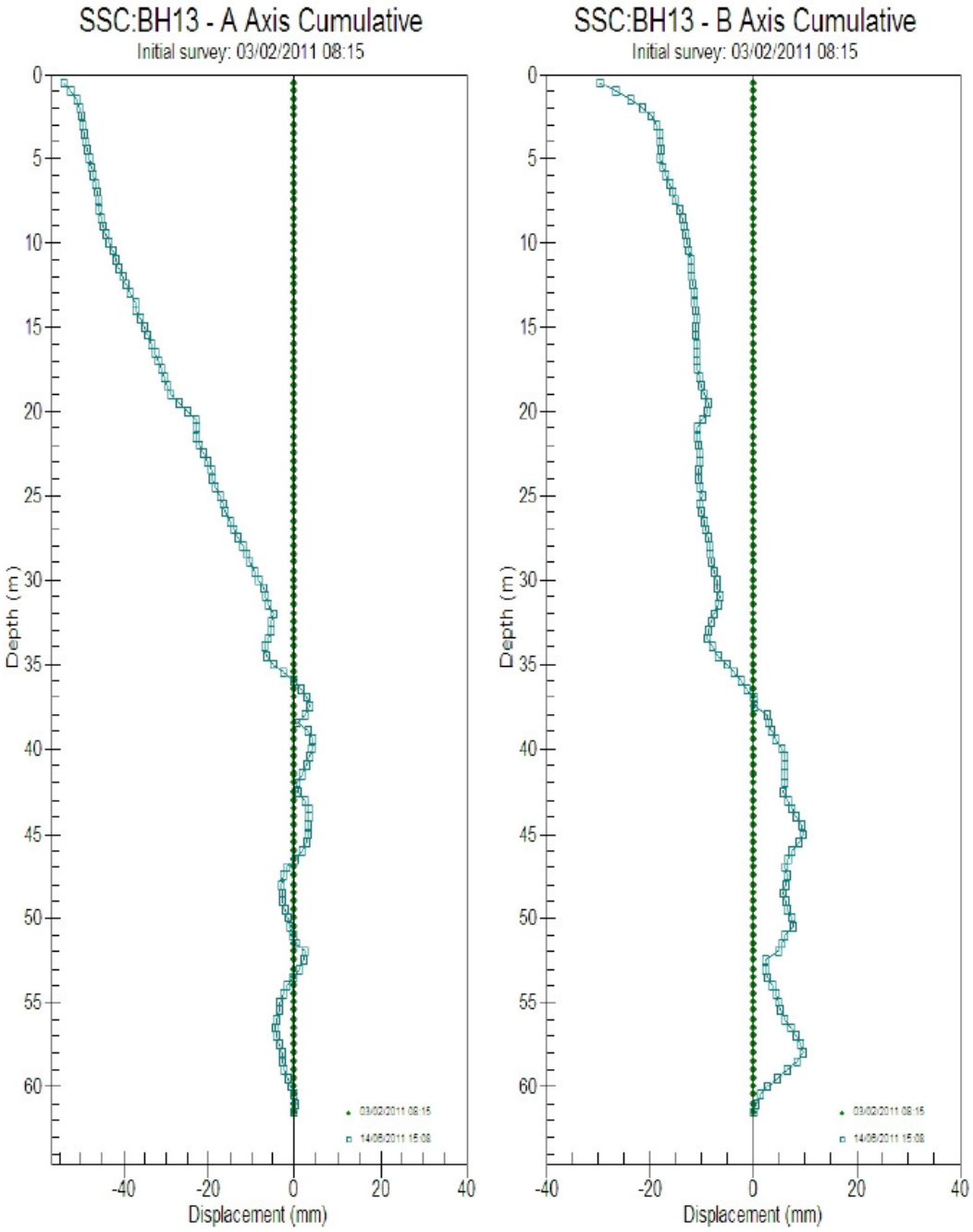
mouchel





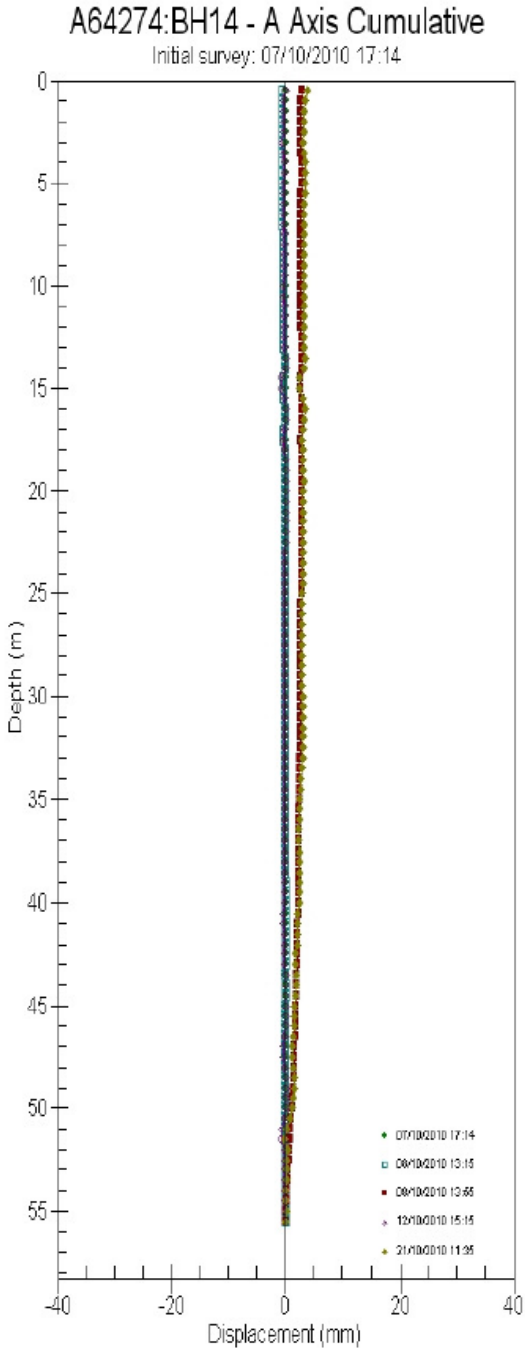
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME
SITE: A64274
INSTALLATION: BH13
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

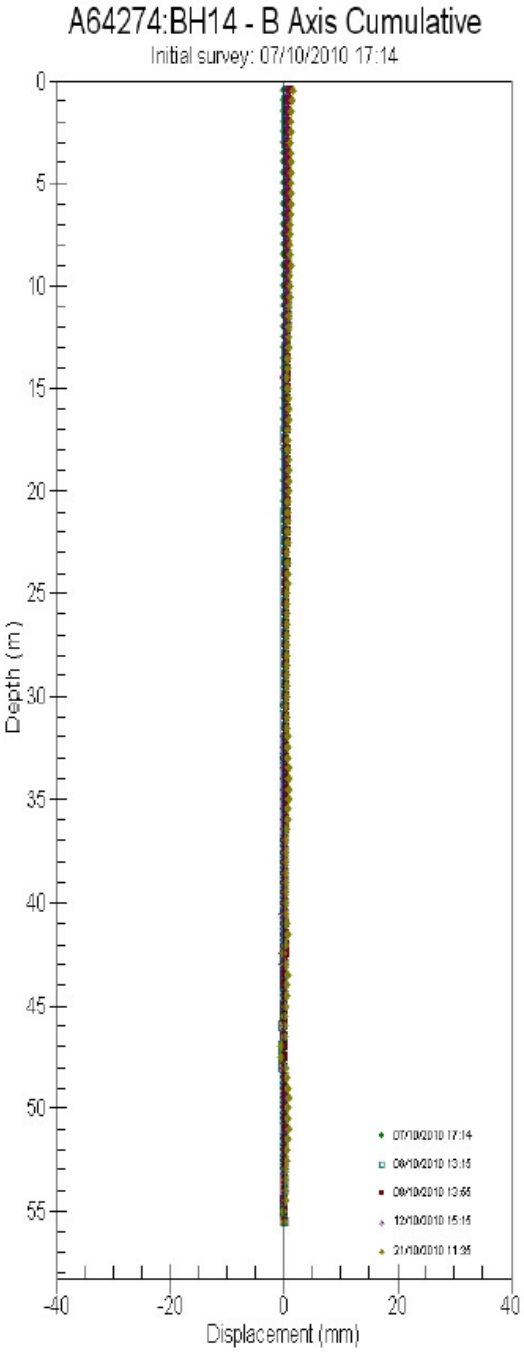
NOTE:



PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data.
Replacement Installations.
SITE: Scarborough South Cliff
INSTALLATION: BH13
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

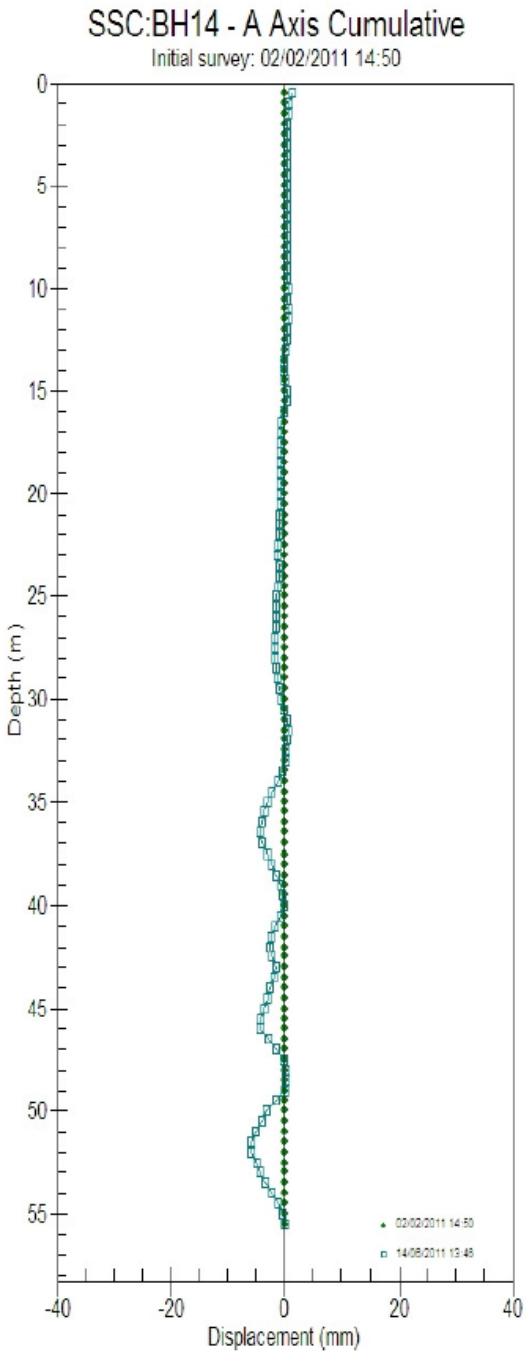
mouchel

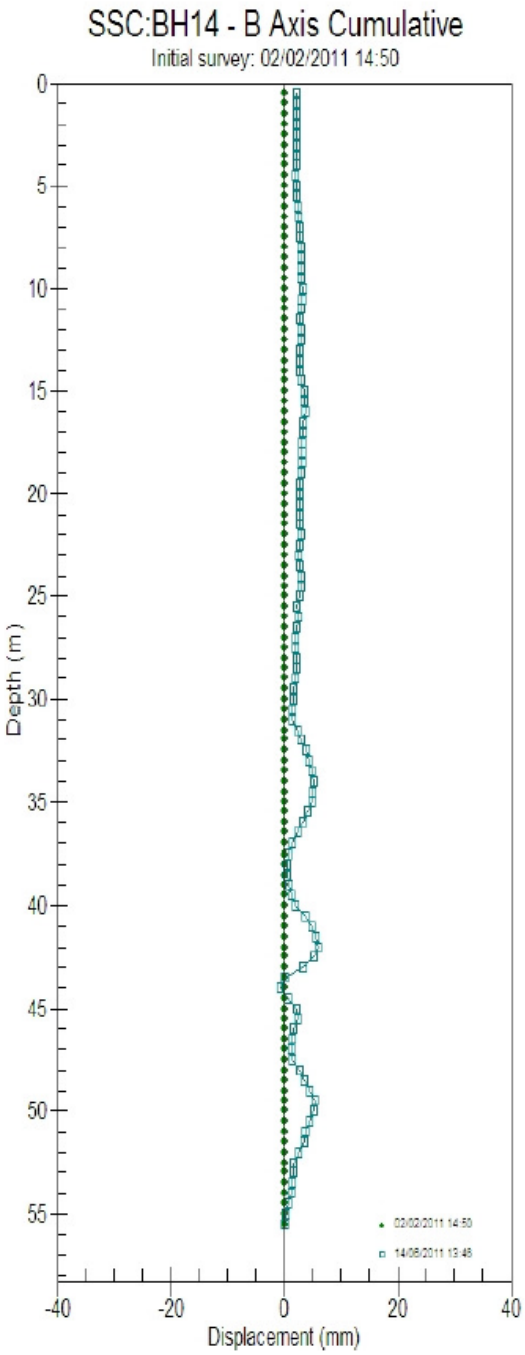




PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME
SITE: A64274
INSTALLATION: BH14
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

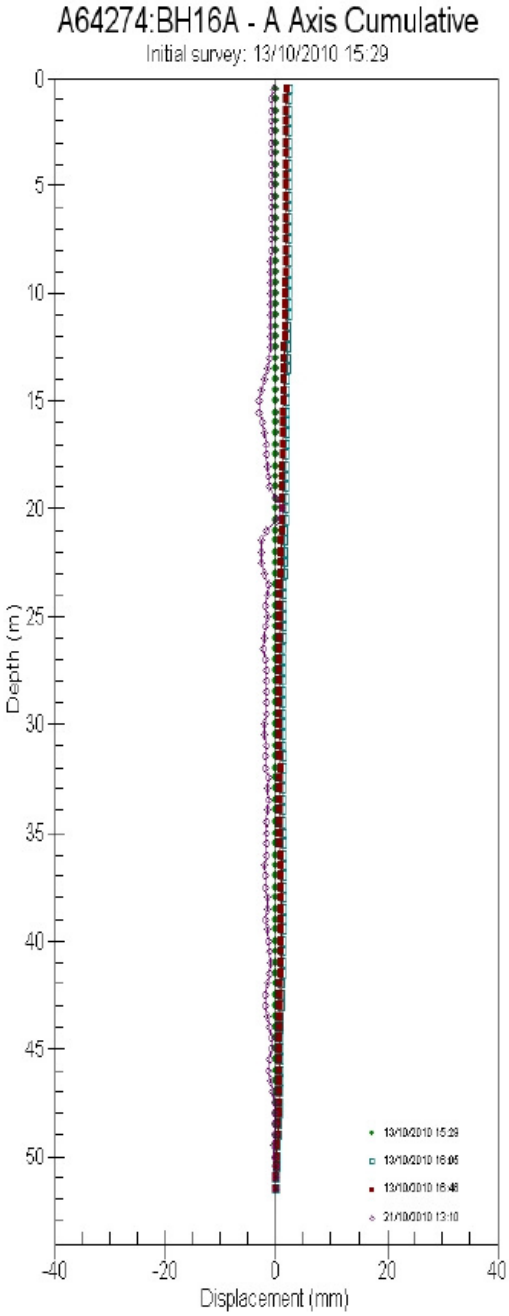
NOTE:

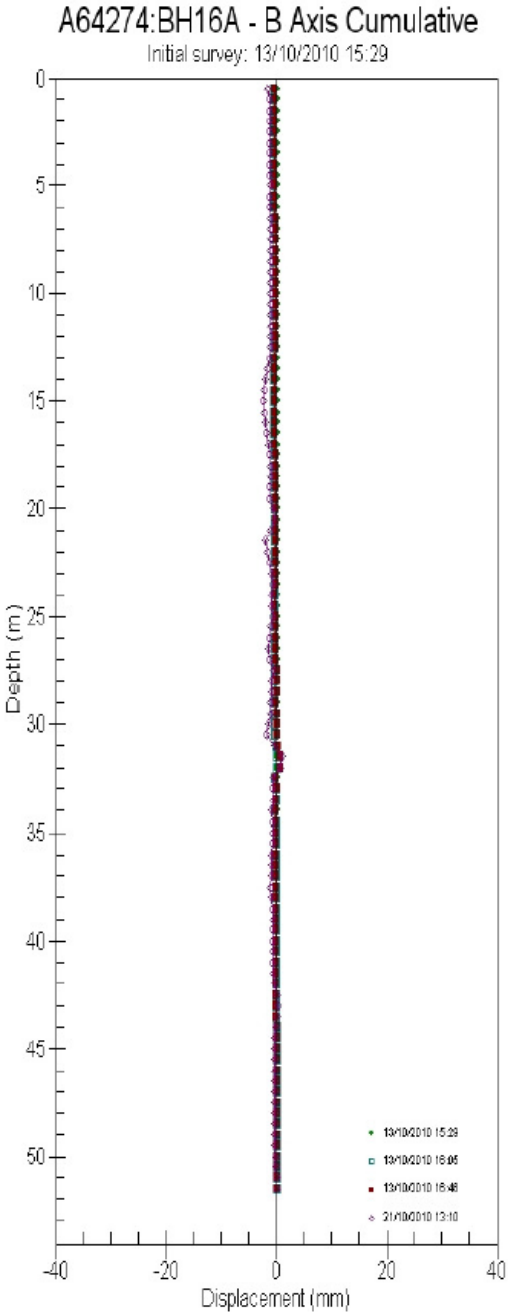




PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data. Replacement Installations.
SITE: Scarborough South Cliff
INSTALLATION: BH14
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

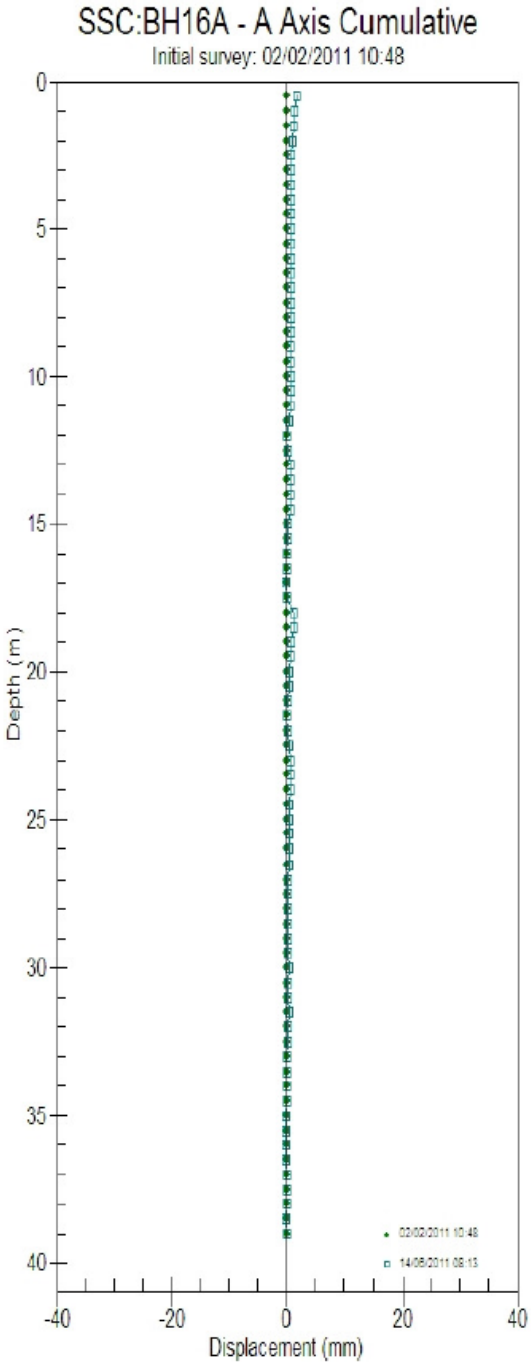
mouchel

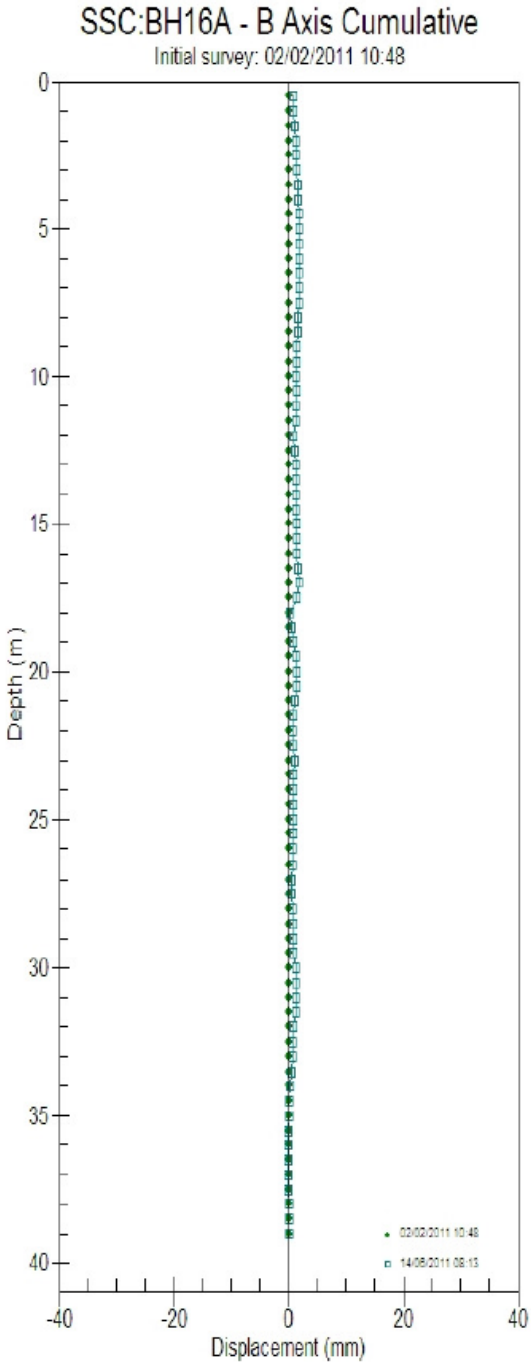




PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT
SITE: A64274
INSTALLATION: BH16A
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

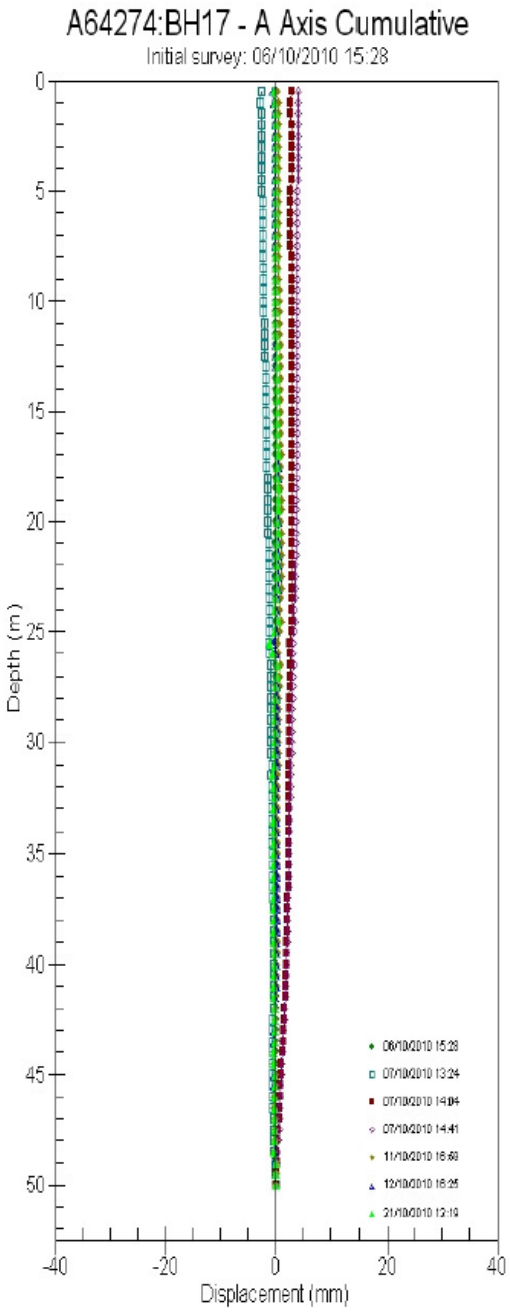
NOTE:

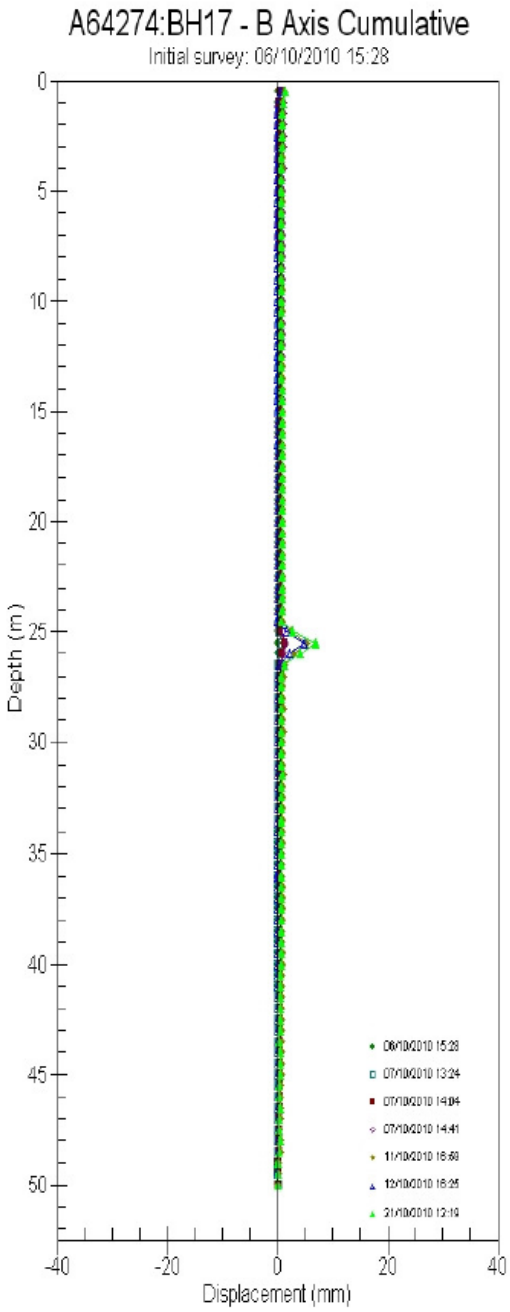




PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data. Replacement Installations.
SITE: Scarborough South Cliff
INSTALLATION: BH16A
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

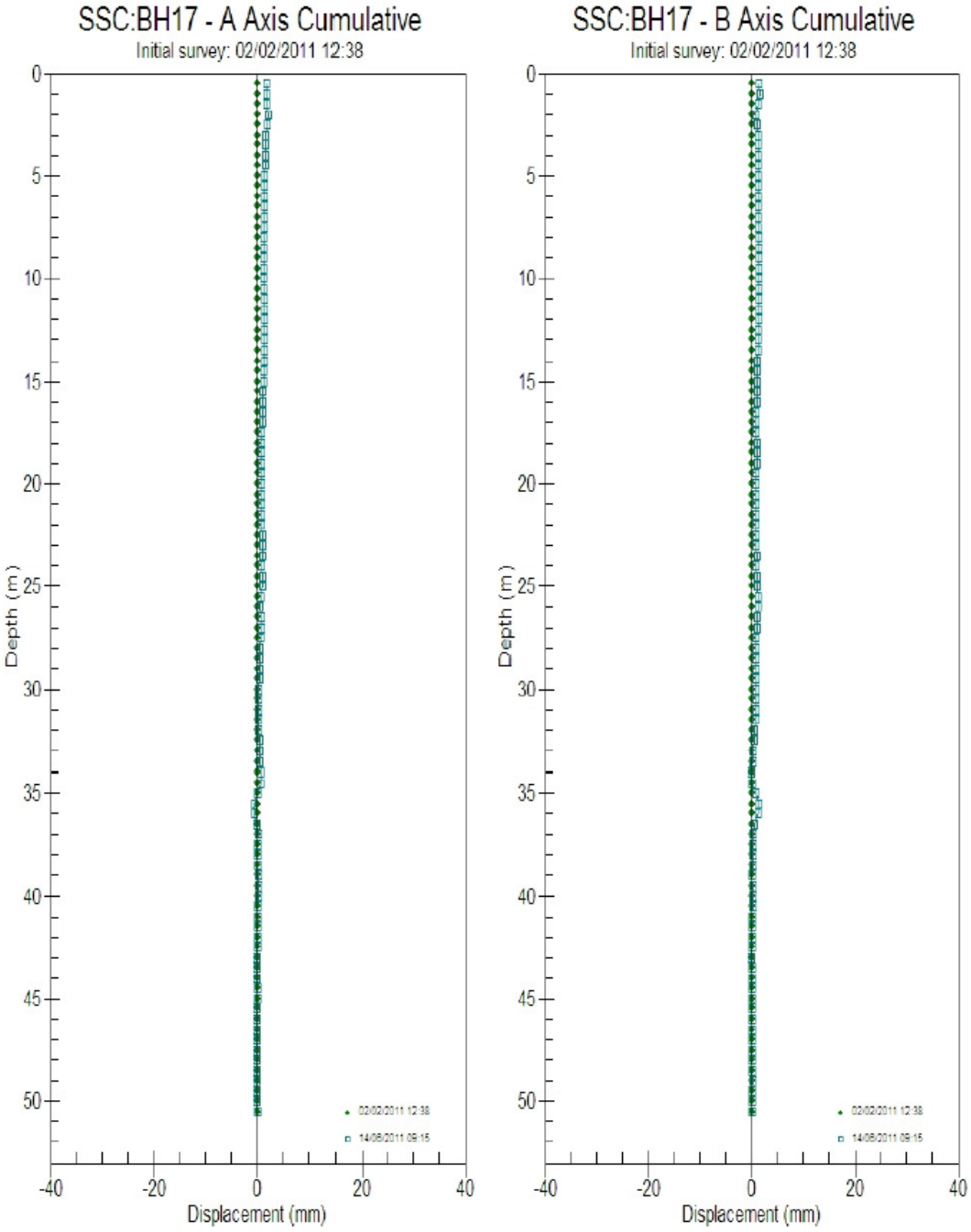
mouchel





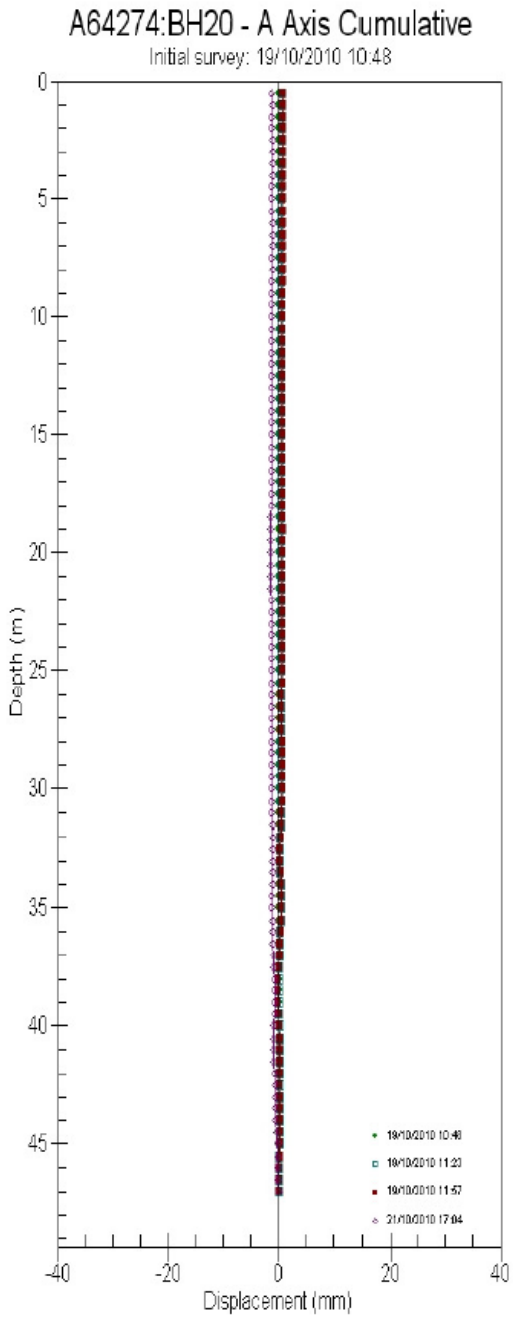
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT PROGRAMME
SITE: A64274
INSTALLATION: BH17
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

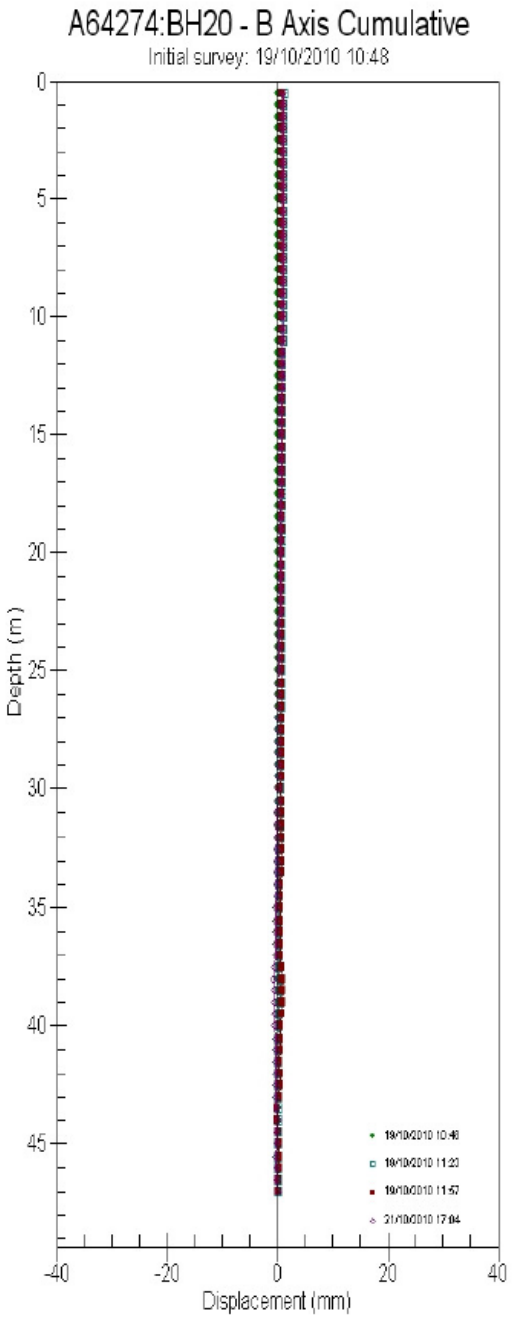
NOTE:



PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data. Replacement Installations.
SITE: Scarborough South Cliff
INSTALLATION: BH17
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

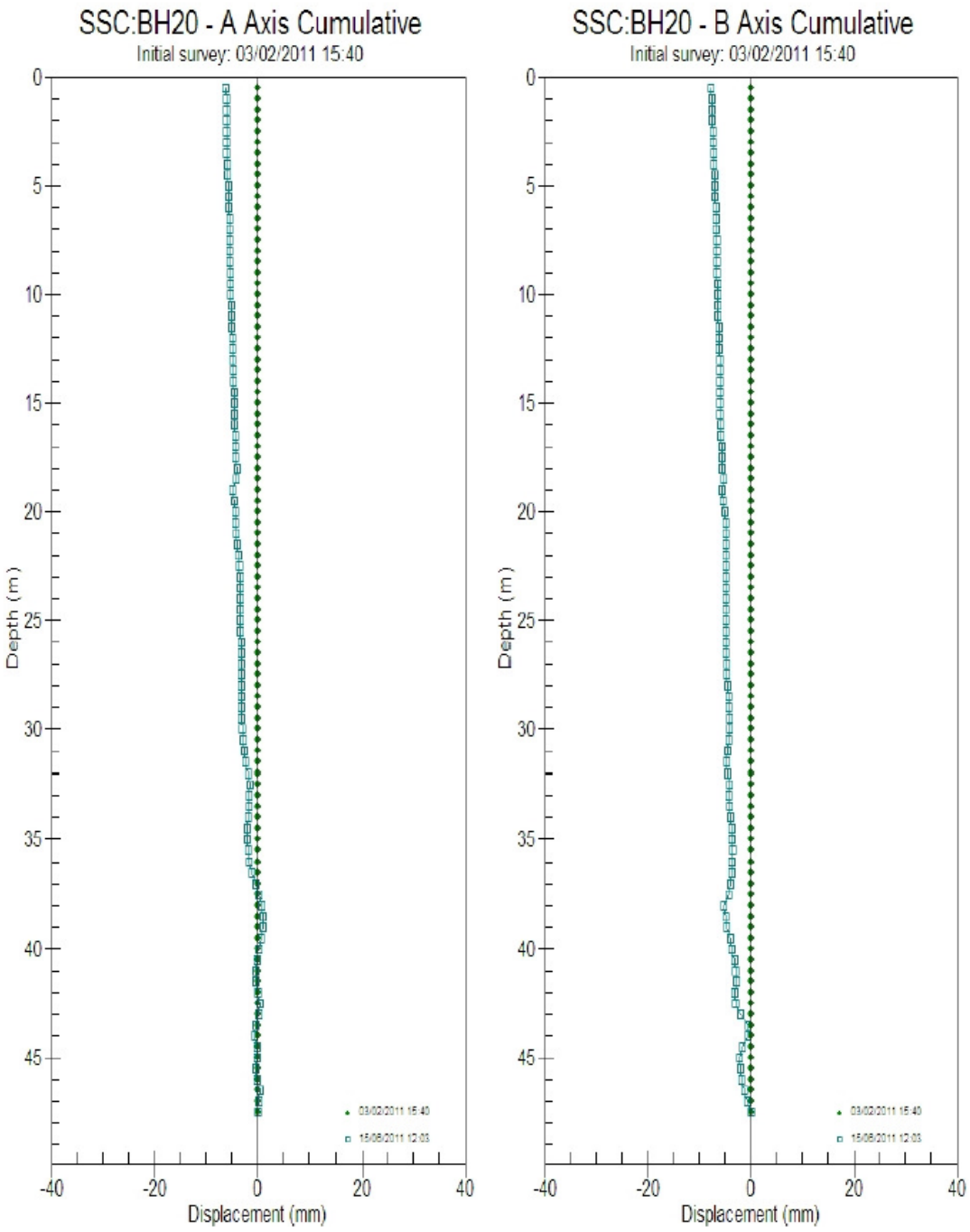
mouchel





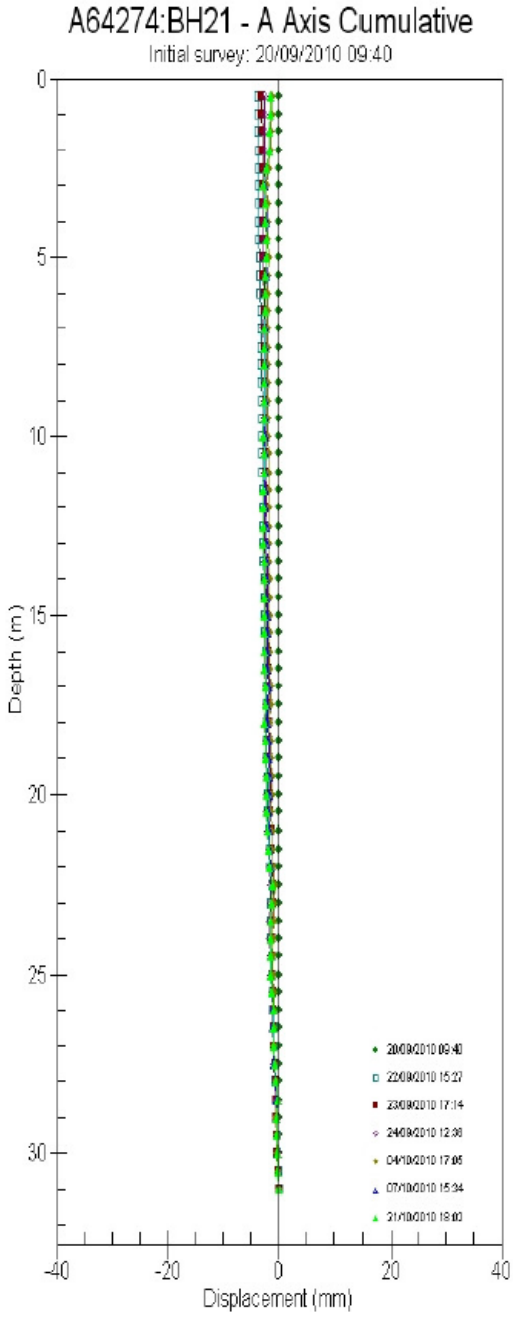
PROJECT: SCARBOROUGH BOREHOLE REPLACEMENT
SITE: A64274
INSTALLATION: BH20
COMPANY: WYG
CLIENT: SCARBOROUGH BOROUGH COUNCIL

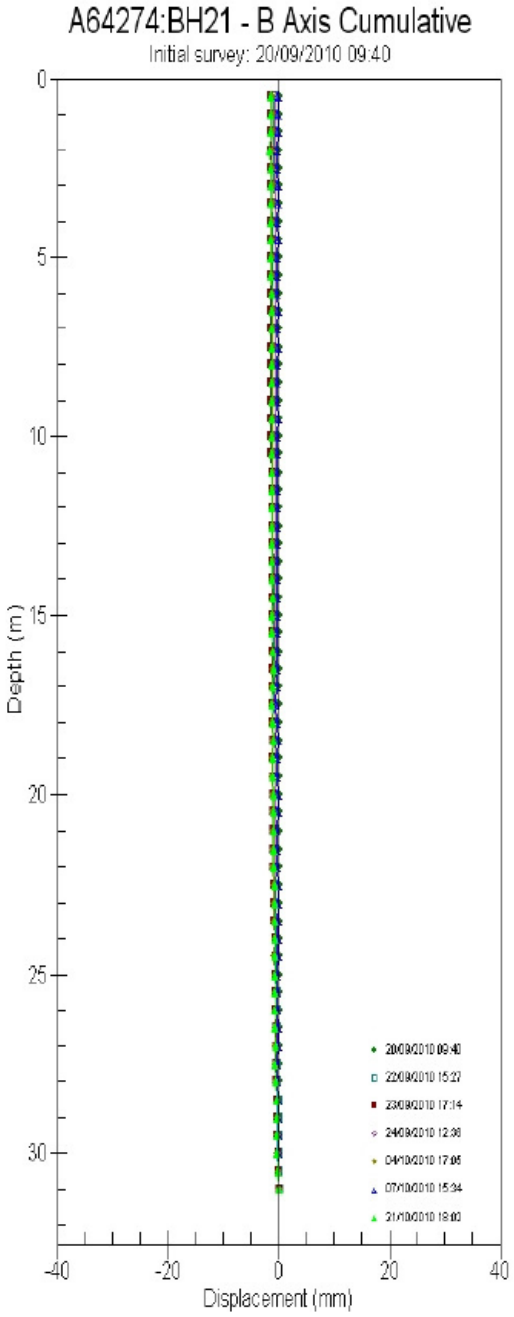
NOTE:



PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data.
Replacement Installations.
SITE: Scarborough South Cliff
INSTALLATION: BH20
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

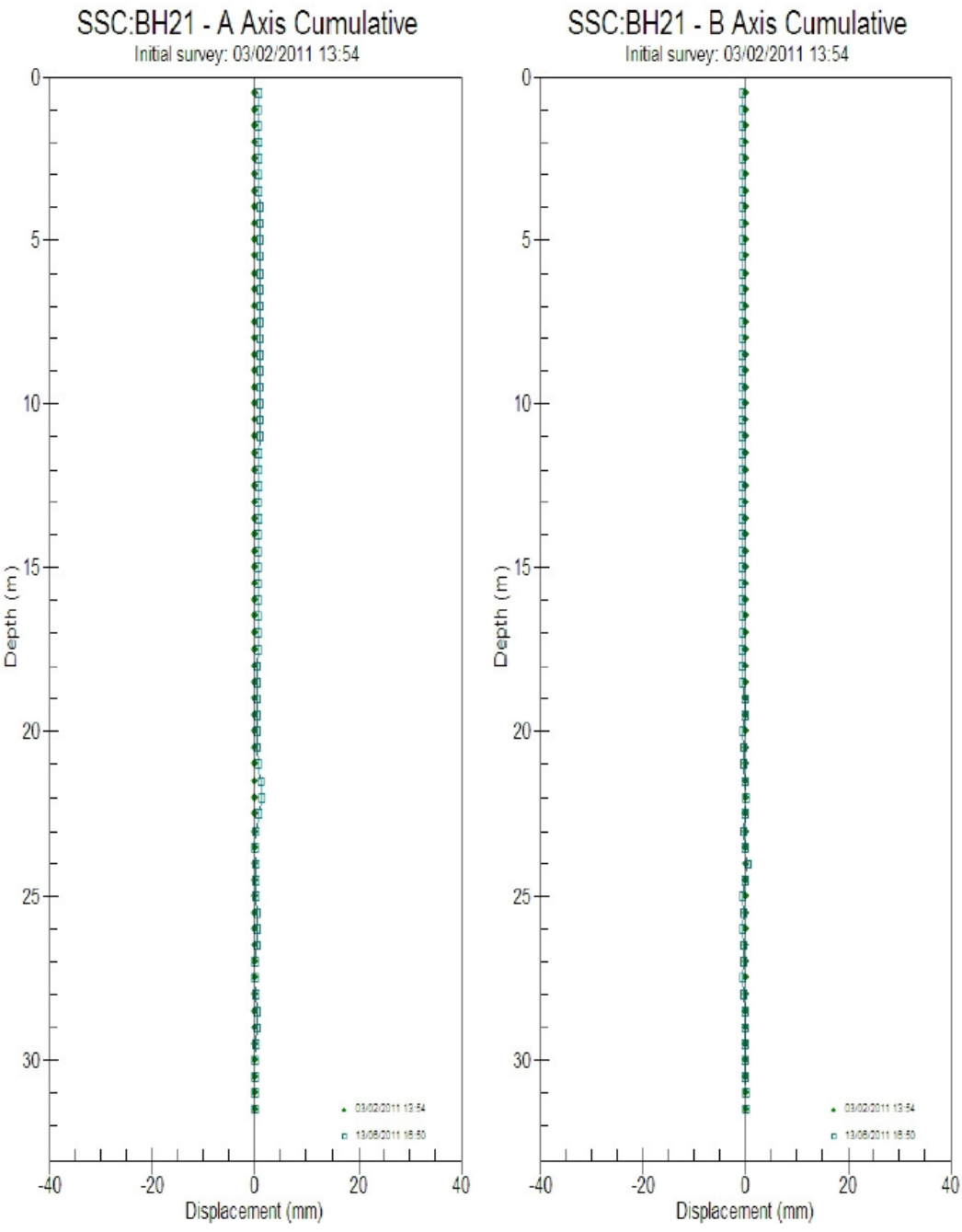
mouchel





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

NOTE:

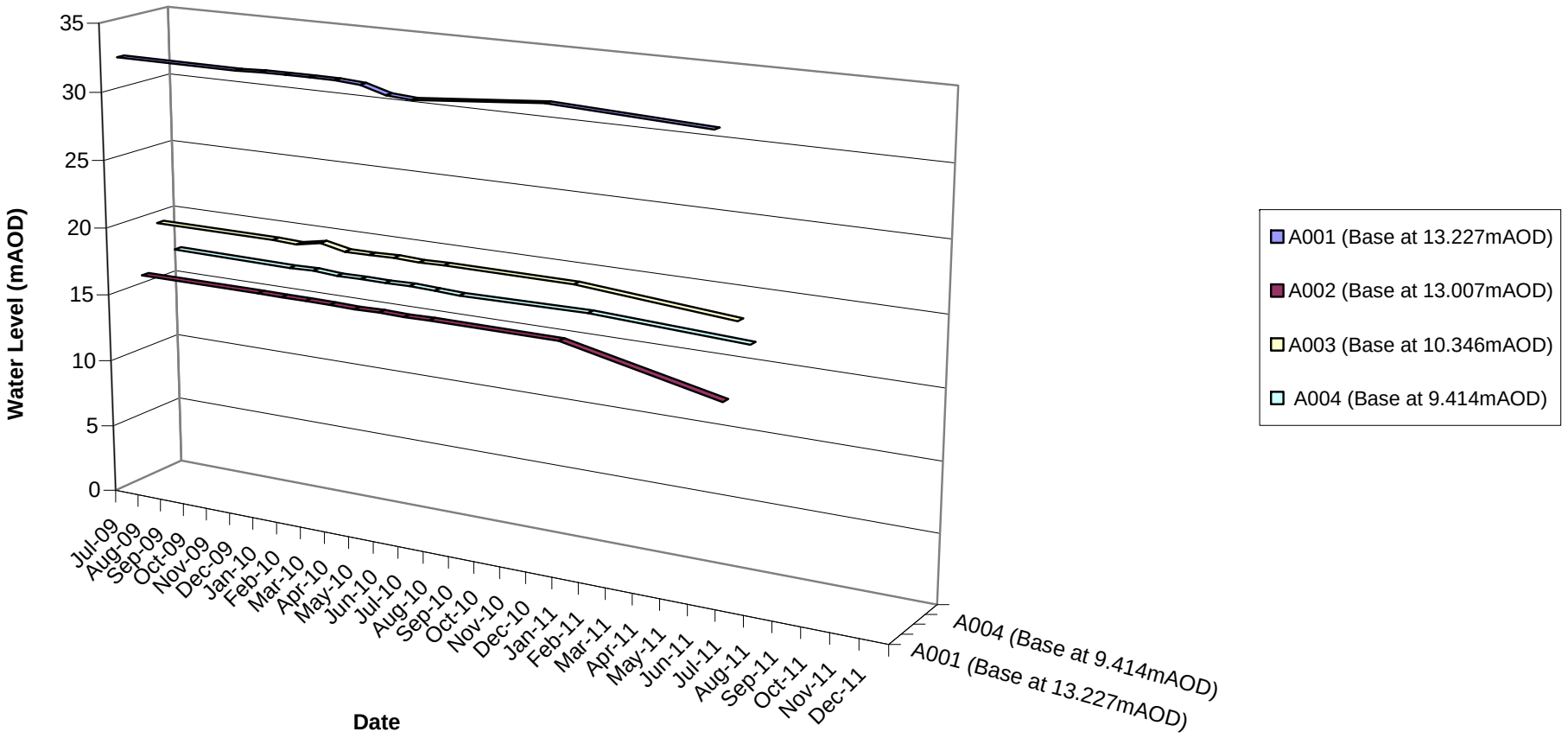


PROJECT: 721229 (1022971) Ongoing Analysis of Coastal Monitoring Data. Replacement Installations.
SITE: Scarborough South Cliff
INSTALLATION: BH21
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council
NOTE: A0 direction: East

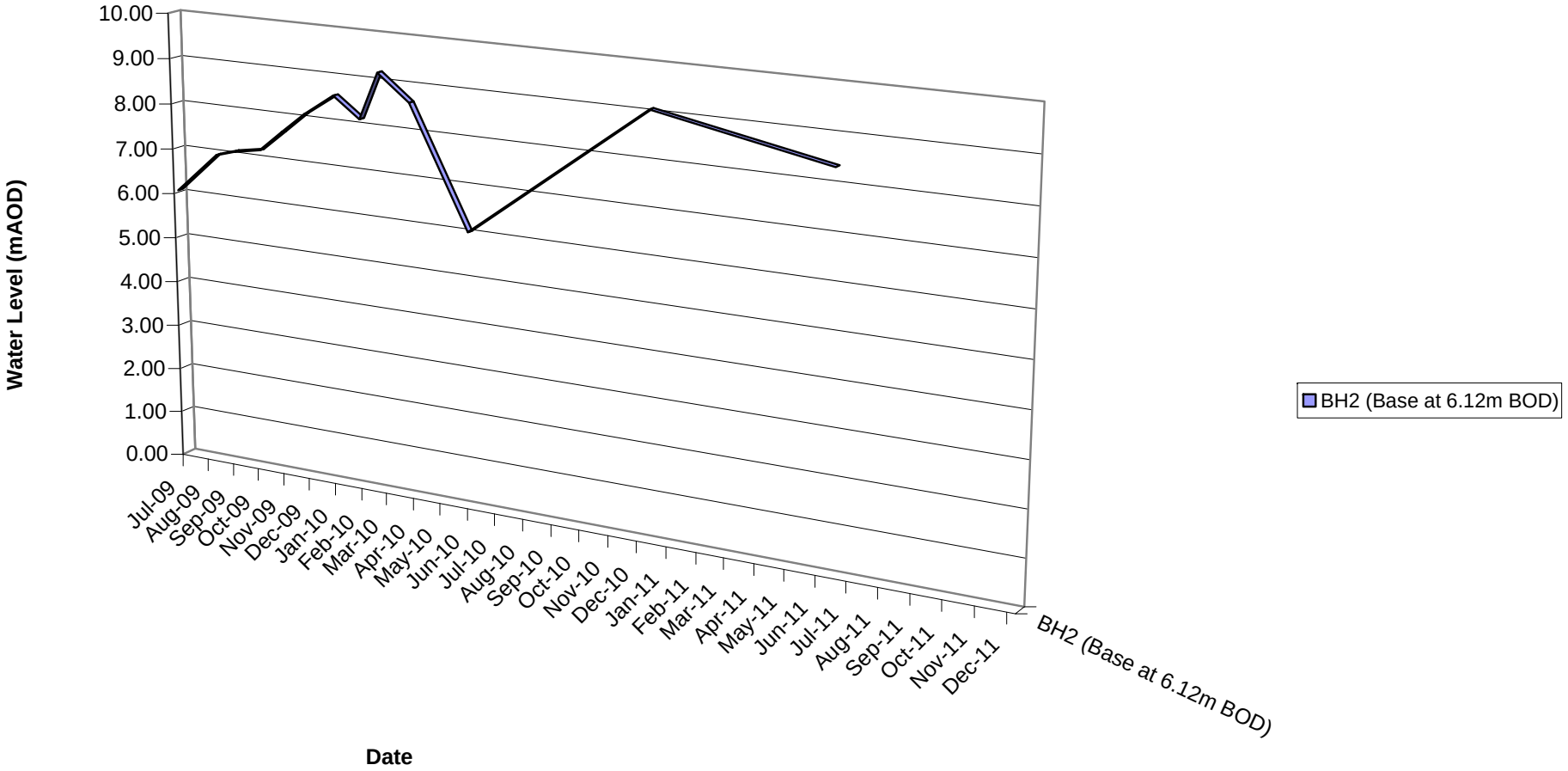
mouchel

Appendix E Groundwater Monitoring Graphs

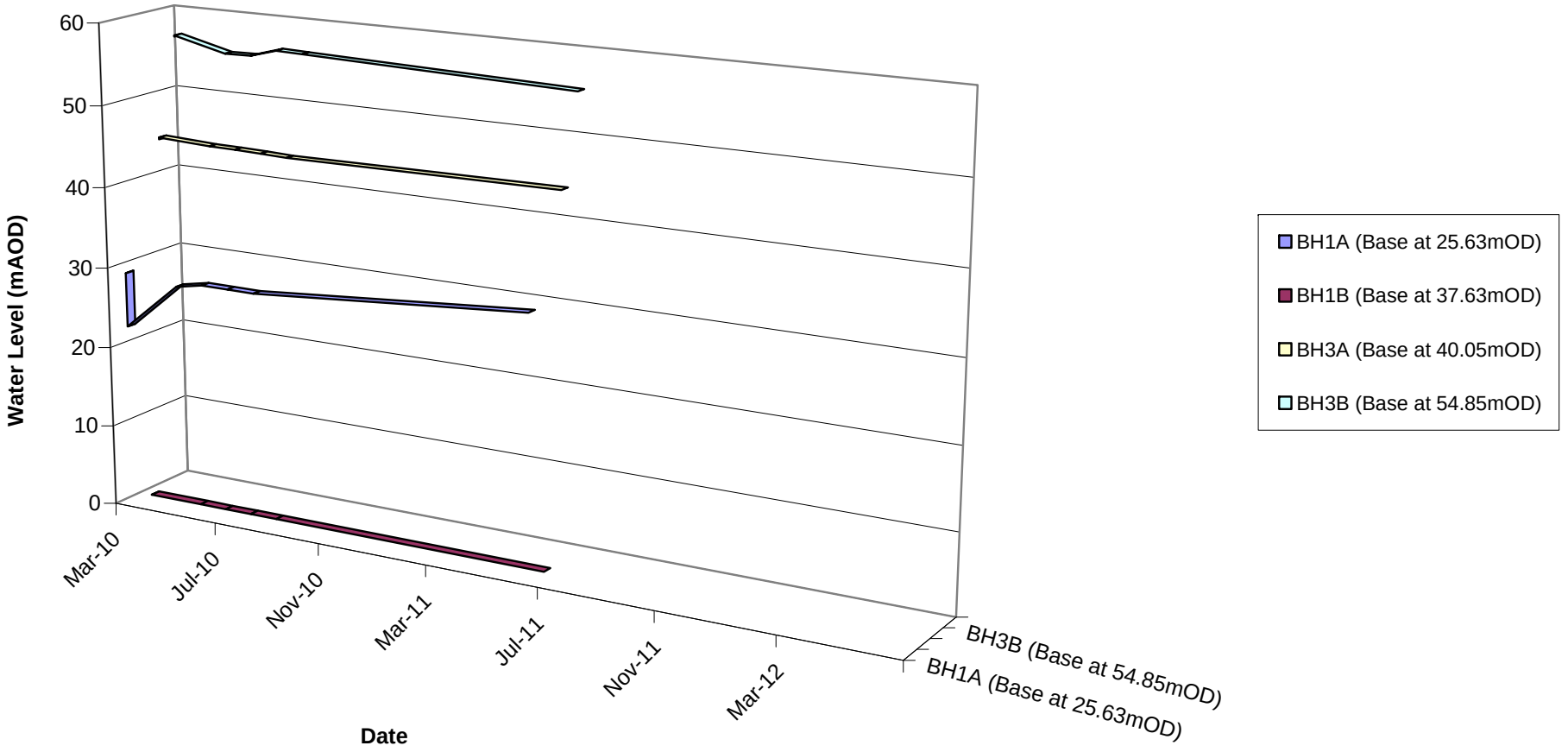
RUNSWICK BAY GROUNDWATER LEVELS



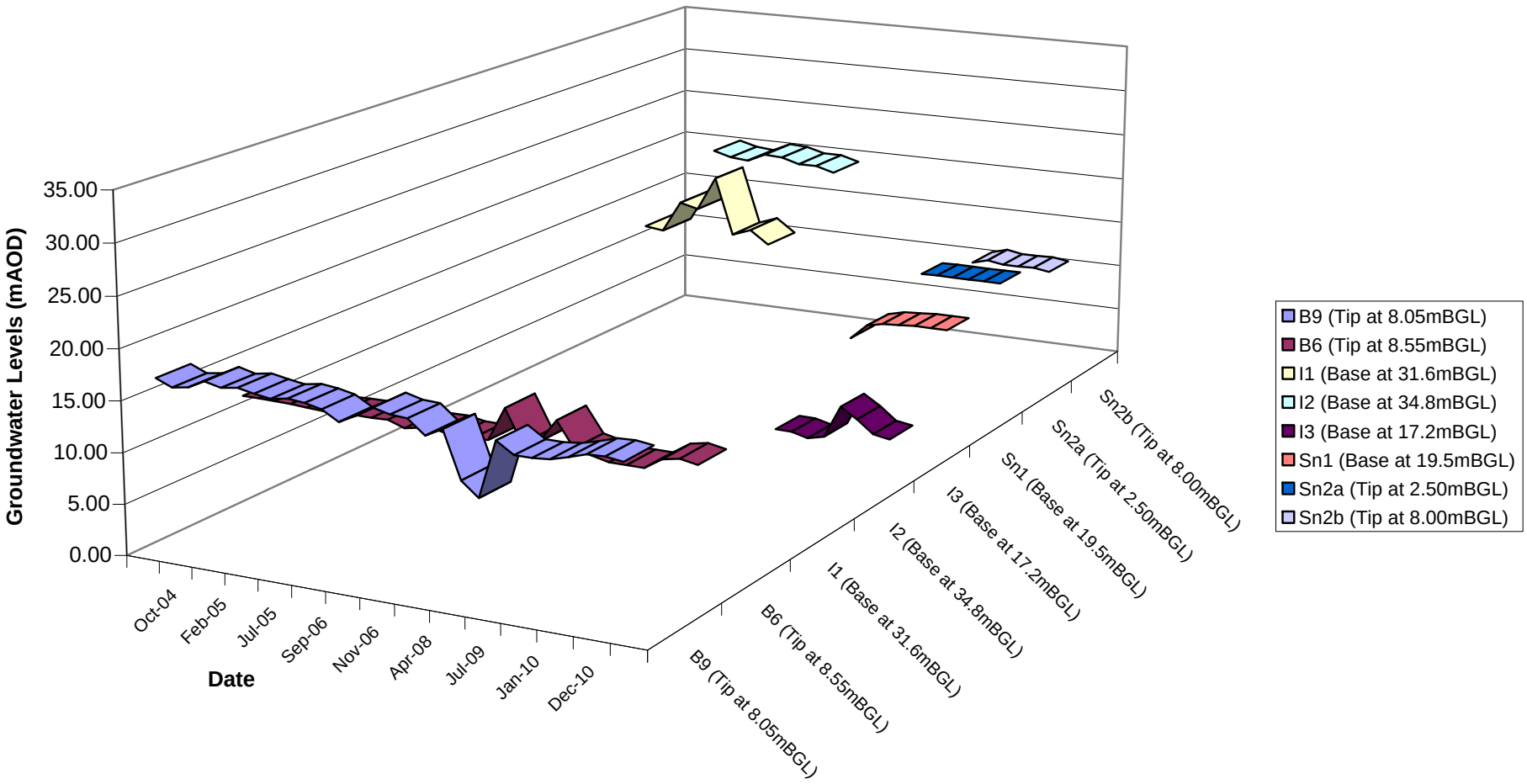
WHITBY WEST CLIFF GROUNDWATER LEVELS



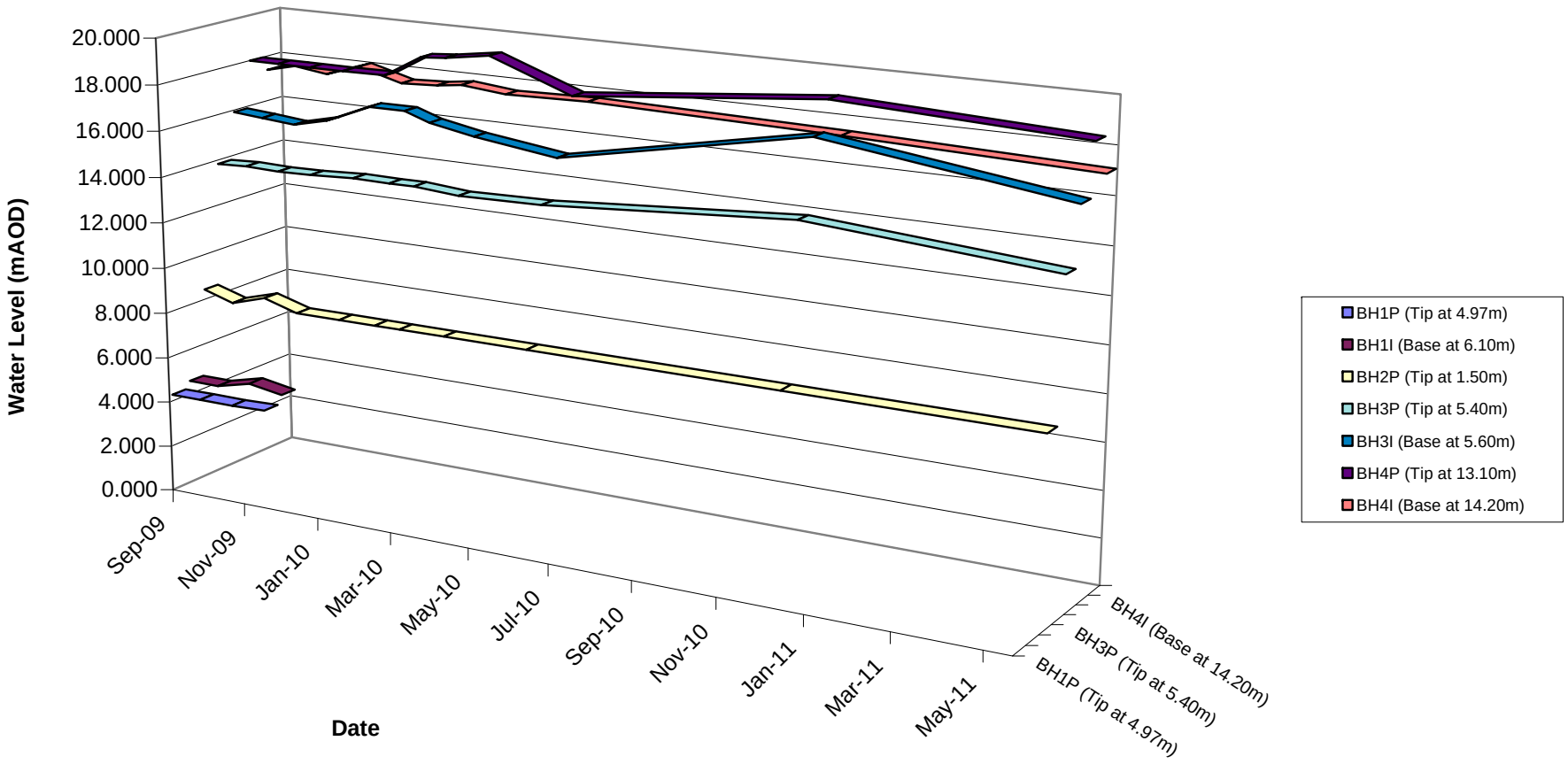
ROBIN HOOD'S BAY GROUNDWATER LEVELS



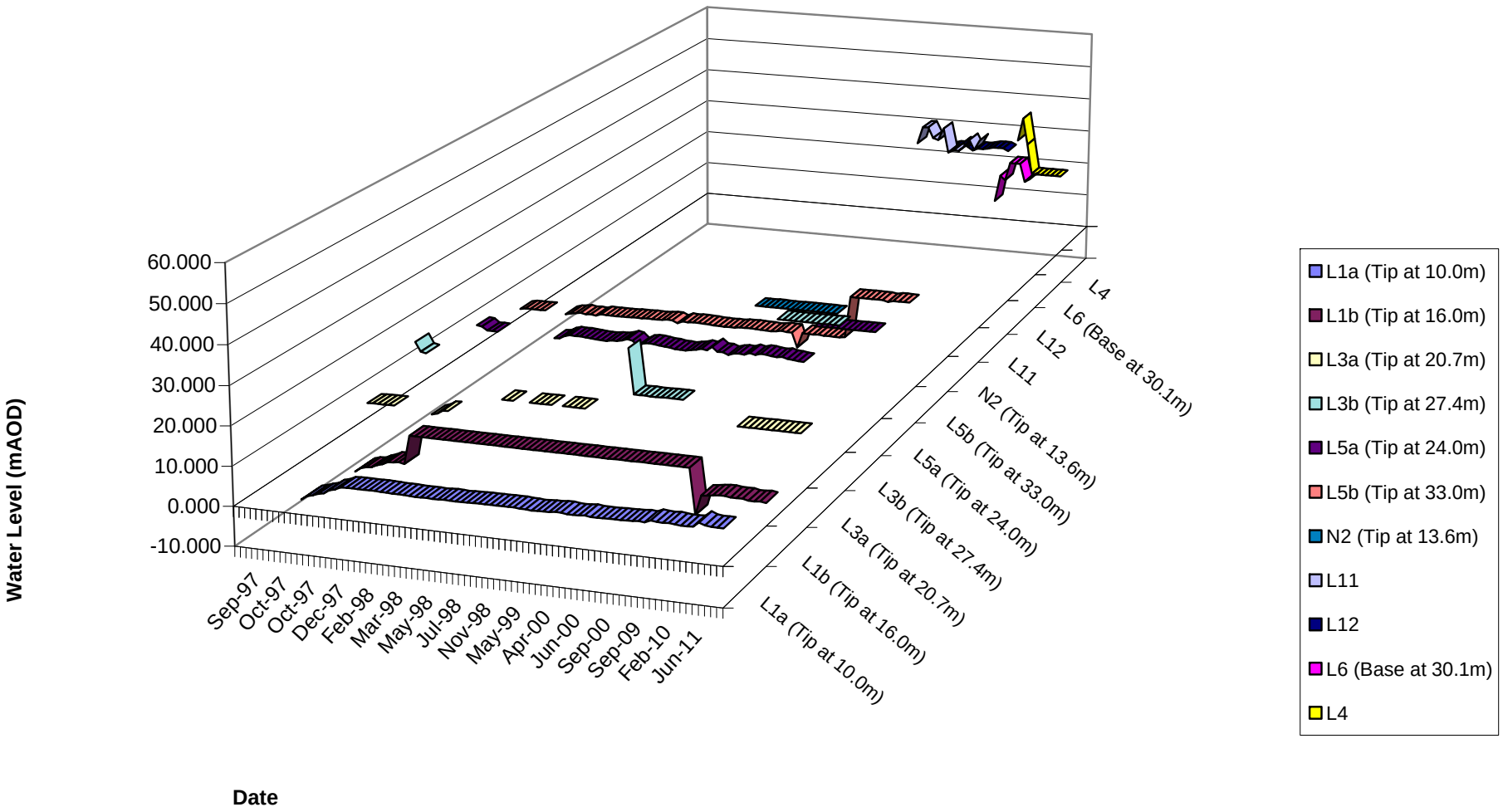
SCALBY NESS GROUNDWATER LEVELS

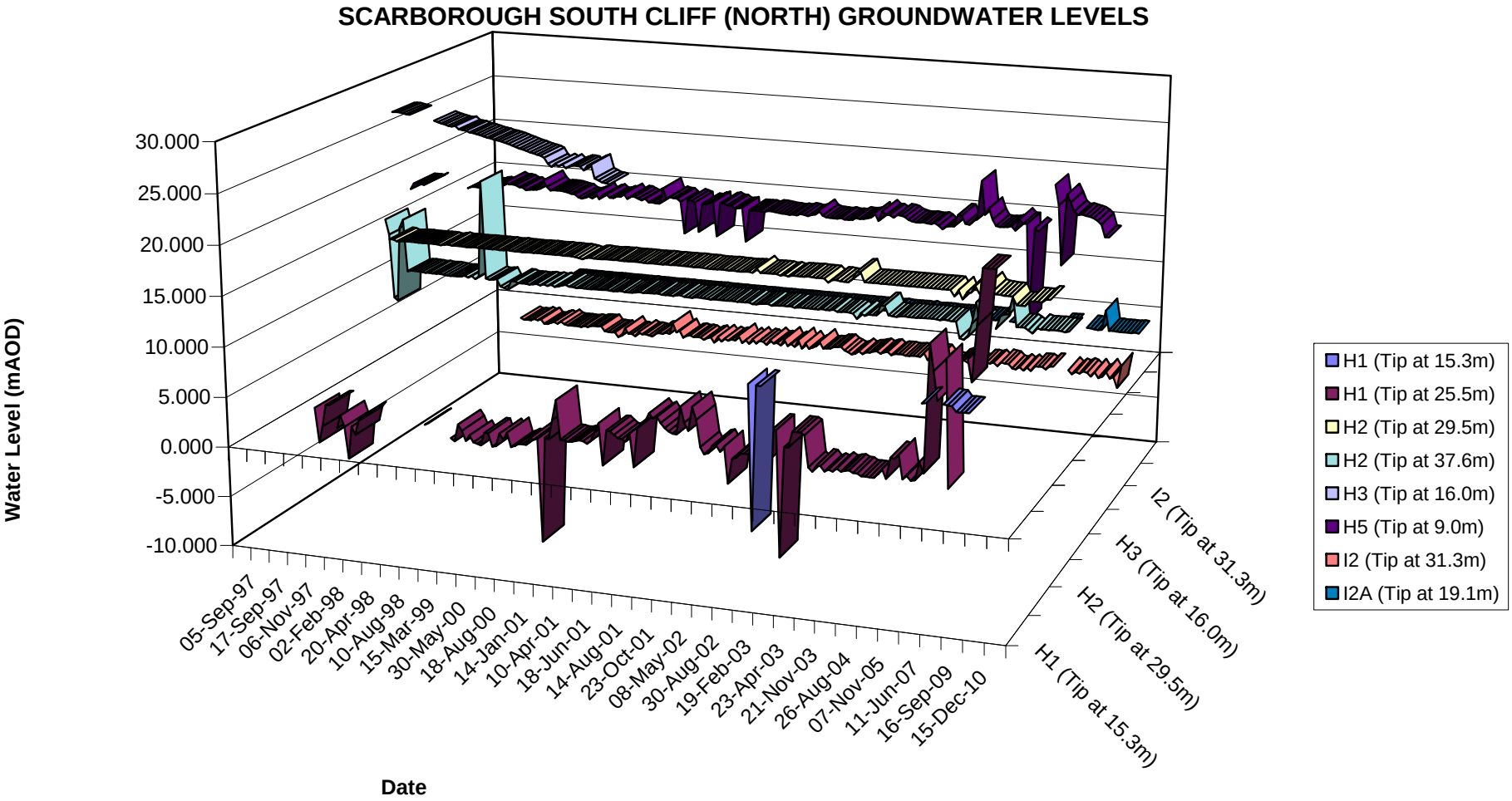


OASIS CAFÉ GROUNDWATER LEVELS

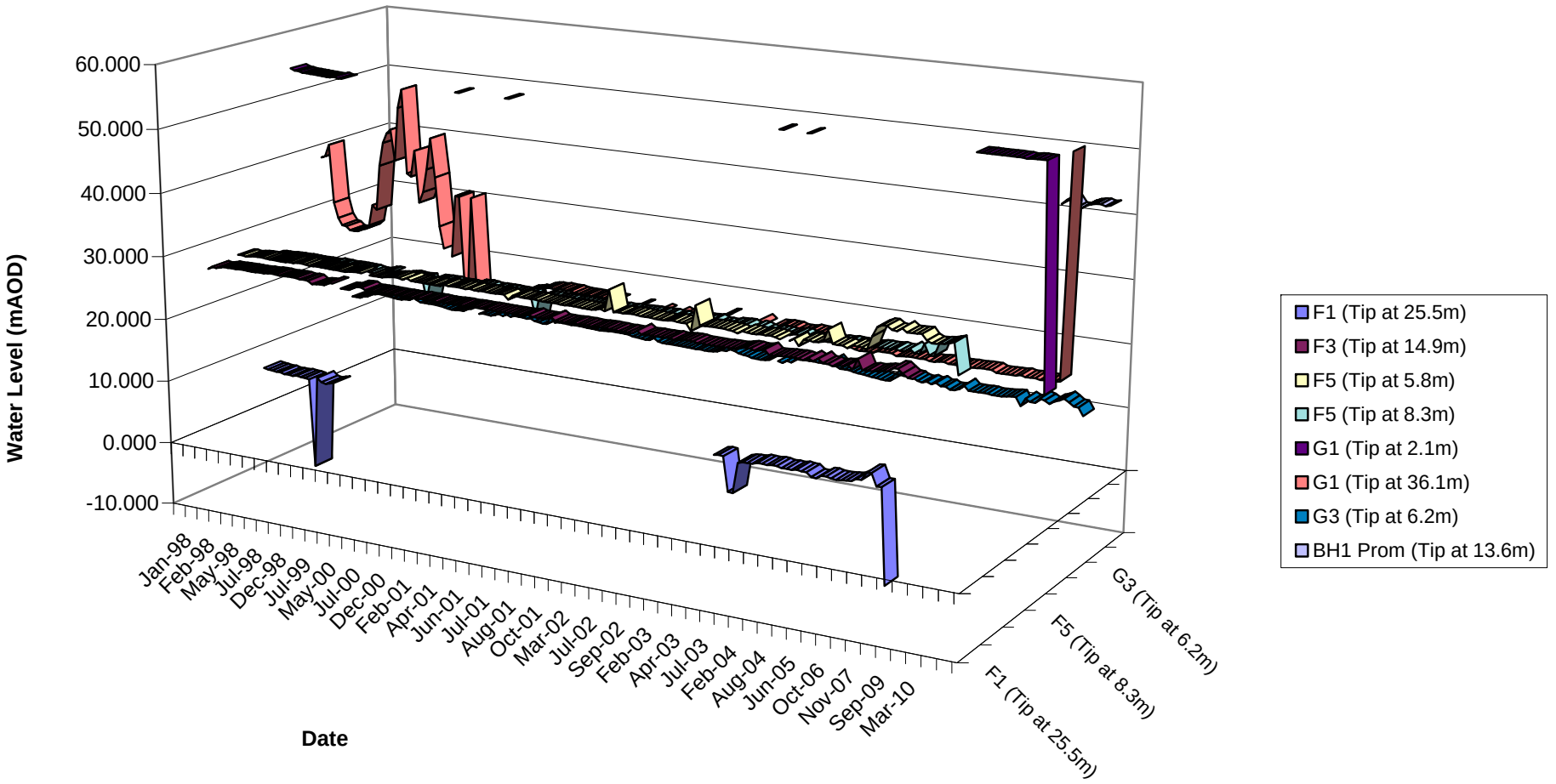


SCARBOROUGH NORTH BAY GROUNDWATER LEVELS

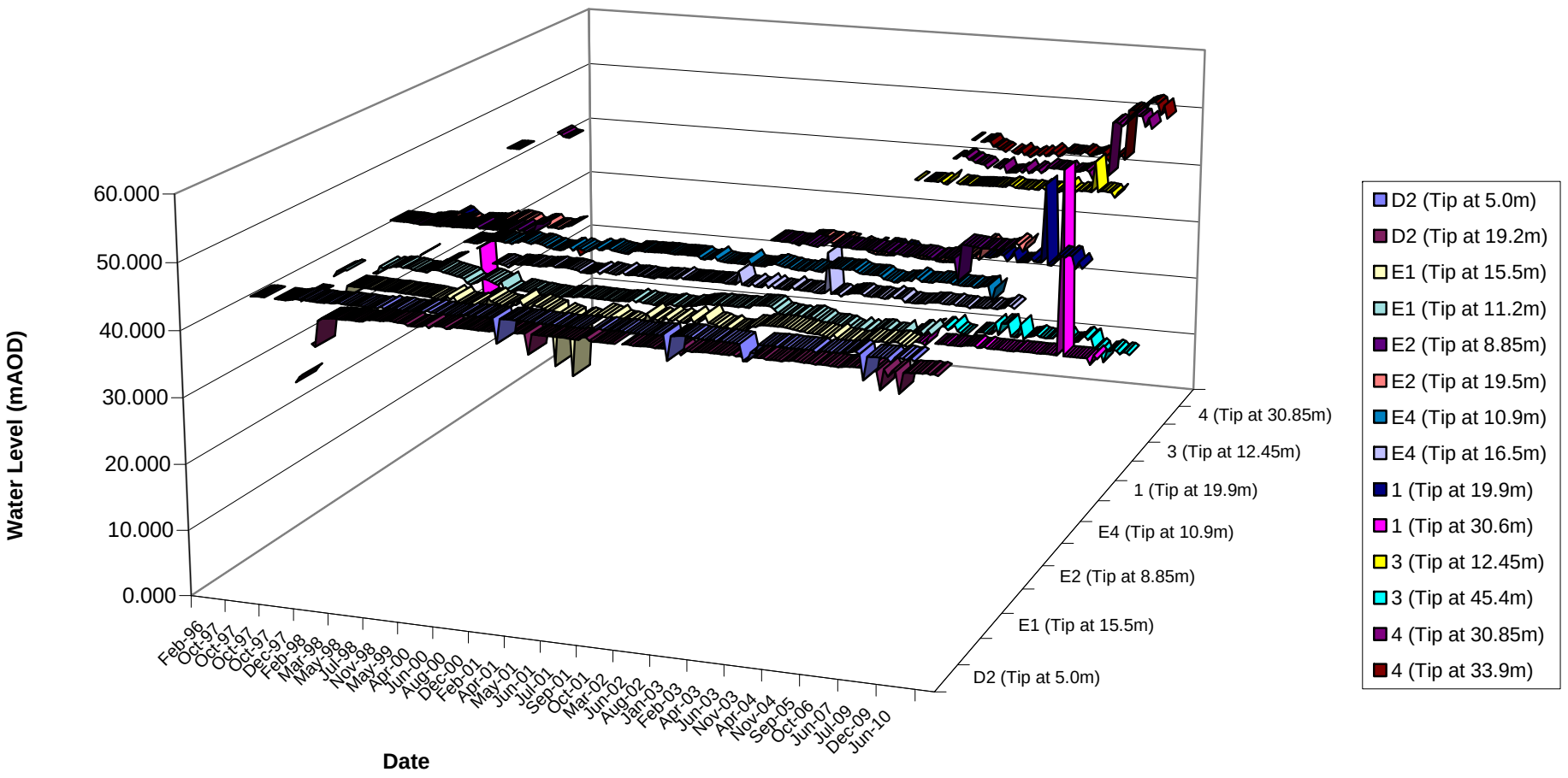



SCARBOROUGH SOUTH CLIFF (NORTH) GROUNDWATER LEVELS
Water Level (mAOD)
30.000
25.000
20.000
15.000
10.000
5.000
0.000
-5.000
-10.000
05-Sep-97
17-Sep-97
06-Nov-97
02-Feb-98
20-Apr-98
10-Aug-98
15-Mar-99
30-May-00
18-Aug-00
14-Jan-01
10-Apr-01
18-Jun-01
14-Aug-01
23-Oct-01
08-May-02
30-Aug-02
19-Feb-03
23-Apr-03
21-Nov-03
26-Aug-04
07-Nov-05
11-Jun-07
16-Sep-09
15-Dec-10
Date
H1 (Tip at 15.3m)
H2 (Tip at 29.5m)
H3 (Tip at 16.0m)
I2 (Tip at 31.3m)
H1 (Tip at 15.3m)
H1 (Tip at 25.5m)
H2 (Tip at 29.5m)
H2 (Tip at 37.6m)
H3 (Tip at 16.0m)
H5 (Tip at 9.0m)
I2 (Tip at 31.3m)
I2A (Tip at 19.1m)

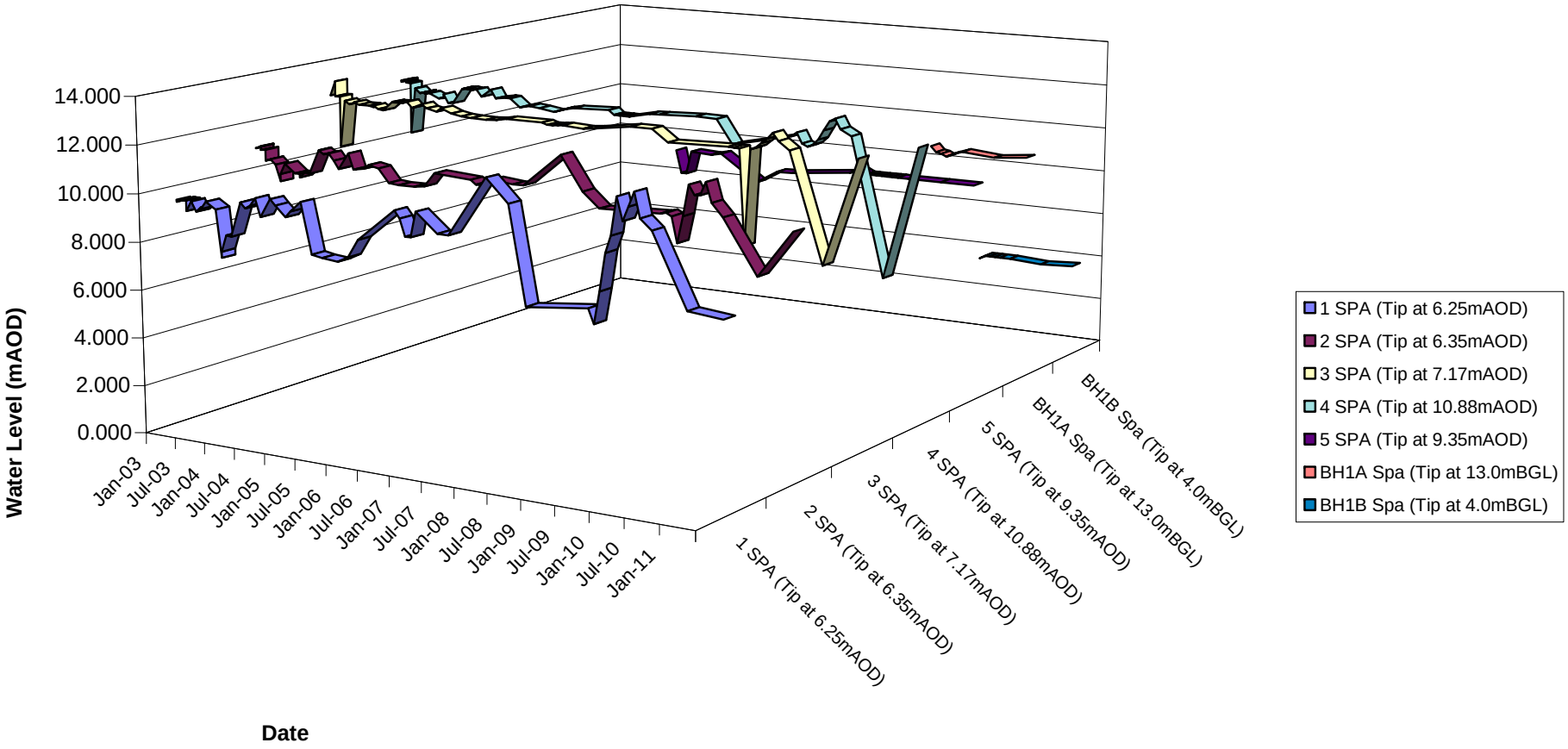
SCARBOROUGH SOUTH CLIFF (MIDDLE) GROUNDWATER LEVELS



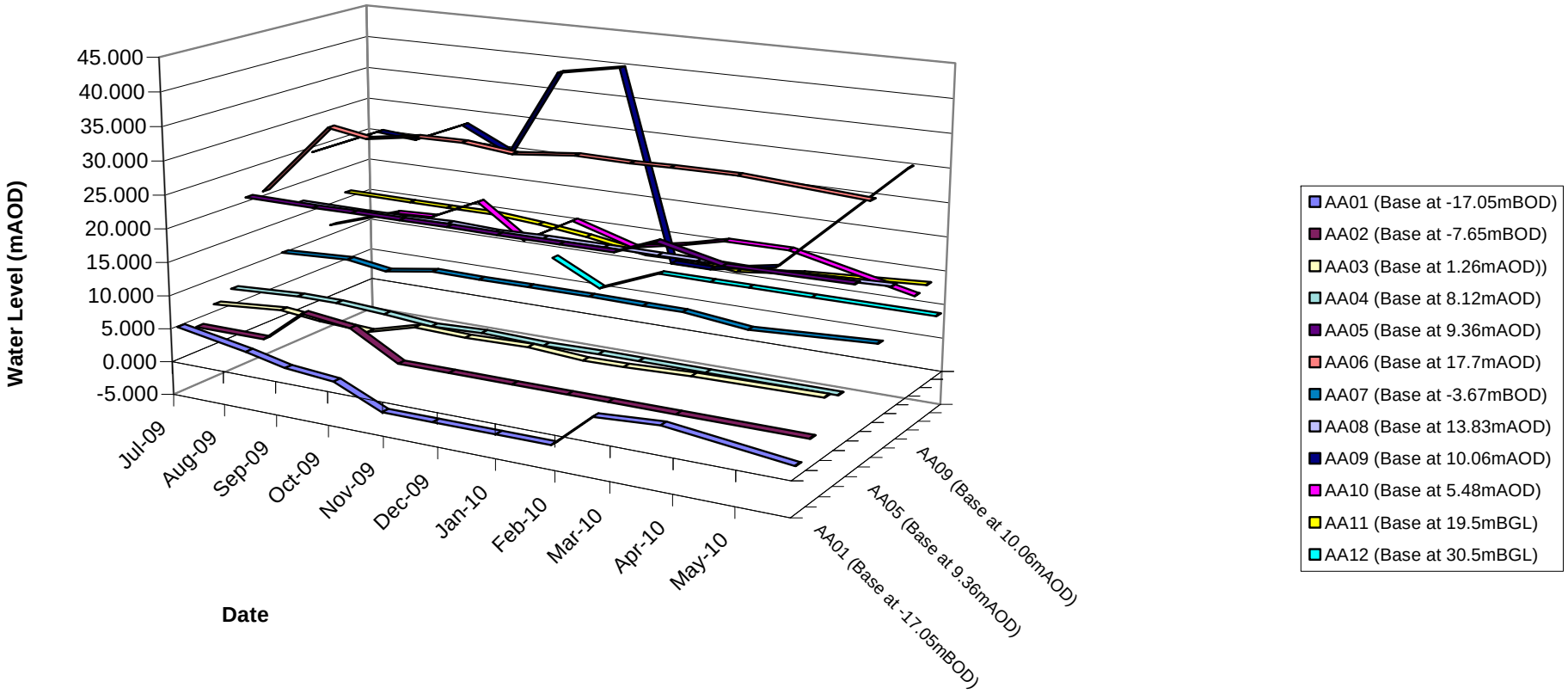
SCARBOROUGH SOUTH CLIFF (SOUTH) GROUNDWATER LEVELS



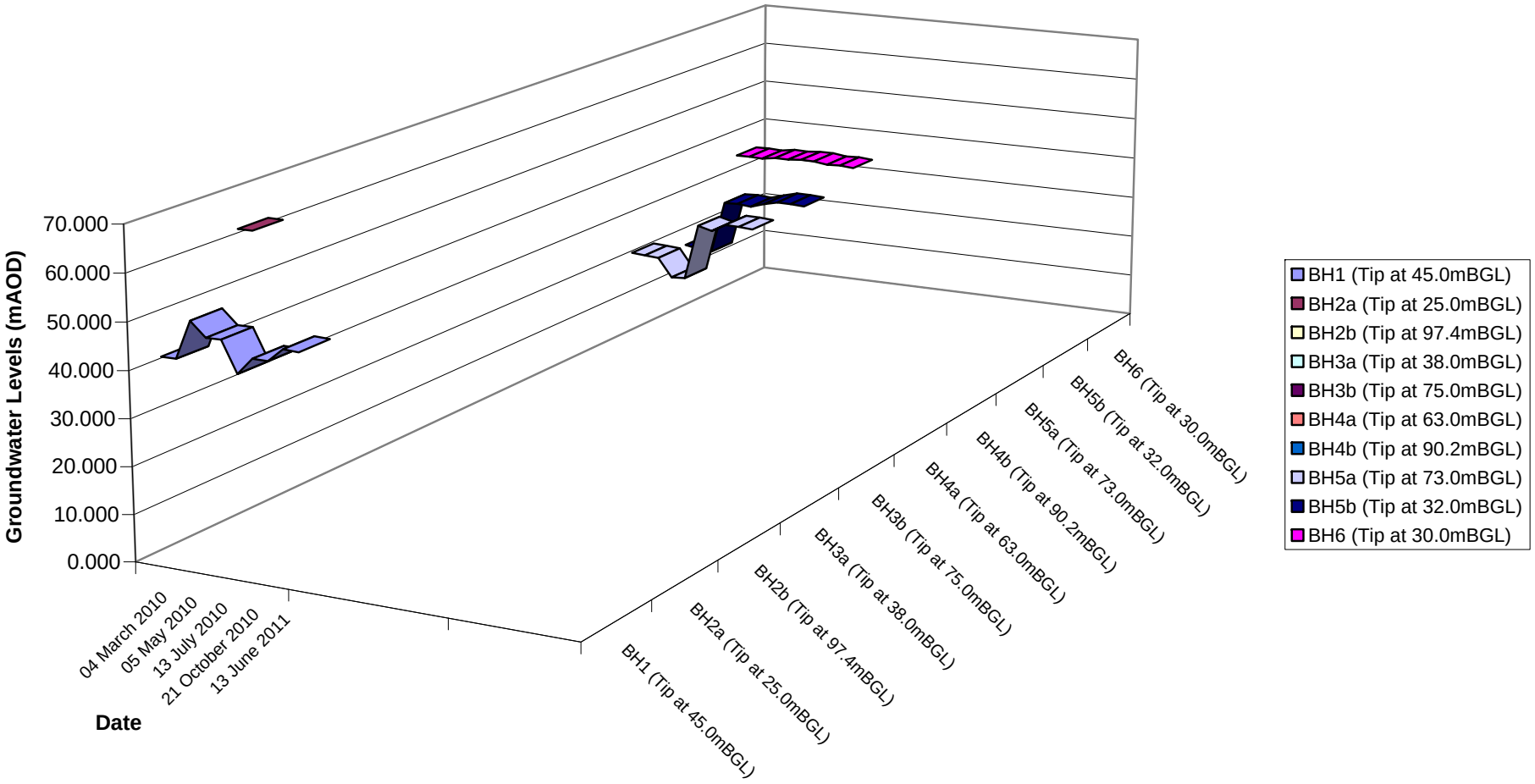
SCARBOROUGH SPA GROUNDWATER LEVELS



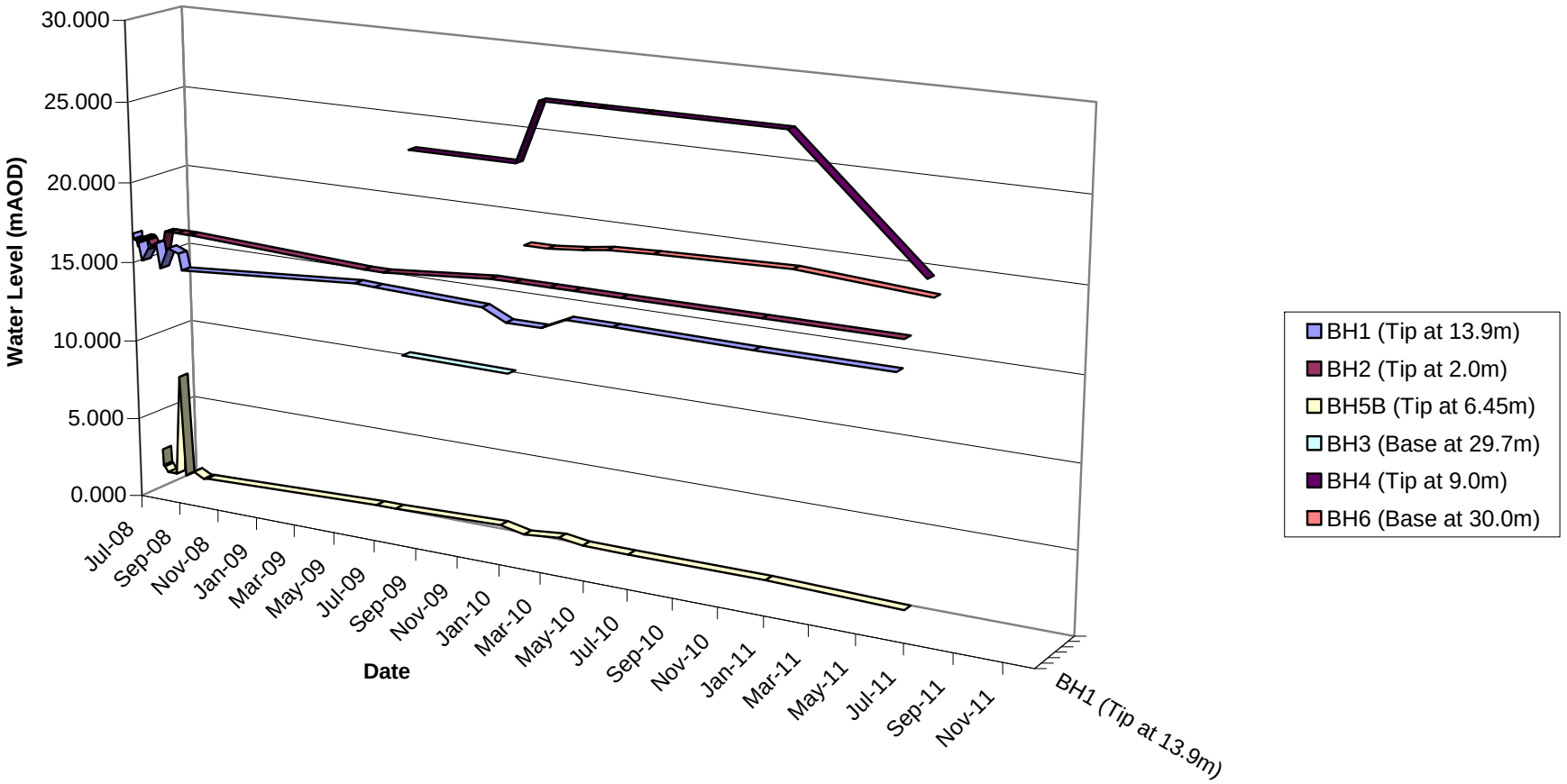
SCARBOROUGH SOUTH CLIFF (Inclinometer) GROUNDWATER LEVELS



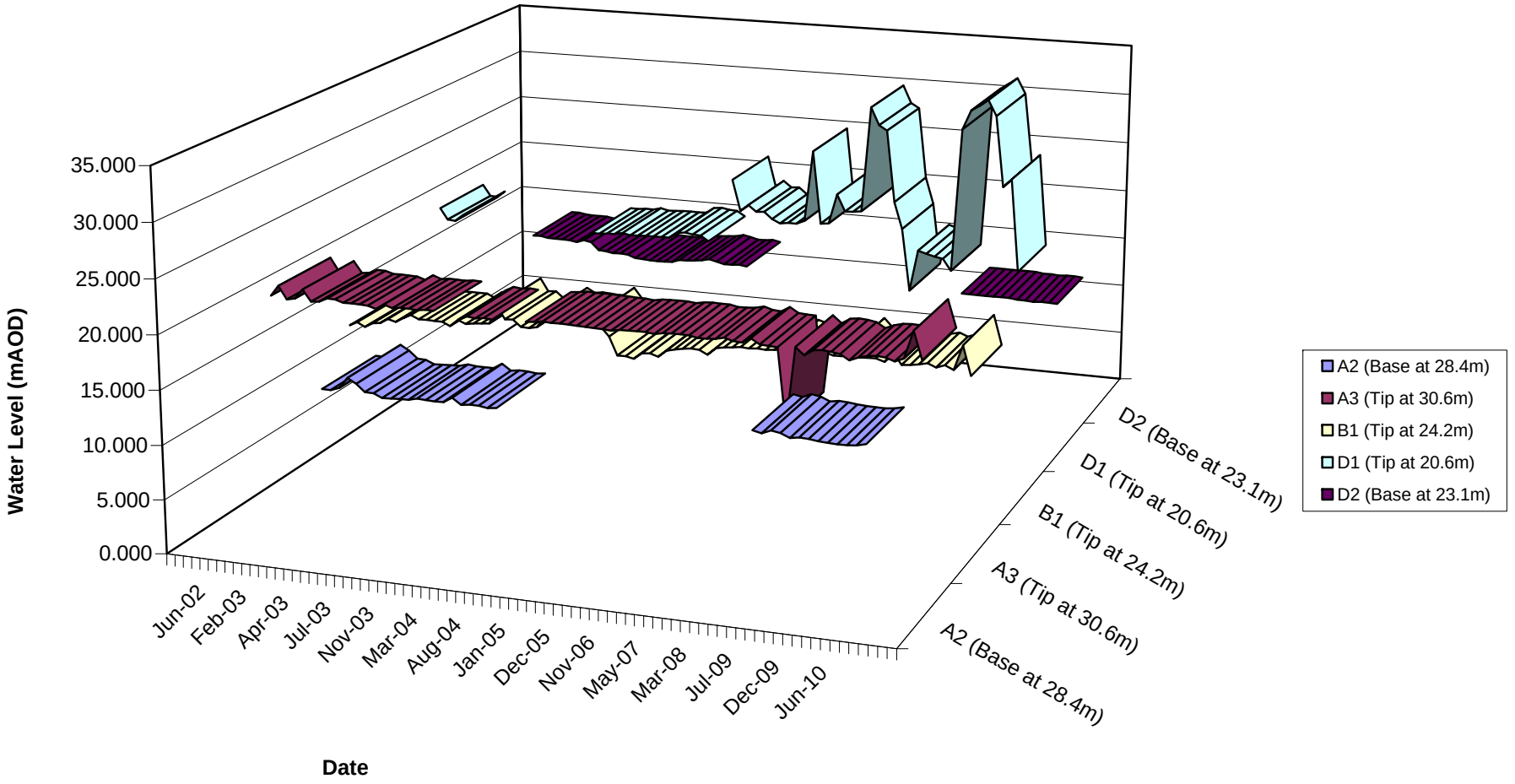
KNIPE POINT GROUNDWATER LEVELS



FILEY TOWN GROUNDWATER LEVELS



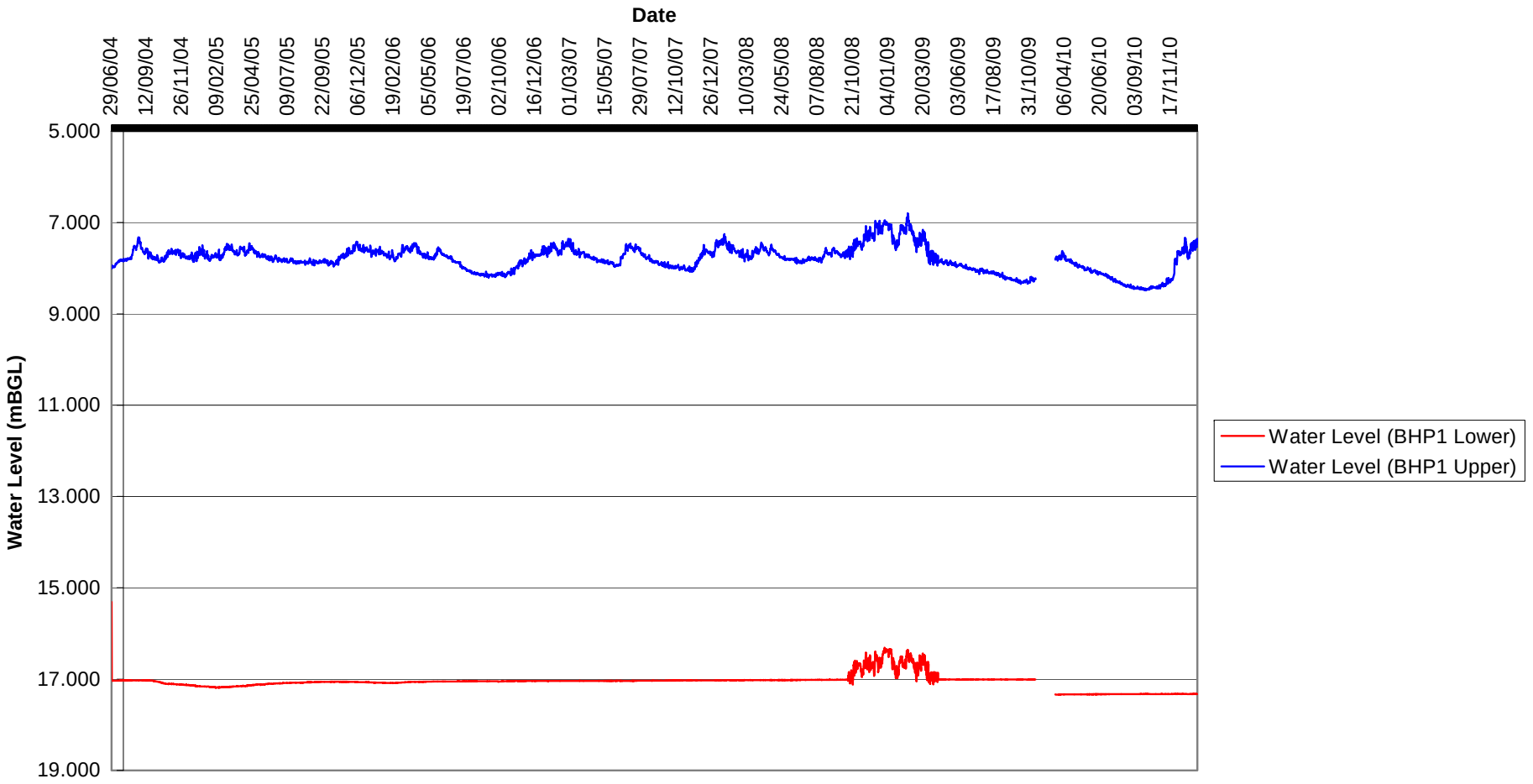
FILEY FLAT CLIFFS GROUNDWATER LEVELS



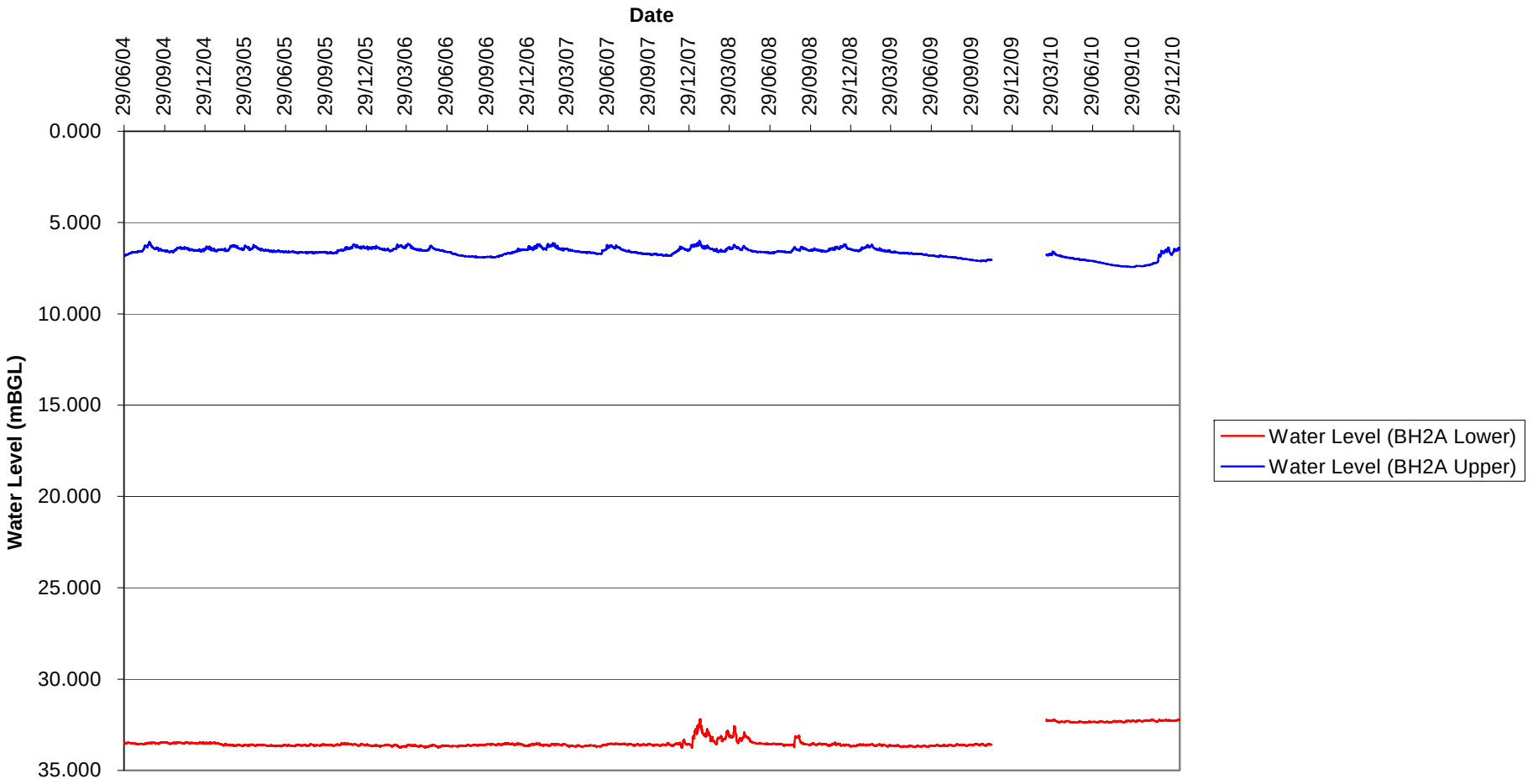
Automated Piezometer Groundwater Monitoring

Readings from Scalby Ness

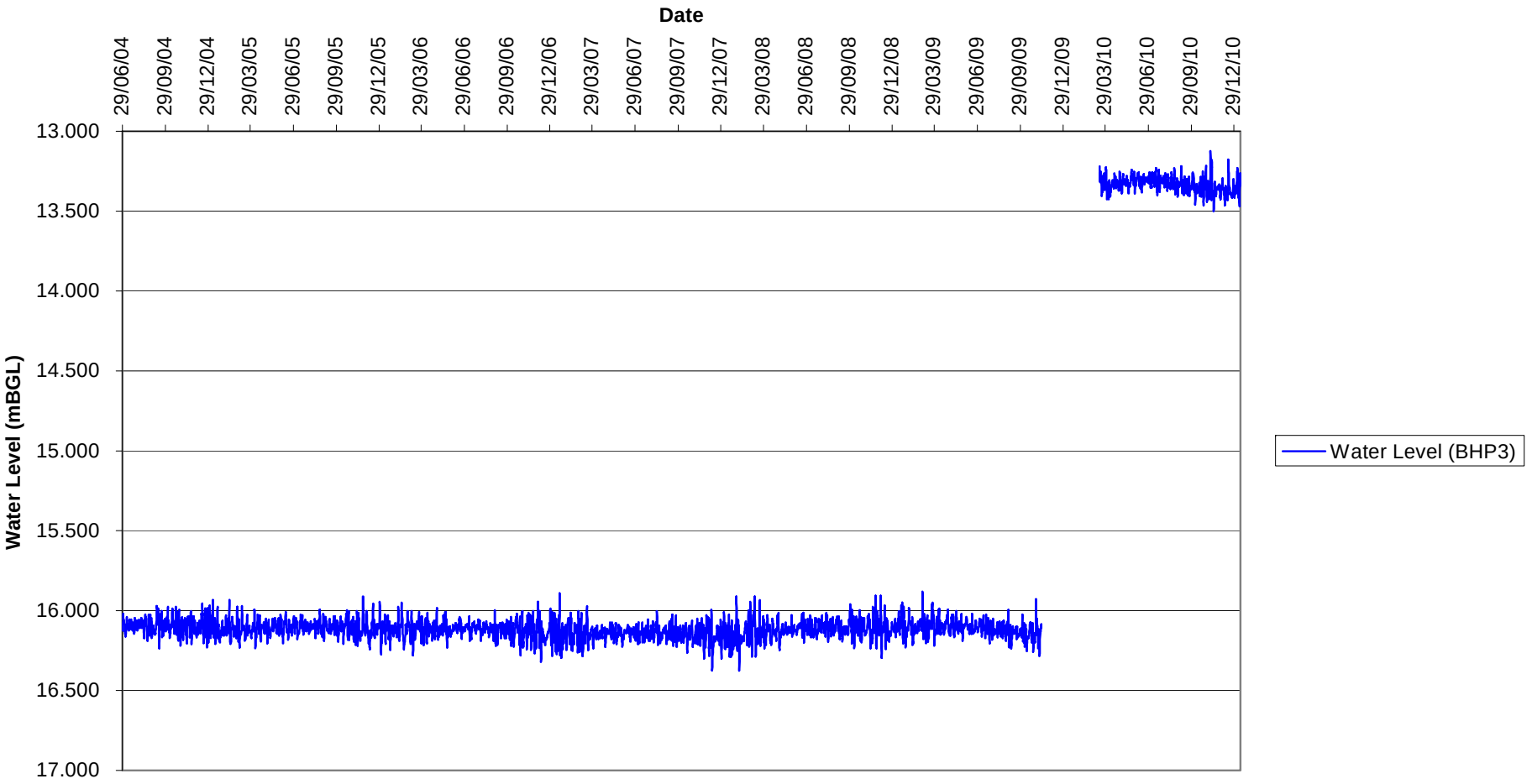
SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



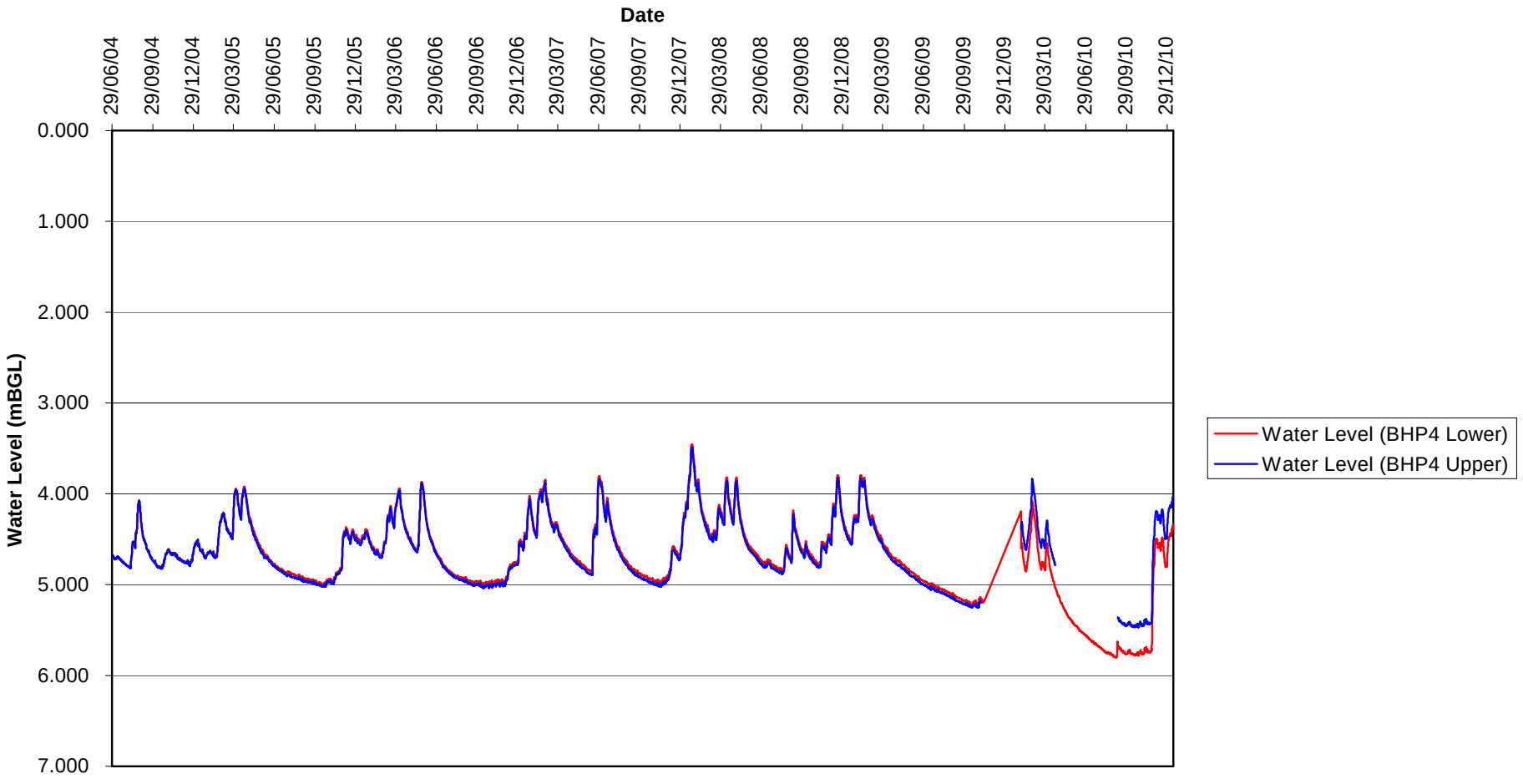
SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS

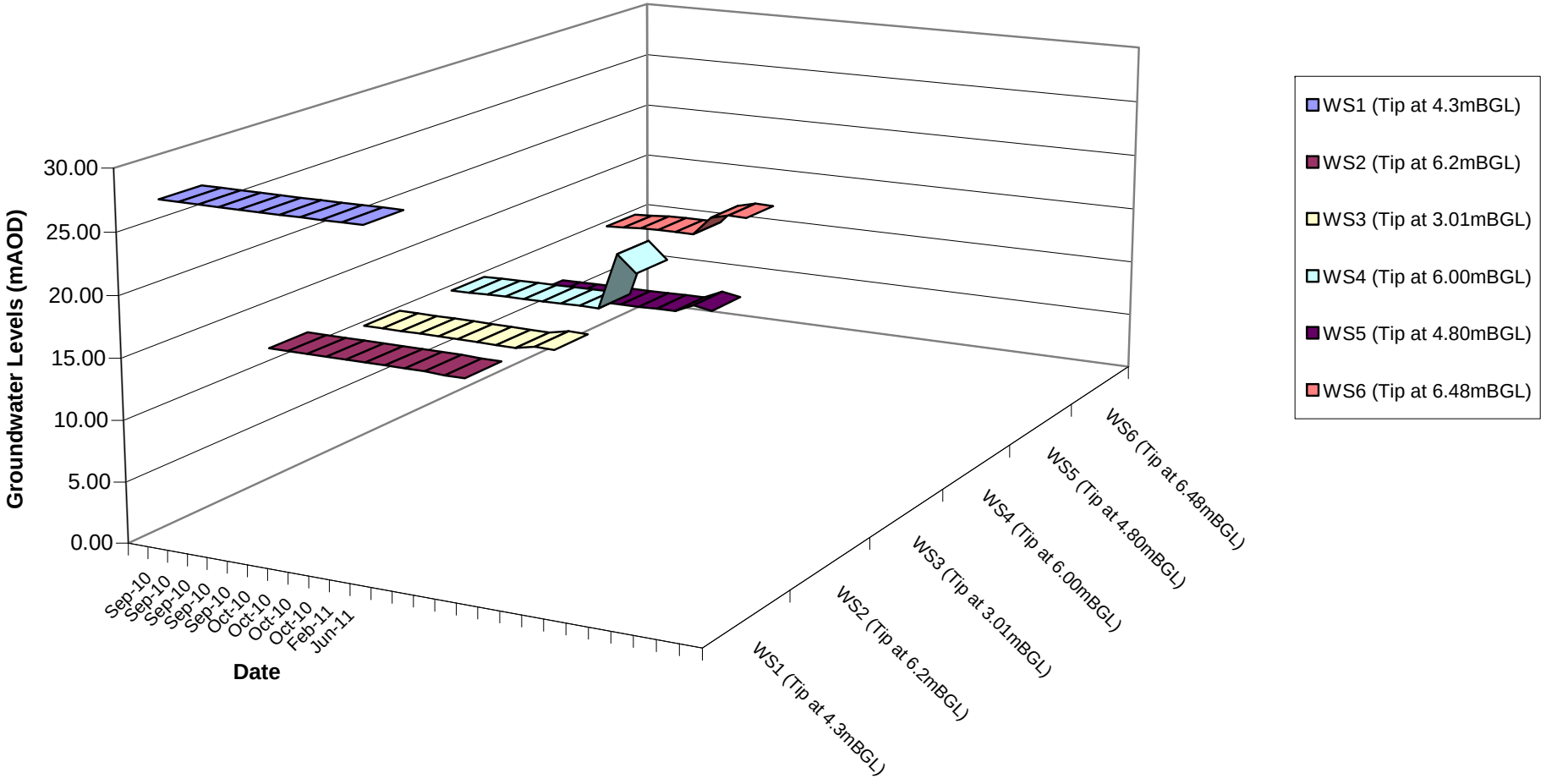


SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS

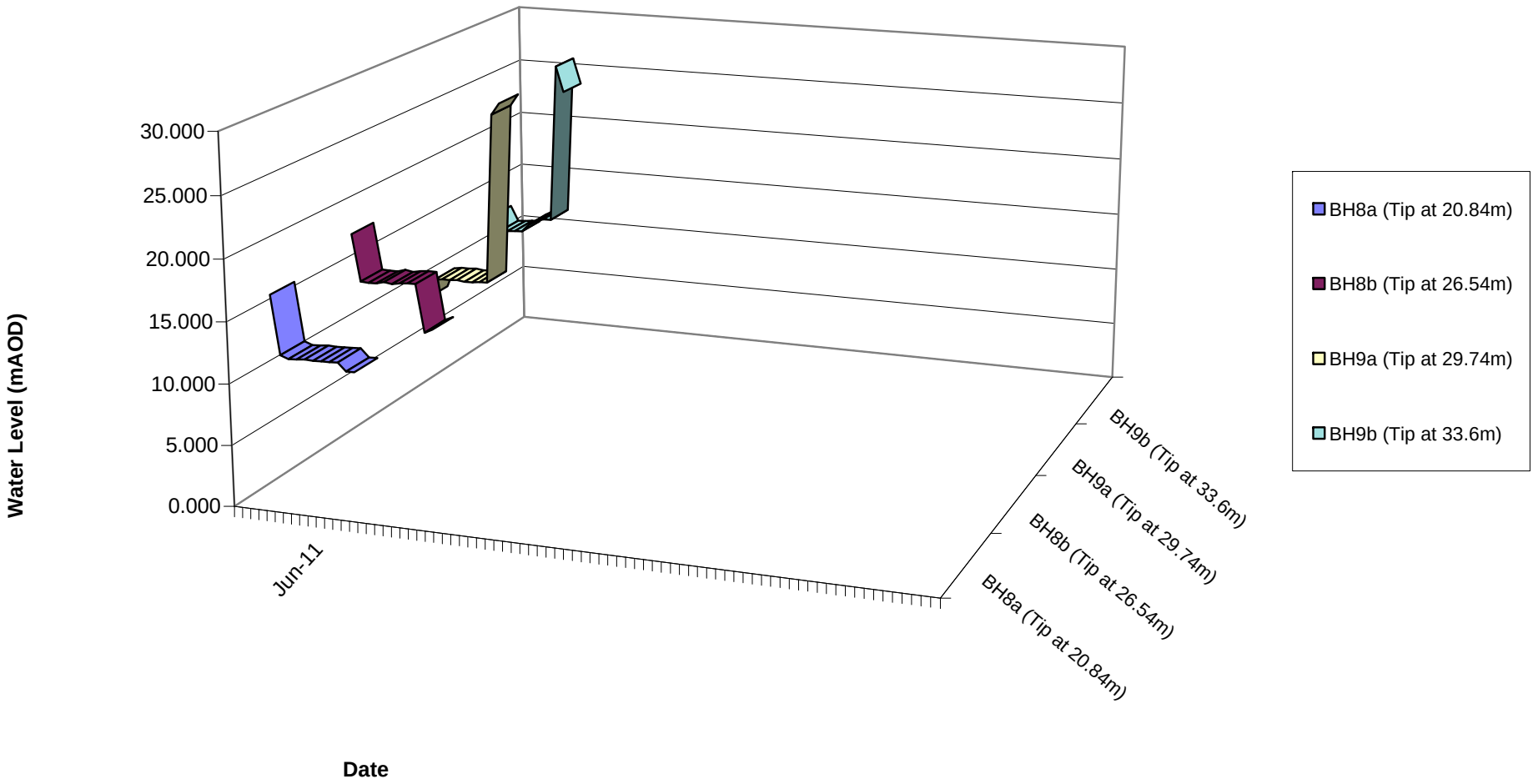


Appendix F Replacement Installation Groundwater Monitoring Graphs

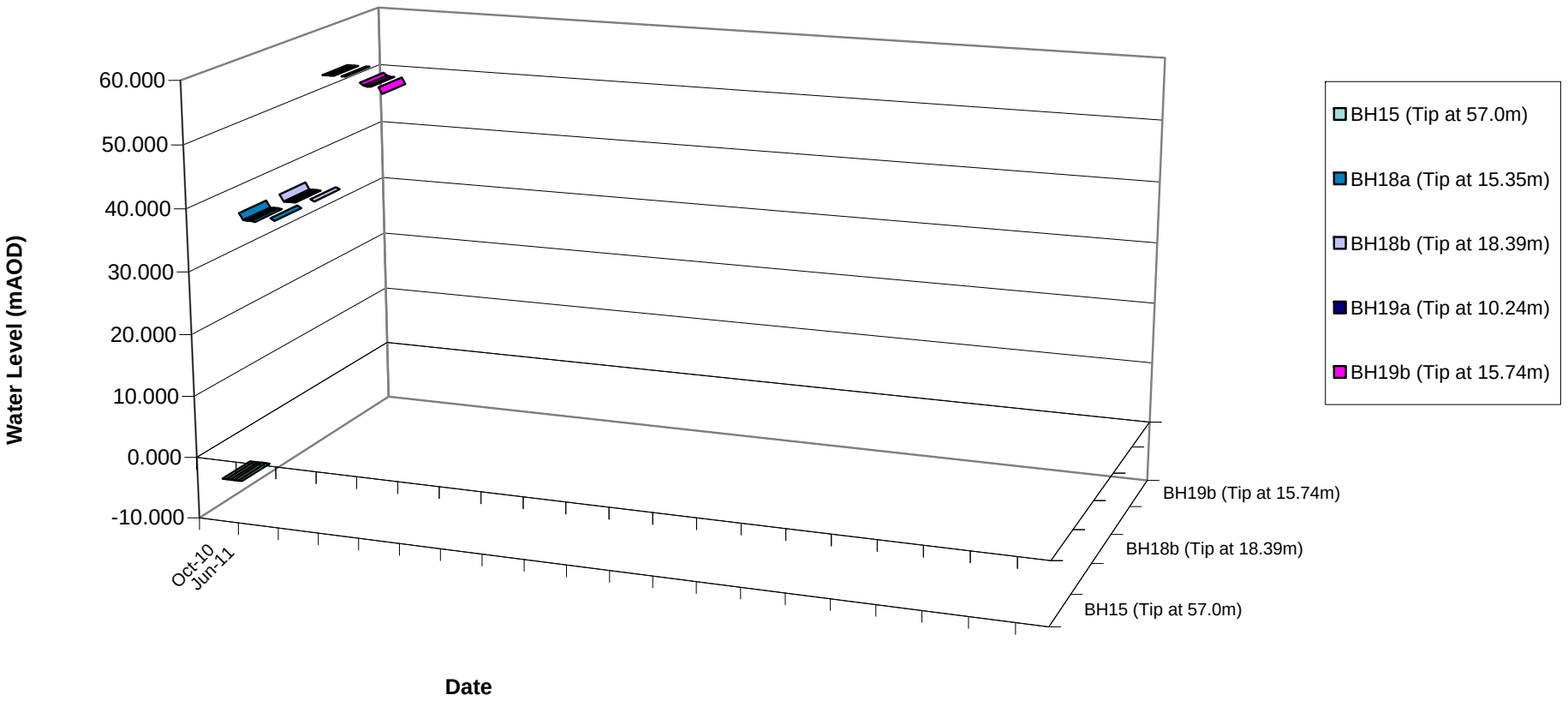
SCALBY NESS REPLACEMENT INSTALLATION GROUNDWATER LEVELS



THE HOLMS, SCARBOROUGH REPLACEMENT INSTALLATION GROUNDWATER LEVELS



SCARBOROUGH SOUTH CLIFF REPLACEMENT INSTALLATION GROUNDWATER LEVELS



Appendix G Survey Data

Initial Monitoring of Survey Points – 22nd 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 – 22nd July 2009 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 – 24th 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 – 24th August 2009 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 – 21st 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 – 21st September 2009 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 – 12th 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 – 12th October 2009 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 – 16th 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 – 16th November 2009 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 – 14th 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 – 14th December 2009 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 – 15th 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 – 15th June 2010 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 – 13th 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 – 13th December 2010 (Continued)

Scarborough South Cliff (Central Section)					
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		

Scarborough South Cliff (South Section)					
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 - 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)

Scarborough South Cliff (Central Section)						
E3	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						

Scarborough South Cliff (South Section)						
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	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	Slope Distance
MP1	8.309m	8.309m	8.310m	8.307m		
MP2	7.870m	7.868m	7.869m	7.872m		
MP3	8.657m	8.656m	8.660m	8.660m		
MP4	12.623m	12.620m	12.618m	12.618m		
MP5	11.657m	11.659m	11.661m	11.662m		
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	Distance to Edge
MP1	3.15m	3.15m	3.15m	3.15m		
MP2	4.30m	4.30m	4.30m	4.30m		
MP3	2.65m	2.65m	2.65m	2.65m		
MP4	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	Slope Distance
MP1	7.207m	7.212m	7.216m	7.213m		
MP2	6.078m	6.073m	6.080m	6.086m		
MP3	9.112m	9.113m	9.112m	9.108m		
MP4	10.320m	10.321m	10.315m	10.322m		
MP5	9.252m	9.247m	9.250m	9.249m		
MP6						

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

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

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

Ongoing Coastal Monitoring of Survey Points - Monthly Comparison

Knipe 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
Knipe Point Headscarp						
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
A165 Old Filey Road Headscarp						
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
R1I	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	*	*	*		*	*
Cornelian Bay Headscarp						
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

Knipe 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
Knipe Point Headscarp						
H01	12.25m	12.22	12.26	12.24	12.20	
H02	5.30m	5.27	5.54	5.50	5.38	
H03	4.40m	4.46	4.42	4.41	4.40	
H04	6.20m	6.15	6.20	6.20	6.15	
H05	19.80m	18.78	Pin Gone	-	-	-
H06	20.90m	20.85	20.78	20.75	18.55	
H07	19.10m	18.73	18.75	18.63	18.60	
H08	3.60m	3.63	3.63	3.61	3.72	
H09	7.40m	7.36	7.36	7.33	7.25	
H10a	10.70m	10.35	10.15	10.17	10.20	
H10b	New	11.83	11.86	11.82	11.60	
H11	7.40m	6.77	6.82	6.80	6.80	
H12	15.90m	15.86m	15.87	15.86	15.86	
H13	4.90m	4.77m	4.79	4.79	4.83	
H14	4.07m	4.08m	4.02	4.03	Pin Gone	-
H14	8.80m	8.79m	8.77	8.77	Pin Gone	-
H14	11.18m	11.21m	11.12	11.12	Pin Gone	-
A165 Old Filey Road Headscarp						
R01	8.21m	8.21m	8.21m	8.21m	8.21m	
R01	17.25m	17.25m	17.25m	17.27m	17.25m	
R01	11.21m	11.21m	11.21m	11.22m	11.21m	
R01	3.10m	3.10m	3.10m	3.10m	3.10m	
R01I	20.10m	19.96m	19.96m	19.97m	19.97m	
R02	11.10m	11.15m	11.15m	11.12m	11.14m	
R03	9.20m	9.37m	9.37m	9.39m	9.39m	
R04	6.20m	6.35m	6.35m	6.31m	6.32m	
R05	7.60m	7.98m	7.98m	7.67m	7.66m	
R06	*	*	*	*	*	*
Cornelian Bay Headscarp						
C01	3.70m	3.70m	3.59	3.53	3.70	
C04	3.90m	3.90m	3.90	3.91	Pin Gone	-
C08	N2.20,E3.01m	N1.86,E3.01m	N1.89,E3.03	N1.73,E2.00	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) BH1I

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 (4th March 2010)

Plate 77 Knipe Point BH02 (4th March 2010)

Plate 78 Knipe Point BH03 (4th March 2010)

Plate 79 Knipe Point BH04 (4th 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 (17th June 2011)

Plate 2 Cornelian Bay side of Knipe Point looking northwest (13th December 2010)

Plate 3 Cornelian Bay side of Knipe Point looking northwest (5th May 2010)

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

(Note loss of survey pin C08, C04 and boundary fence)

Plate 5 Cornelian Bay side of Knipe Point looking east (13th December 2010)

Plate 6 Cornelian Bay side of Knipe Point looking east (5th May 2010)

Plate 7 Cliff recession at Knipe Point Headscarp (17th June 2011)

Plate 8 Cliff recession at Knipe Point Headscarp (13th December 2010)

Plate 9 Cliff recession at Knipe Point Headscarp (17th June 2010)

Plate 10 Cliff recession at Knipe Point Headscarp looking east (17th June 2010)

Plate 11 View of mudslide on Knipe Point Headscarp, below survey pin H06 (13th December 2010))

Plate 12 Cliff recession at Knipe Point Headland (5th May 2010)

Plate 13 Cliff recession at Knipe Point Headland (13th December 2010)

Plate 14 Cliff recession at Knipe Point Headland (17th June 2011)

Plate 15 Cliff recession at Knipe Point Headland looking east (17th June 2010)

Plate 16 Cliff recession at Knipe Point Headland looking east (13th December 2010)

Plate 17 Cliff recession at Knipe Point Headland looking east (17th June 2011)

Plate 18 Cliff recession at Knipe Point Headland looking east (17th June 2010)

Plate 19 Cliff recession at Knipe Point Headland looking east (13th December 2010)
(Note tension crack development in foreground)

Plate 20 Cliff recession at Knipe Point Headland looking east (17th June 2011)

Plate 21 Knipe Point Residential Plan

Plate 22 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