Ongoing Analysis and Interpretation of Coastal Monitoring Data

Second Review of Full Suite Monitoring

Geotechnical Interpretative Report

January 2010

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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 detailed a definition and understanding of the problems at each site based upon the existing data, identified current and potential risks associated with ground movements at each 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 above 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. 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 carried out over this period.

This report describes and details the findings of the **Second Full Suite** monitoring event undertaken, in early December 2009, as part of the monitoring regime recommended in the preceding report of March 2009.

At the majority of sites, little or no ground movements have been identified by the remaining, installed instrumentation during the period of monitoring so far undertaken. Monitoring data from the inclinometers at Whitby West Cliff and Filey Flat Cliffs have so far shown that no discernible ground movements have occurred within the slopes at these two sites (although the survey stations at Whitby have recorded surface movements of -7mm since November). Results of monitoring at Scalby Ness indicate both slopes are also relatively stable and currently display no signs of cliff recession. The results of inclinometer monitoring in Scarborough North Bay indicate the slopes above the Oasis Café are presently in a stable condition in the vicinity of the inclinometers, although limited movement is indicated in BH1 and 4 of up to 4mm in a down slope direction. However, the lack of inclinometers and limited piezometer coverage of the remainder of The Holms site means that any ground movements over

this area may not be detected. Along the gardens of South Cliff, monitoring data from the inclinometers and survey pins has generally shown that any ground movements so far detected are restricted to relatively shallow disturbances around AA04, AA11 and AA10 with no ground movements indicated at the remaining inclinometers.

Monitoring at Runswick Bay has taken place on two occasions, the first in July and a repeat visit in December 2009. The initial visit collected 'baseline' readings against which all successive readings are compared. The latest readings indicate some movement has occurred within inclinometers installed at A001 and A004. Within A001, 5mm of movement has been indicated between 22.0 and 20.0 metres depth and in A004; 5mm movement is indicated from 10.0m depth increasing to 15mm at 2.0m depth. In each installation the ground movements are indicated as taking place in a down slope direction.

At Filey Town, a similar pattern of monitoring has been undertaken on the inclinometers (BH03 and 06) which have been installed atop glacial slopes above Royal Parade. Due to possible vandalism, BH03 has not been monitored and no further analysis of this instrument is available. The results of monitoring BH06 since July 2009, illustrates at depths of between 10.5 and 7.0 metres up to 2mm ground movement has occurred in a down slope direction (perpendicular to the coastline).

A summary of total observations made from the start of monitoring (July 2009) and observations made since the last monitoring event of November 2009 are presented below in Table 1.

Table 1 Summary of Site Observations

SITE	Observations made since last Monitoring Event (Nov. 2009)*	Total observed movement since first Monitoring Event (July 2009)
Runswick Bay	Not monitored since July, no comparison available	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
Whitby West Cliff	Survey pins show -6mm movement in top one metre of ground. Inclinometer indicates slopes are stable	Survey pins show -7mm movement in top one metre of ground. Inclinometer indicates slopes are stable
Scalby Ness	No further cliff recession observed from all survey stations. Inclinometers indicates slopes are stable	10mm cliff recession recorded at MP3 between July-August, none at other three stations
Oasis Cafe	Slopes stable, limited movement of <4mm indicated in BH1 and 3	Slopes stable from August up to November 2009
North Bay	Slopes stable as above - Oasis Café, no coverage of The Holms area	Slopes stable as above - Oasis Café, no coverage of The Holms area
South Cliff	AA04 shows no further movement AA07 and 08 no movement AA10 shows no further movement AA11 shows no further movement	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
Filey Town	Slopes indicated as stable around Glen Gardens above Royal Parade	2mm ground movement indicated in BH06 between 10.5 and 7.0 metres depth. Slopes stable BH03 'lost' to vandalism
Flat Cliffs	Slopes indicated as stable though very limited coverage of site	Slopes indicated as stable though very limited coverage of site

* Runswick Bay and Filey Town sites were previously monitored in July 2009.

1 Introduction

1.1 Description of the Project

1.1.1 Monitoring

Scarborough Borough Council's (SBC) local coastal monitoring programme extends along the length of its North Yorkshire coast from Staithes in the north to Speeton in the south, a distance of approximately 68 km. Coastal settlements include Runswick Bay, Whitby, Scalby Ness, Scarborough North and South Bay, Knipe Point, Killerby, Filey Town & Brigg and Filey Flat Cliffs, most of which have defended frontages. Some of these coastal defences are now ageing, in poor condition and are subjected to an aggressive wave climate. Furthermore the defences are, for the most part, backed by coastal slopes which show evidence of both instability and climatic denudation. These factors, together with environmental considerations of predicted climate change scenarios and sea level rise, focus the need for constant attention in order to minimise potential risks to the public and coastal assets of the Borough.

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

Table 2 Frequency of Ongoing Monitoring

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

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. 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.

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

Runswick Bay - Six monthly (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 remaining two and a half years if no significant movement detected.

Scalby Ness - Three monthly intervals for three years. Install 4No. recession points along north west and north east facing crests and monitor every month following installation for six months and then bi-annually for remaining two and a half years.

Scarborough North Bay - 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 E3, BH2 and H4 and monitor in line with instrumentation.

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

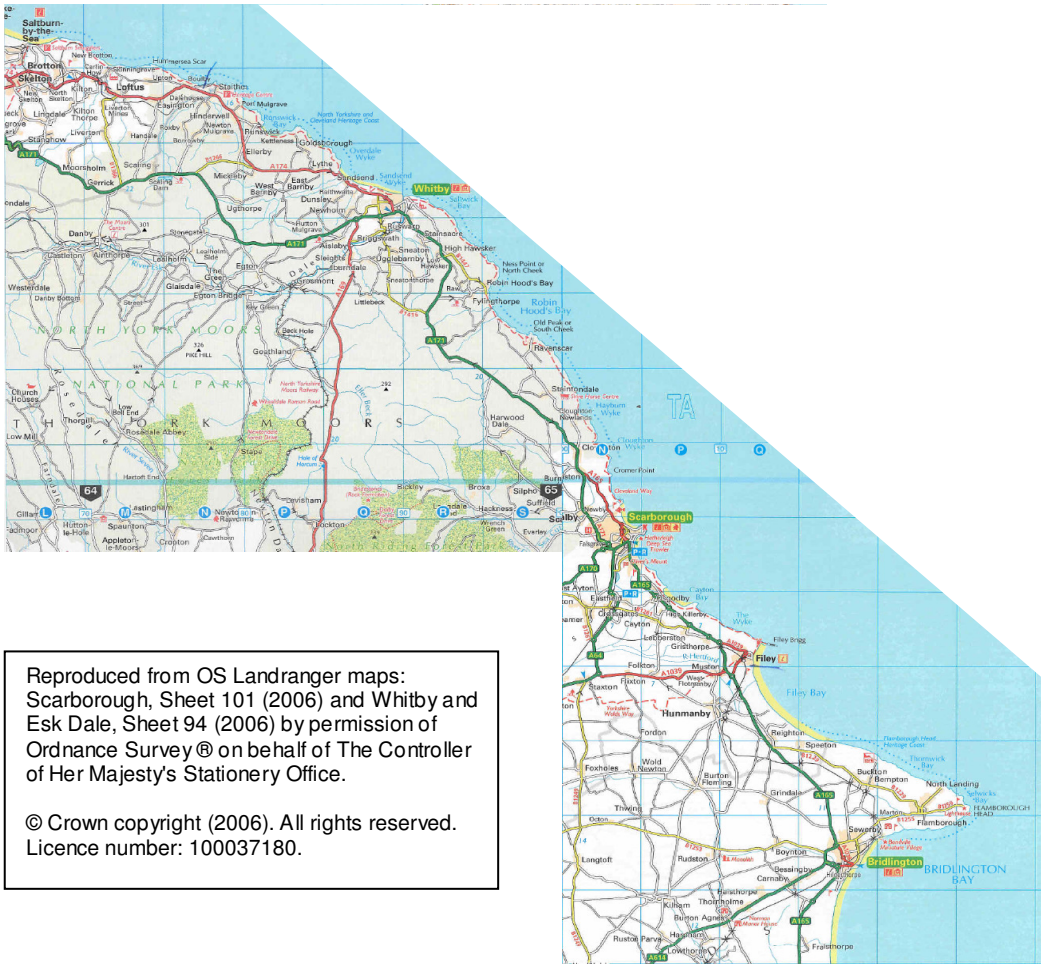
Filey Flat Cliffs - Monthly intervals for six months and then every two months until month twelve. Revert to bi-annual intervals for the remaining two years if no significant movement detected.

In addition to the sites detailed above, SBC have instructed Mouchel that Robin Hood's Bay site and additional borehole installations at other sites are to be included within successive analyses at some point in the future, while the site

at Knipe Point has been removed from our remit until further notice. The recession point sites along with that at Killerby are similarly not under consideration for this analysis at the time of writing this report. The monitoring of instrumentation installed at Knipe Point is currently being undertaken by a third party on behalf of The National Trust.

Site location plans are presented as Figures 2 to 8 within the relevant chapters. Exploratory holes location plans illustrating the locations of instrumentation (automated piezometers, piezometers / slip indicators and inclinometer installations) are presented in Appendix A.

Figure 1 Scheme Location



1.2 Previous Studies

Mouchel were required to review, analyse and interpret existing data, provided in electronic and hardcopy forms, held by SBC for all the sites mentioned in Section 1.1. This data covered previous plans, monitoring records, strategies,

ground investigations, borehole records, groundwater information, laboratory test data and geomorphological mapping. A geotechnical interpretation and appraisal of these reports has been presented in Mouchel Report No. *721228/001/GR/01/02/FINAL*. An Arcview GIS layer has been produced with all the data and reports made available by SBC as well as reports produced by Mouchel. At each interval of monitoring, this layer is subsequently up-dated with the results of recorded monitoring data.

1.3 Definition of Prolonged Periods of Rainfall

Rainfall data records have been made available to Mouchel by SBC and the Environment Agency (EA). Data supplied is referenced to weather stations throughout the region at Loftus, Fylingdales, Whitby School, Scarborough and Knipe Point, Mulgrave Castle and Ruswarp. Within Mouchel Report "*Analysis and Interpretation of Coastal Monitoring Data" 721228/001/GR/01/02/FINAL,* reference has been made to 'periods of heavy and / or prolonged rainfall' in terms of considering such an event with respect to their effects upon slope stability.

This subject has been refined through analysis of rainfall data records made available by the EA and SBC and the definition of such an event has been quantified within the context of the effects of such an event on the present monitoring regime frequency. The analysis and definition of this subject is to be presented in a separate report entitled '*Definition of Heavy and / or Prolonged Rainfall* – 721229/004/GIR/001'.

1.4 Instrumentation Monitoring Procedures

1.4.1 Inclinometers

The initial monitoring event for the Ongoing Monitoring Regime was initiated in July 2009 by a suitably qualified geotechnical engineer. Inclinometer instruments were initially investigated using a test probe (dummy) inclinometer on a 100 metre length cord. The test probe was lowered to the base of the tubing to prove its integrity. Where the instrument did not reach the base, due to a blockage or loss of tubing integrity, this depth was recorded and no further inclinometer data was recorded. Groundwater within the instrument tubing was measured and recorded using a dip meter. The measurement of groundwater in inclinometers is to continue throughout the term of the contract.

Although some inclinometer instruments are not monitored due to various failures / blockages within the installed tubing, these instruments are still being read with a dip meter to provide an indication of groundwater levels.

Where the instrument tubing was proved to be intact, a Vertical Digital Inclinometer probe {using a Bluetooth system (MkII) with a TDS Recon 200 PDA} was lowered to the base of the tubing, allow the probe to temperature stabilise and measurements were recorded at half metre intervals as the probe is raised. (The probe must be left at the base of the tube to allow for temperature stabilise prior to beginning data acquisition). Readings of inclination were recorded in two directions (A0 and A180) within the inclinometer tube; A0 being the principal direction of interest in ground movements 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. The 'B' directions are not read manually as the biaxial accelerometers read both B axes during the survey.

This process was repeated in order to give two sets of 'Baseline' readings, which are averaged to give a more accurate 'Baseline' reading and create repeatable base data. Successive sets of readings are compared to the initial 'Baseline' readings to provide an indication of ground movements. The follow-up readings consist of recording a single set of readings in the A0 and A180 direction for each individual inclinometer instrument.

As further readings are recorded and processed, a graph of individual plots is built up over the monitoring period which will either display the effects of ground movement as successive plots deviate further from the baseline reading or, if no movements occur then the graphs will plot within millimetres of the baseline reading.

1.4.2 Piezometers and Slip Indicators

Groundwater levels within piezometer tubes have been recorded using a 50 metre length dip meter. A piezo tip emits an audible signal when it comes into contact with water, the depth to water is read off the tape and this is recorded. 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 depth.

Where slip indicators are present, they consist of one metre length mandrels resting at the base of piezometer tubes attached to a chord at ground level. The mandrels are lifted from base to top of the tube to indicate if any distortion or blockages have occurred within the tubing. Where mandrels were found to be jammed within the tubes, a reading was taken from ground level to the top of the mandrel to give an indication of the depth at which possible failure of the ground had taken place. Where this had 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 as the inserted mandrels function free of any obstacles. Hence, these instruments continue to demonstrate that no discernible ground movements are occurring.

Groundwater level readings recorded from inclinometer instruments should be viewed and interpreted with care. This type of installation is used for the monitoring of sub-surface ground movements and not groundwater monitoring. However, in conjunction with the correct instrumentation (piezometers), readings extracted from inclinometers can provide extra information on the nature of the prevailing groundwater regime at a site under observation.

1.5 Interpretation Views

1.5.1 Cumulative displacement

The most commonly used plot type is the Cumulative Displacement plot, which shows a displacement profile of 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.

1.5.2 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 plotted from reading to reading (i.e. delta previous not delta datum).

1.5.3 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.

The Cumulative displacement plot is used to display results of inclinometer readings in-line with historic inclinometer data.

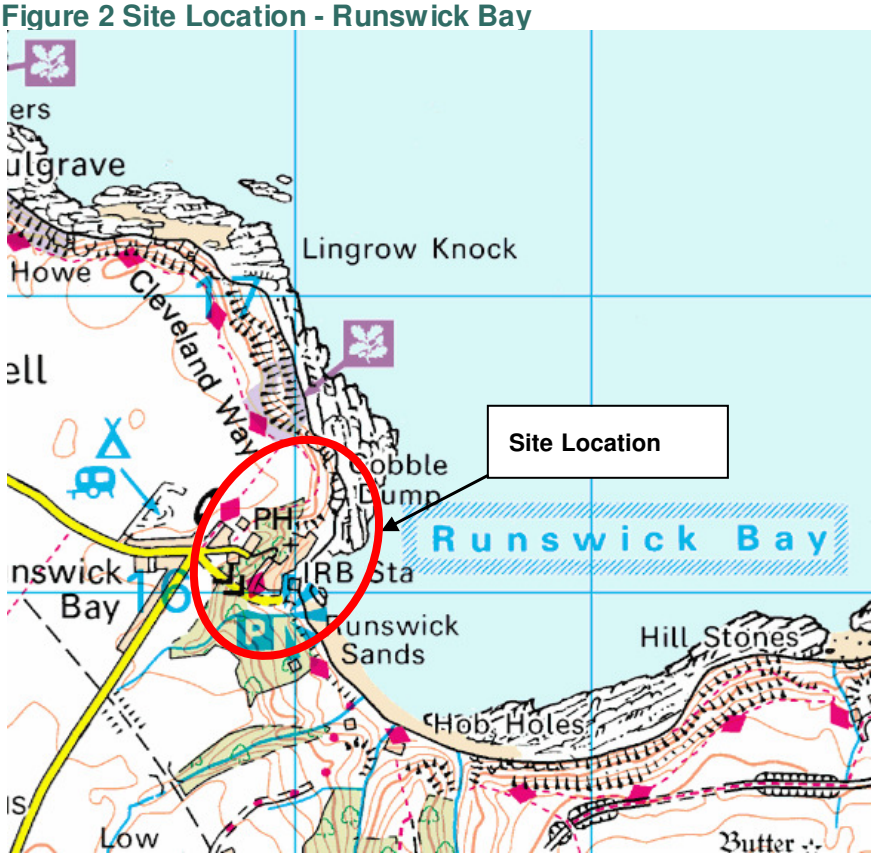
Historic inclinometer data has not been amalgamated with that currently being collated as the various formats of the data would not produce a true, coherent interpretation of possible ground movements occurring at each of the sites being monitored. In some cases historic inclinometer monitoring data is not available (i.e. Filey and Filey Flat Cliffs) and hence comparisons with current data have not been possible. Where an interpretation of historic inclinometer data has been formulated, this will permit a continuum of interpretation to be developed. As more readings are taken, consecutive graphs may illustrate the nature and rate of any ground movements present at a site.

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 to 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 rockfalls 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 3 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 the sandstone present further inland. Groundwater seepages have been experienced, during ground investigations, from the basal backscarp areas and from within disturbed shales immediately below the glacial tills some distance from the slope toe.

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

2.1.2 Existing Information

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

2.2 Stratigraphy

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

The map indicates a north-south trending fault passing beneath the village and across the upper beach area to the south, with down throw and inclination to the west.

2.3 Groundwater Regime

Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Non-Aquifer because of 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 with persistent pollutants. 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 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 increasing slope stability. The greater significance has been the re-orientation of the vector angle of slope movement in a clockwise direction, in a more easterly direction. It is envisaged that following prolonged periods of heavy rainfall, the slopes would continue to fail. However, the probability and risk to village infrastructure of deep seated failures occurring in the future is considered low due to 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 monitoring 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. Groundwater was measured with a dip meter.

2.5.3 Ongoing Monitoring Results

Inclinometer Readings

Monitoring inclinometers has been undertaken in accordance with the procedures detailed in Section 1.4 of this report. Monitoring at Runswick Bay has taken place on two occasions, the first in July and a repeat visit in December 2009. The initial visit collected 'baseline' readings against which all successive readings are compared. The latest readings indicate some movement has occurred within inclinometers installed at A001 and A004. Within A001, 5mm of movement has been indicated between 22.0 and 20.0 metres depth and in A004; 5mm movement is indicated from 10.0m depth increasing to 15mm at 2.0m depth. In each installation the ground movements are indicated as taking place in a down slope direction.

Inclinometer readings are presented in Appendix B of this report.

Groundwater Readings

Groundwater levels were recorded during the Condition Survey (16th June 2009), the initial Full Suite Monitoring readings (9th July 2009) and the Second Full Suite Monitoring (8th December 2009). A comparison of the readings shows very little change in groundwater levels over this period, the maximum difference of 110mm recorded in A004 (BH3) between July and December 2009. Groundwater readings are presented in Appendix C.

2.6 Conclusions

Inclinometer instrumentation was installed within selected piles of a portal frame shear key system which was constructed as part of remedial works to restrict ground movements within the Runswick Bay area. Inclinometers were installed in piles in order to measure 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 from 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 movement has taken place in A002 and A003. However, readings indicate that some movement has occurred within inclinometers installed at A001 and A004. Within A001, 5mm of movement has been indicated between 22.0 and 20.0 metres depth and in A004; 5mm movement is indicated from 10.0m depth increasing to 15mm at 2.0m depth. In each installation the ground movements are indicated as taking place in a down slope direction.

Due to the frequency of monitoring undertaken at this site (6-monthly intervals) coupled with the evidence of ground movements now reported from the last visit (December 2009), it is recommended that Runswick Bay site should be included into the Restricted Suite of monitoring. At the time of writing this report (January 2010), a Full Suite of monitoring is being undertaken, to be followed by a Restricted Suite (February and April 2010) and a further Full Suite of monitoring in March 2010. This would provide more frequent monitoring results covering a 5-month period (December 2009 to April 2010) on which to analyse the nature and rates of ground movements.

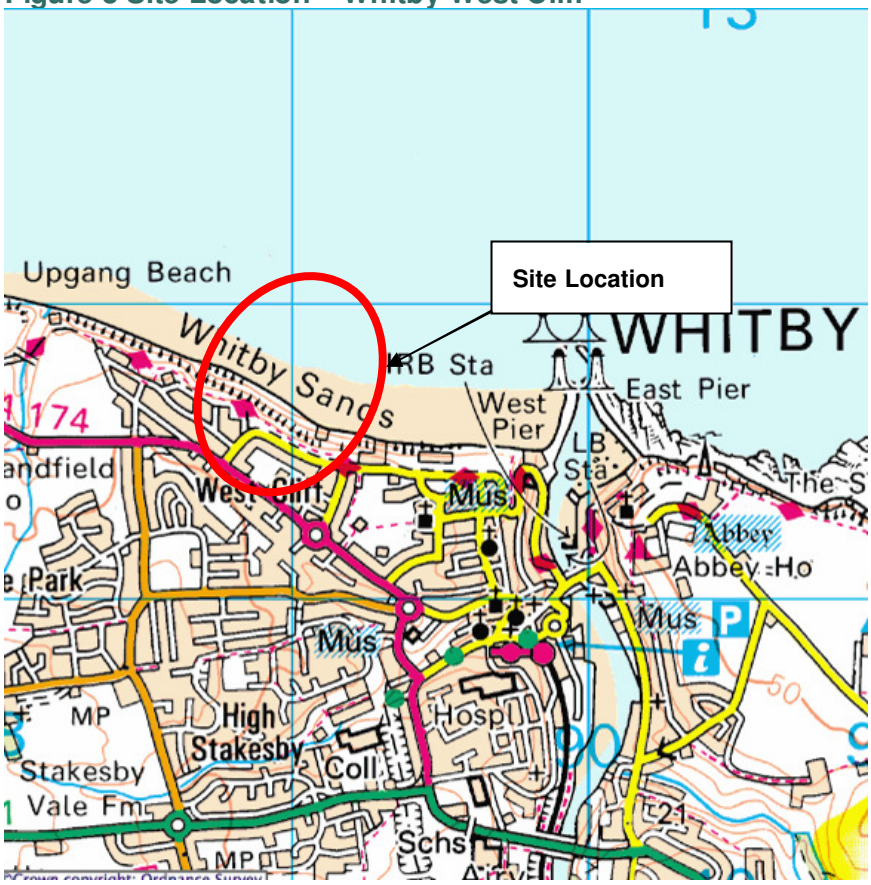
3 Whitby West Cliff

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 protected soft, glacial till cliffs to the west of Whitby harbour and, further west towards Sandsend the coastline is formed of unprotected soft, glacial till cliffs.

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 Cliffs 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. Soils of class I1 are those possibly able to transmit a wide range of pollutants. 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-cycle. 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. 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 is detected.

A line of survey pins was installed at 5 metre intervals down the line of the slope from beyond the crest and in line with the existing inclinometer (BH2). The survey stations are to be measured initially at a monthly frequency for six months to build up base data. If there is no significant movement (<5 mm) between each survey point, (between each monitoring event) then the frequency will be reduced to that in line with the inclinometer monitoring i.e. on a bi-annual frequency.

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 was measured with a dip meter.

3.5.3 Ongoing Monitoring Results

Inclinometer Readings

Monitoring of inclinometers has been undertaken in accordance with the procedures detailed in Section 1.4 of this report and are presented in Appendix B. Readings have so far shown that little or no ground movements have occurred within the slopes around BH2 at West Cliffs.

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 7.73 metres consecutive readings have recorded successive rises in water levels of +900mm, +130mm, +110mm, +450mm and +460mm. Given that the tidal position was known and observed at the time readings were taken, this data can be interpreted as reflecting the changes in tidal levels at the time of monitoring. Groundwater readings are presented in Appendix C.

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 were surveyed monthly between July and December and showed that over a distance of 49metres, -7mm of surface movement had occurred during that period. The readings from the survey points are presented in Appendix D.

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. The successive readings of October, November and December 2009 confirm this to be the case as these plots follow the first set of readings and indicate that no ground movements have occurred. The inclinometer data, recorded so far, 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 reflect this type of movement (showing -6mm movement between November and December 2009), ground movements of up to +13mm, in a down slope direction, were recorded by survey pins within the surface of the slopes between October and November 2009. During the previous period, from September to October, a difference of +11mm was recorded illustrating that there is some differential fluctuation in ground movements. The total recorded movement within the slope is -7mm, measured between July and December 2009. The variation in spacing between the survey pegs could be accounted for by seasonal temperature fluctuations.

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.

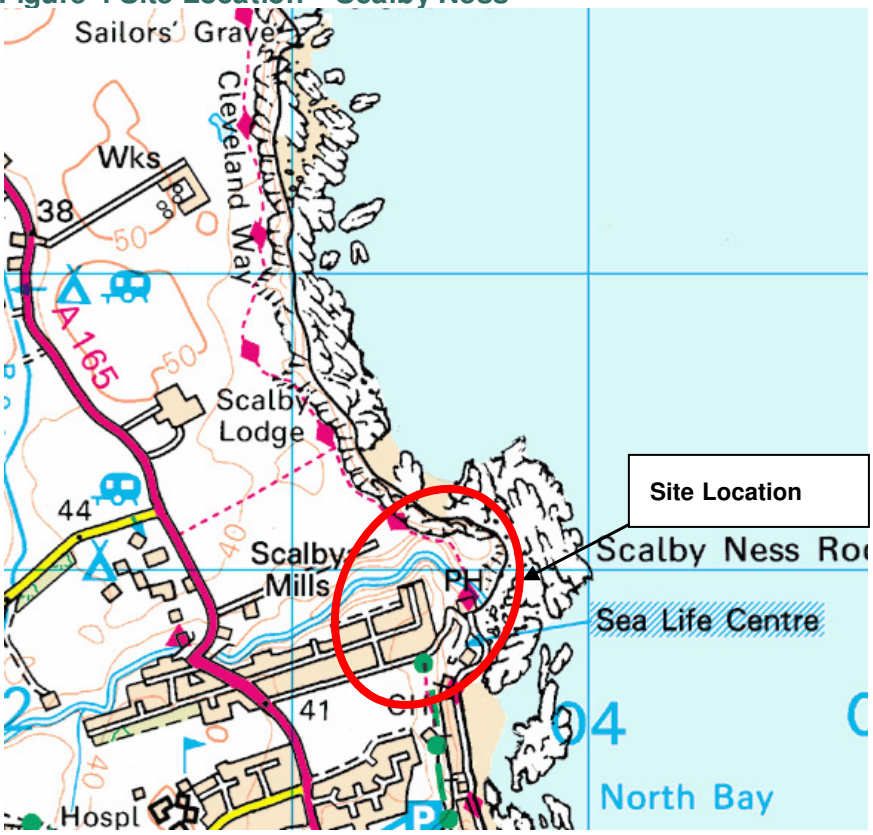
4 Scalby Ness

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.

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. All 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 pollutants are unlikely to penetrate the soil layer because either water movement is largely horizontal or because they have the ability to attenuate diffuse pollutants. 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 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 instability and the assets located above results from coastal erosion of the toe and crest erosion from 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.

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 3no. inclinometers (I1, I2 and I3) and 2no. piezometers (B6 and B9) located within the inner headland of Scalby Ness. The monitoring of the automated piezometers (P1, P2, P3 and P4) was carried on 12th November 2009. 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 reduced monitoring regime is based upon the findings of the *Condition Survey Report*. This detailed 6no. piezometers recommended for replacement due to differences in dipped and installed depths and, an inclinometer (Sn1) and a piezometer (BH114) as not being located due to dense vegetation and hence not available to monitor. Following vegetation clearance Sn1 was found (20th October 2009) and is now included within the monitoring regime. BH114 has yet to be located. The inclinometer tube of Sn1 was initially dipped with a dip meter and then tested for internal integrity by lowering a test inclinometer probe through the length of the casing. The base of the instrument was proved to a shallower depth than the original installed depth, thus concluding that the instrument was damaged (sheared) due to ground movements. In future, this instrument is to be monitored for groundwater levels only and no further inclinometer monitoring is to be undertaken on it. The dipped depth and the installed depth of this instrument are included in Appendix C.

4.5.3 Ongoing Monitoring Results

Inclinometer Readings

Monitoring inclinometers has been undertaken in accordance with the procedures detailed in Section 1.4 of this report and are presented in Appendix B of this report. Readings from the inclinometers have so far illustrated that little, if any, ground movements have occurred since the baseline readings were taken on 16th July 2009.

Groundwater Readings

Groundwater levels were recorded during the Initial Full Suite Survey (16th July 2009), during the Fourth Restricted Suite monitoring (11th November 2009) and the Second Full Suite on 8th December 2009. Water levels recorded at each interval have reflected reductions in ground water across the site ranging from 0.01m (B9) to 0.43m (I3). Increases in groundwater levels were experienced in I1 (+2.86m) and Sn1 (+1.60m) compared to previous readings of November 2009. Rainfall data revealed that rainfall from March to June 2009 was lower than average ranging between -5% and -52% less and August was also drier than average with -61% less rainfall. Groundwater data would seem to highlight the lower than average amounts of rainfall recorded over a similar period of time from July to September.

Piezometric data has been downloaded from data loggers operating within 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 up to 5th November 2009. Within the upper piezometers, groundwater levels are similarly affected by rainfall. At various times over the monitoring period, peaks in groundwater levels have been experienced. An analysis of rainfall data shows that peaks in groundwater levels have been preceded by periods of precipitation which have resulted in raised groundwater levels. This phenomenon is clearly illustrated in graphical data from BH4 where the peaks and troughs of groundwater levels are more pronounced than in 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 (Tip at 18.12mAOD), P2 (Tip at -0.75mBOD) and P3 (Tip at 9.80mAOD), installed to target a lower water table; have remained reasonably constant over the monitoring period. Within P1 the recorded water levels have remained fairly constant at a level of approximately 17.20mBGL. A similar situation can be seen within P2 and P3 where the lower piezometer has recorded regular groundwater levels at approximately 33.50mBGL and 16.10mBGL, respectively within separate water tables. Groundwater readings are presented in Appendix C.

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. Initial readings are presented in Appendix D.

4.6 Conclusions

The survey pins were measured at monthly intervals from July to November 2009. 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. At recession point MP3 a cliff recession rate of 10mm was noted to have occurred between July and August, though zero recession rates have been recorded from August onwards.

The results of inclinometer monitoring indicate both slopes are relatively stable although the on-set of wetter autumn / winter months with higher rainfall may lead to some increased activity of slope recession. Due to the limited coverage of the site offered by the reduced number of instruments, there is the possibility of undetected ground movements occurring elsewhere, particularly below the plateau area, where the majority of instruments are recorded as having failed. During a site visit on 17th December 2009, fresh, minor slumping of mid-slopes and large ponds of rain water forming in mid-slope of Behavioural Unit II were observed (See Appendix H, Plate 14). It is evident that recent periods of heavy rain have resulted in some degradation of the slopes of Scalby Ness.

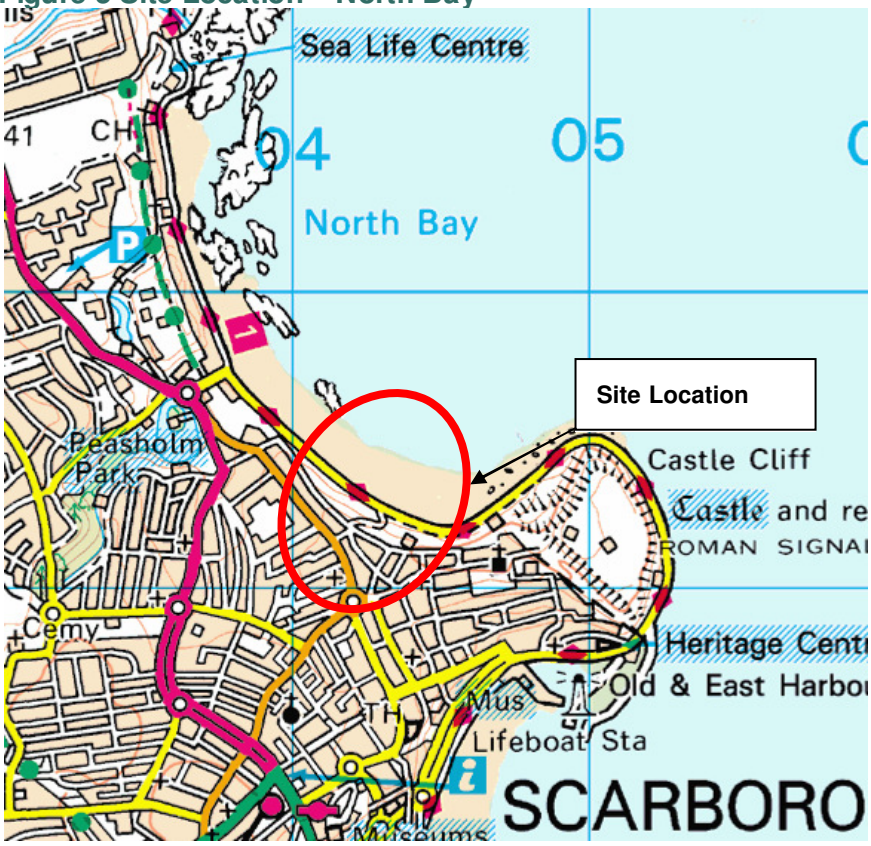
An analysis of rainfall data illustrates peaks in groundwater levels have been preceded by periods of precipitation which have resulted in raised groundwater levels. This is clearly illustrated in graphical data from the shallow piezometers of P1, P2, P3 and P4 where the peaks and troughs of groundwater levels are more pronounced than in other graphs of deeper instruments. The lower instruments in P1, P2 and P3 have targeted 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 variable rainfall.

5 Scarborough North Bay

5.1 Site Location and Description

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. 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.

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 1.50m 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 to the Castle Headland above. The slopes are heavily terraced, displaying hummocky, irregular ground comprising glacial till and possible landslide debris with a mid-slope bench feature dominating the slopes. The glacial slopes rise from Marine Drive, at approximately 7.0mAOD, at angles of 20-35 degrees to a mid-slope bench and terrace at 35.0mAOD, beyond this plateau the slopes composed of rock debris and scree rise to approximately 50 to 55.0mAOD to near shear cliff faces. These cliff faces rise to the pinnacle (83.31mAOD) of Castle Hill on which the remains of Scarborough Castle are apparent. A thin mantle of top soil, up to 0.17m 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 16.0m in the west section and 2.50m-2.95m 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. All 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 200mm had occurred.

Additional installations comprised of 3no. inclinometers and 4no. piezometers located on slopes above The Oasis Café, North Bay were included in the monitoring regime in August 2009.

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.*

Due to the lack of valid continuous data from the installed piezometers, it has been recommended that piezometer monitoring is reinstated. Inclinometer and piezometer monitoring is to be carried out at monthly intervals for six months then every two months until month twelve. If no significant movement is 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 and 2no. inclinometers (located within the grounds of The Holms) and 2no. inclinometers located atop the cliffs above The Holms.

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 then 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 concluding that these instruments were damaged (sheared) due to ground movements. In the future, these instruments are to be monitored for groundwater levels only and no further inclinometer monitoring is to be undertaken on them. The dipped depths, accompanied by the installed depths, of these instruments are included in Appendix C.

Additional installations comprising 3no. inclinometers and 4no. piezometers located on slopes above The Oasis Café, North Bay were included in the monitoring regime in August 2009.

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 above The Oasis Café continue to be monitored within the regime of North Bay.

Groundwater Readings

Groundwater levels were recorded at monthly intervals from the Initial Full Suite Survey (15th July 2009) to the Second Full Suite Survey (8th December 2009). Groundwater levels recorded over this period show very little fluctuation although a variance of 5.67m has been recorded in L1 (b) which is attributed to changes in tidal levels. Also, within L11 and L12 a variance in groundwater levels of 4.77m and 1.85m, respectively was recorded over this same period. Groundwater readings are presented in Appendix C.

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.

Cumulative inclinometer data for inclinometer BH4 (from the Oasis Café) appears to indicate ground movements of up to 5mm although the incremental inclinometer data for BH4 shows 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. Data from BH1 illustrates a similar pattern where three sets of data (September to November 2009) vary from the initial 'baseline' reading indicating some degree of movement. However, the last reading of 9th December 2009 deviates from previous readings indicating ground movements have only occurred since November 2009. The nature of this ground movement is 1mm from 5.0m to 3.0m and <4mm movement from 3.0m up to ground level. At BH3, ground movements have been detected from data showing 4mm of movements have taken place at depths from 3.5m to 2.5m; movement is in a down slope direction.

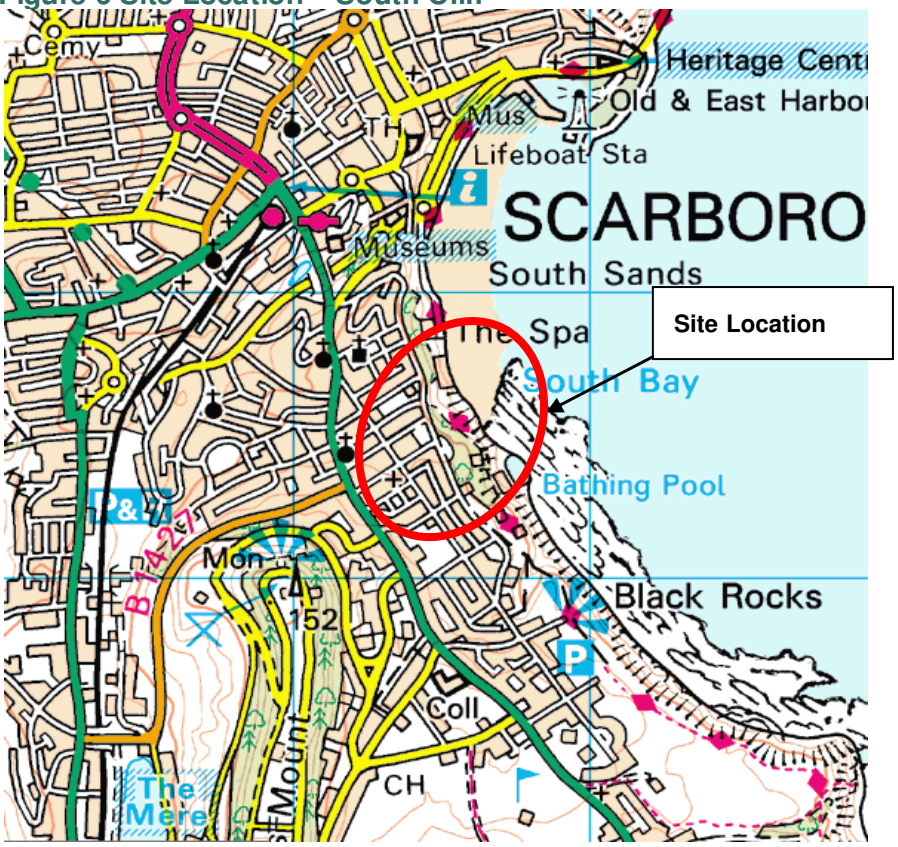
BH3 does not show this 'apparent' movement seen in the other instruments as a single probe has been used to record data. The results of inclinometer monitoring indicate that slopes above the Oasis Café are presently in a stable condition within the vicinity of the inclinometer instruments, although there is evidence of limited shallow ground movements within the slopes. However, due to the limited coverage of the site offered by the inclinometers at Oasis Cafe, there is the possibility of undetected ground movements occurring elsewhere in North Bay.

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. 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's south bay 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 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 200metres 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 150metres 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 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.

6.1.3 Topography and Geomorphology

Late Devensian age glacial tills have been emplaced across much of the 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 South Cliff, the till has completely in-filled a pre-glacial valley and now the whole cliff profile has developed in these glacial tills attaining a height of between 50m and 65m. 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 thickness 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. At 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 and promenade has been built along the base of the cliffline 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. All 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 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 Scalby Formation mudstones and sandstones. 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 South Cliffs vary between and 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 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 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 sites covering 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 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 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. The monitoring encompasses recording readings of inclination in two directions (A0 and A180) within the inclinometer tubes and also monitoring 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 five inclinometers, fourteen piezometers and three lines of survey pins (associated with boreholes H4, E3 and BH2) located within the gardens of South Cliff. 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 reduced monitoring regime is based upon the findings of the *Condition Survey Report.* This detailed 6 no. inclinometers (I1, H4, H6, E3, E5, D1) and 8 no. piezometers / slip indicators (H1, G1, F5, F3, F1, E1, E4, BH1) blocked at varying depths. Also, inclinometer A1 was reported as not being located due to dense vegetation and hence not available to monitor. Following vegetation clearance this instrument is to be introduced into the monitoring regime.

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.

Inclinometer Readings

Monitoring of inclinometers has been undertaken in accordance with the procedures detailed in Section 1.4 of this report and are presented in Appendix B. Readings have so far illustrated the occurrence of ground movements in the form of surface creep within several inclinometers at South Cliff.

Groundwater Readings

Groundwater levels were recorded during the Initial Full Suite Survey (15th July 2009) and the Second Full Suite monitoring readings (09th December 2009). A comparison of the readings show a wide variation in depth changes illustrating variations in tidal levels and groundwater regimes active across the sites of South Cliffs. Groundwater readings are presented in Appendix C.

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. Initial readings are presented in Appendix D and photographs of the survey points are presented in Appendix E.

6.6 Conclusions

Monitoring data from the fifth set of inclinometers and survey pins readings has generally shown that ground movements are restricted to relatively shallow disturbance around AA10 and AA04. In inclinometer AA11 a slight movement of <3mm was recorded within the top 3 metres of ground. In the previous reading ground movement of <2mm was recorded between 17m and 13m in a down slope direction. The provision of further data has verified the interpretation to be due to an erroneous reading since the latest data follows a similar trend to the first two sets of readings and illustrates no ground movement is taking place.

Within inclinometer AA10 ground movements of up to 4mm are apparent from 3.5 metres depth to ground level. This movement has occurred in made ground and is probably evidence of surface creep. A similar scenario of ground movements is evident in AA04 where 2mm of movement is illustrated from 7 metres depth to ground level within Glacial Till and made ground. Further 'apparent' movements indicated by the readout graphs for AA08, AA07 are attributed to the use of two different probes for monitoring. Due to the limited coverage of the site offered by the reduced number of inclinometers, there is the possibility of undetected ground movements occurring elsewhere particularly along the promenade where the majority of instruments are recorded as having failed.

Plates 68 and 69 (Appendix E) illustrate the effects of ground subsidence in the pavement along the promenade.

The results of groundwater monitoring have so far shown an overall increase in the general water table or the perched water tables targeted by piezometers at South Cliff. The results of monitoring reflect the affects of increased rainfall expected to occur during and throughout the wetter months of winter. Several exceptions to this were recorded in BH1 Spa (Top), E5, D1, H2b, G3, E2b and D2a where water levels had apparently fallen in comparison to previous results. Decreases in ground water levels varied between a minimum of 0.01m (D2a) and a maximum of 0.99m (BH1), at each location the piezometer tip is in Glacial Till. Discounting the 'exceptional' readings recorded from inclinometers, 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.

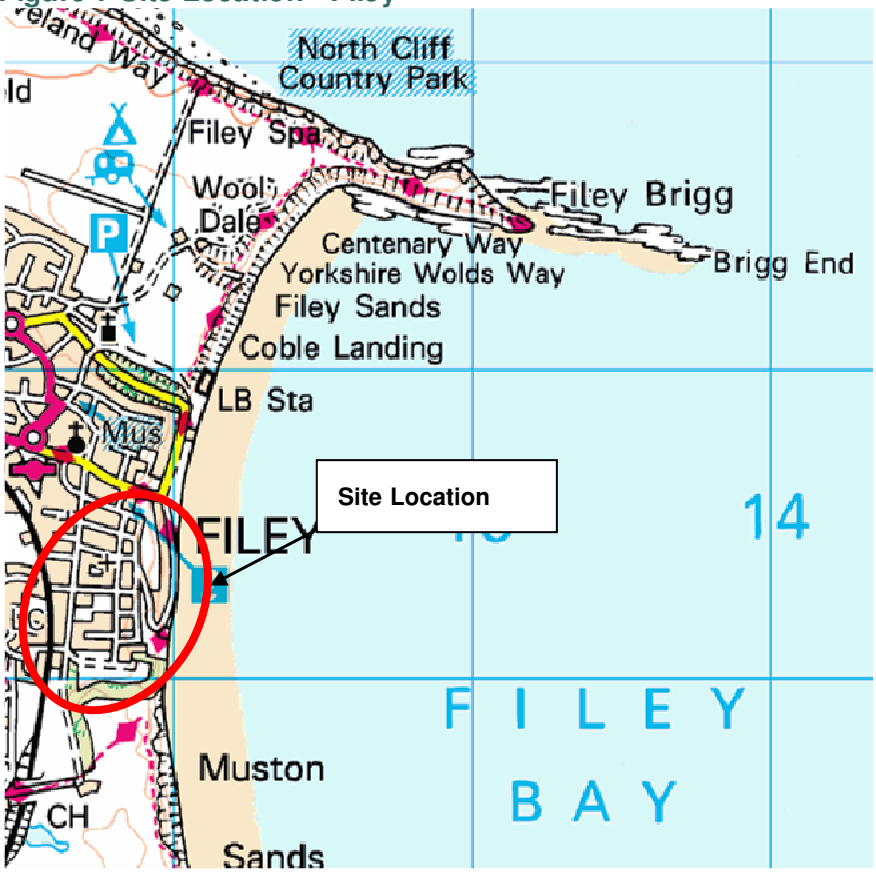
7 Filey Town

7.1 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.

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 7 Site Location - Filey



7.1.1 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 failures and scour damage to riffles and bridge abutments in a stream 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.

7.1.2 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.

7.1.3 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 and, further south towards Reighton the coastline is formed of unprotected, soft, glacial till cliffs. The slopes attain a height of up to 30metres 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 12m in height at their highest point. The toe of the slope has been scoured by recent floodwater leading to more extensive slope failure at isolated locations. There is evidence of past instability at the toe of the slopes with remnants of rock armouring present in the stream bed. The presence of sheet piles, low retaining walls and lengths of culvert indicates past erosion / stability problems within the Ravine.

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

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, pp107-108.* Additional reports were presented by SBC for further consultation for the Ongoing Analysis. All 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 (Boulder Clay) composed of stony clay. The solid succession at depth in the area is indicated as solid strata of the Kimmeridge Clay Formation of Upper Jurassic age. This typically comprises bituminous clays.

7.3 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 with persistent pollutants. Some Non-Aquifers can yield water in sufficient quantities for domestic use. Major and Minor Aquifers may occur beneath Non-Aquifers.

7.4 Instrumentation

7.4.1 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 by a railway embankment trending

north-south, to the west of the site. Surface water east of the embankment flows towards the coast where it is channelled and concentrated within the ravines. The erosive potential of the waters is increased by flowing down the steep gradients of the ravines 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 plateaux north and south of the ravine.

7.4.2 History of Monitoring

Standpipe piezometers were installed in BH01 at 14.00m and BH04 at 9.00m in cohesive boulder clay, in BH02 at 2.00m in non cohesive boulder clay and in BH05B at 6.45m 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 29.70m and 30.00m, respectively have been similarly monitored.

A photographic record of the sites covering Filey Town and The Brigg 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.

7.4.3 Recommended Monitoring Regime

It is recommended that a regime of regular monitoring and inspection of Filey should be undertaken at six monthly intervals (bi-annually). This should be carried out over a period of three years in order 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 should be increased following periods of heavy and prolonged rainfall.

7.5 Monitoring Regime

7.5.1 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 were that a regular monitoring and inspection regime should be undertaken at six monthly intervals (bi-annually) for a period of three years to retrieve long term data for analysis to determine any seasonal patterns of rainfall, ground water levels and ground movements.

7.5.2 Ongoing Monitoring Regime

The ongoing monitoring regime was initialised in July 2009 and follows that detailed in Section 7.5.1, above. Following on from the findings of the *Condition Survey Report*, monitoring consists of a single inclinometer and a piezometer located within Glen Gardens above the coastal slopes of Royal Parade. Piezometer instruments were located south of and also at the base of Martin's Ravine and on Royal Parade below Glen Gardens.

The reduced monitoring regime is based upon the findings of the *Condition Survey Report*. This detailed an inclinometer (BH6) and a piezometer (BH4) 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.

7.5.3 Ongoing Monitoring Results

Inclinometer Readings

Monitoring inclinometers BH03 and BH06 has been undertaken in accordance with the procedures detailed in Section 1.4 of this report and are presented in Appendix B. While undertaking this round of monitoring of the site (10th December 2009), BH03 was found to be dipping at a reduced depth of 18.35mBGL. Further investigation carried out on 11th December 2009 revealed a blockage within the tube at this same depth. A stainless steel, one metre length mandrill was lowered down to the obstruction and pushed it downwards to 19.40m.

The mandrill was raised and dropped in an attempt to move the blockage further, at this point the mandrill was found to be 'stuck' in the obstruction. The mandrill with obstruction was forcibly pulled up the tube to a depth of 8.80m, at which point no further progress was made. The mandrill was released with difficulty and the obstruction remains at 8.80m depth. It is unclear what the blockage consists of although there was gravel and cobbles of hardcore laid close-by the borehole and the borehole lock had been broken. It is possible that the borehole has been vandalised with foreign matter forced into the tube. The blockage precludes any further inclinometer and groundwater readings being taken from this installation.

Groundwater Readings

Groundwater levels were recorded during the Initial Full Suite Monitoring (8th July 2009) and the Second Full Suite Monitoring (10th December 2009). Groundwater readings from BH03 show very little change over this period. The largest difference of 310mm, recorded in BH01, is indicative of a decrease in the groundwater level over this period. (The piezometer in this borehole, along with that in BH02, reflects groundwater levels within the stream flowing through Martin's Ravine). Within BH05B a difference of 200mm was recorded which indicates the tidal influence upon the water level in this instrument. There is limited data available for BH04 as this could not be located. Groundwater readings are presented in Appendix C.

7.6 Conclusions

The results of monitoring inclinometer BH06 so far seem to indicate that between depths of 10.5m and 7.00m, a total of 2mm of ground movements has occurred over the period from July to December 2009. Ground movements are in a down slope direction towards Royal Parade along the coastline. Despite the apparent movement shown in the inclinometer data, the slopes at this location would seem to be in a stable condition. Inclinometer readings for BH03 are inconclusive as they only consist of initial 'Baseline' readings. These are presented in Appendix B.

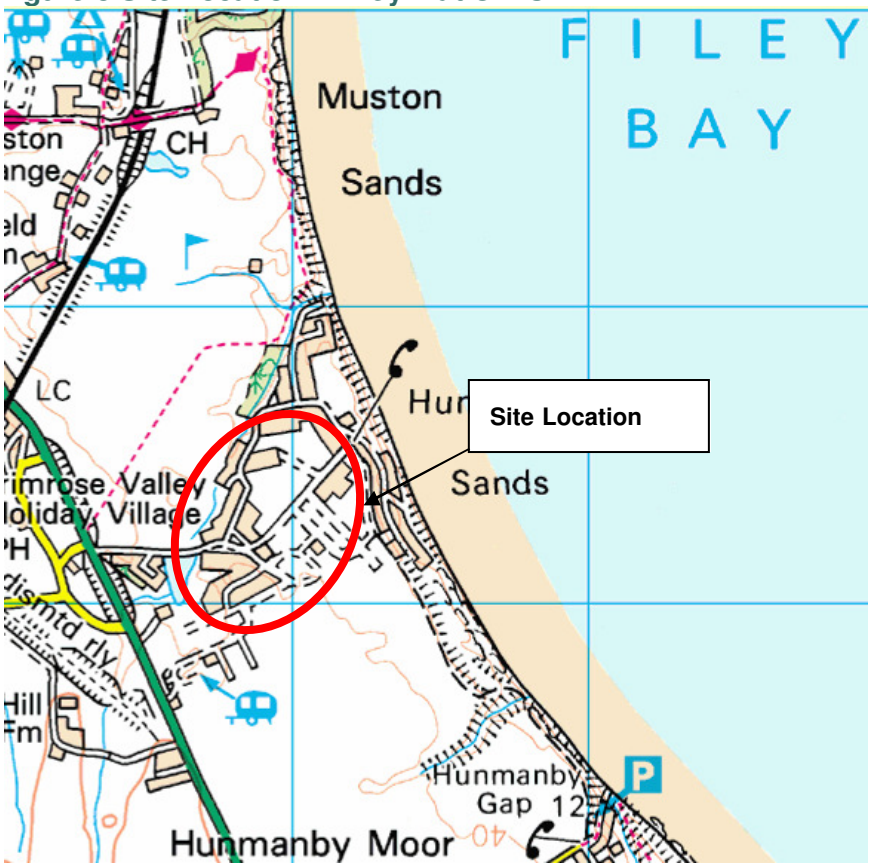
Groundwater levels at this site remain fairly static. BH05B reflects the tidal fluctuations affecting water levels in this borehole, while water levels in BH01 and 02 illustrate the variations prevalent in the groundwater regime particularly levels within the stream at Martin's Ravine.

8 Filey Flat Cliffs

8.1 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. 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 8 Site Location – Filey Flat Cliffs



8.1.1 Historic Review of Problems

At 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.

8.1.2 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 Flat Cliffs, large-scale, deep-seated failure of the glacial till cliffs has occurred. At the north end of Flat Cliffs, the surface morphology indicates rotational failure of the glacial till has occurred. At 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.

8.1.3 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. All 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 (Quaternary), overlying the Speeton Clay Formation. This formation overlies the Kimmeridge Clay Formation.

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 with persistent pollutants. 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 presence of confined granular strata within the glacial till slopes may result in excess groundwater pressures to develop resulting in the collapse and recession of the head scarp and cliff crest.

8.5 Monitoring Regime

8.5.1 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 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.

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*, monitoring is to consist of a single inclinometer (BB02/A2) located on the landside of the main access road down through Flat Cliffs and 3 no. piezometers (A3, B1 and D1), one located within Flat Cliffs and the remainder located above the village beyond the cliff crest.

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

8.5.3 Ongoing Monitoring Results

Inclinometer Readings

Inclinometer readings for BB02 (A2) has been undertaken in accordance with the procedures detailed in Section 1.4 of this report and are presented in Appendix B.

Groundwater Readings

Groundwater levels were recorded at monthly intervals from the Initial Full Suite Survey (8th July 2009) up to the Full Suite monitoring readings (10th December 2009). A comparison of the readings showed maximum variations of groundwater levels within boreholes of up to +330mm BB02 (A2), -1110mm (D1), -460mm (A3) and +990mm (B1). Borehole BB01 (D2) was recorded as dry on each occasion although this inclinometer has failed at 14.20m depth. This instrument was originally installed to 22.50m depth. Groundwater readings are presented in Appendix C.

8.6 Conclusions

Monitoring data from the inclinometer (BB02) have illustrated very little or no ground movements occurring within the vicinity of this borehole. A very slight deviation (<1mm) is apparent in the inclinometer readings though this is likely to be due to temperature variations and the use of two different probes for recording the sets readings. To-date the monitoring data indicates that no ground movements have taken place within the location of inclinometer BB02. However, the single inclinometer offers very limited coverage of the site of 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 also carry out slope stability analyses.

Groundwater levels at this site indicate the variations prevalent in the groundwater regime at Flat Cliffs, although readings from BB02 (A2) are probably influenced by tidal fluctuations.

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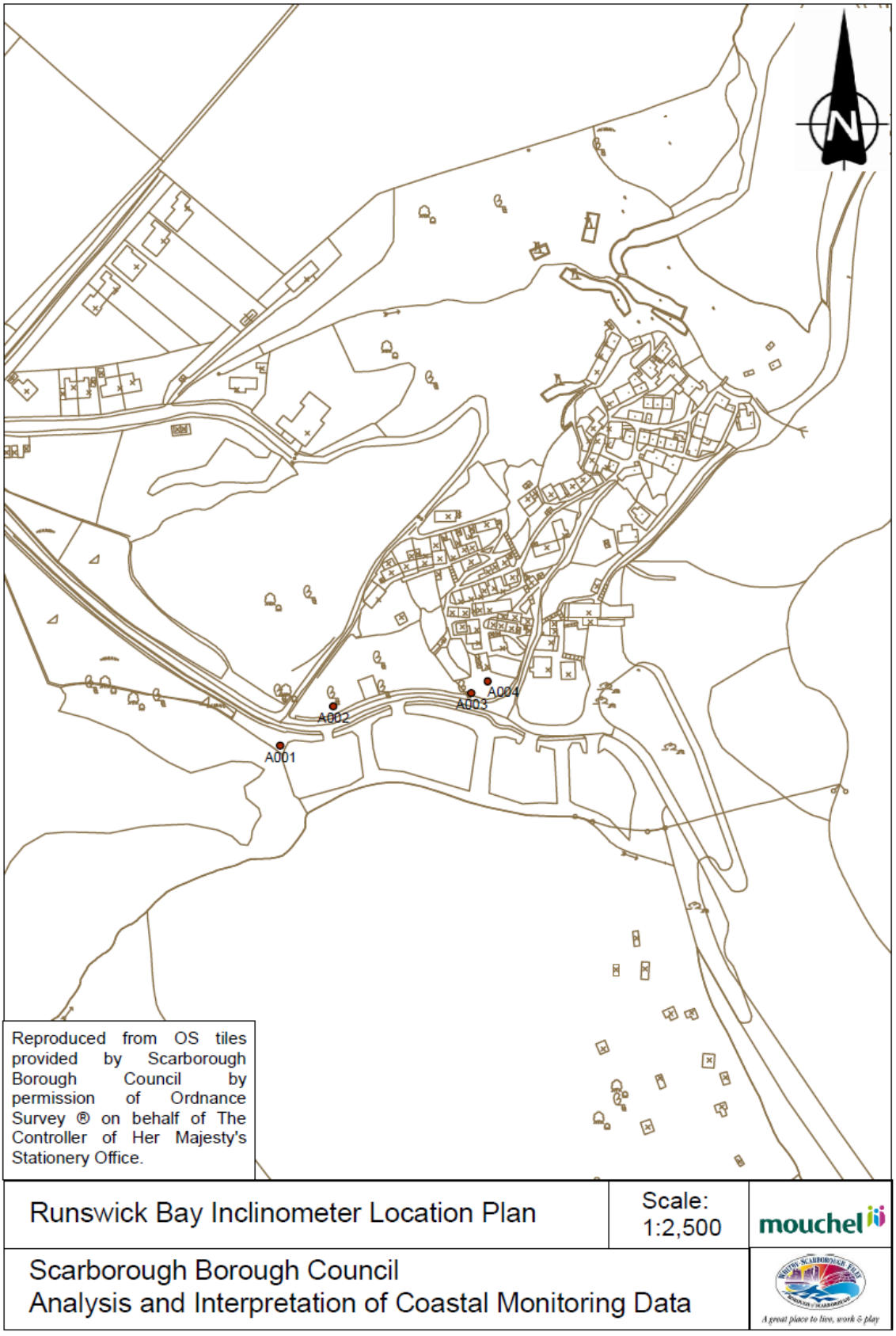
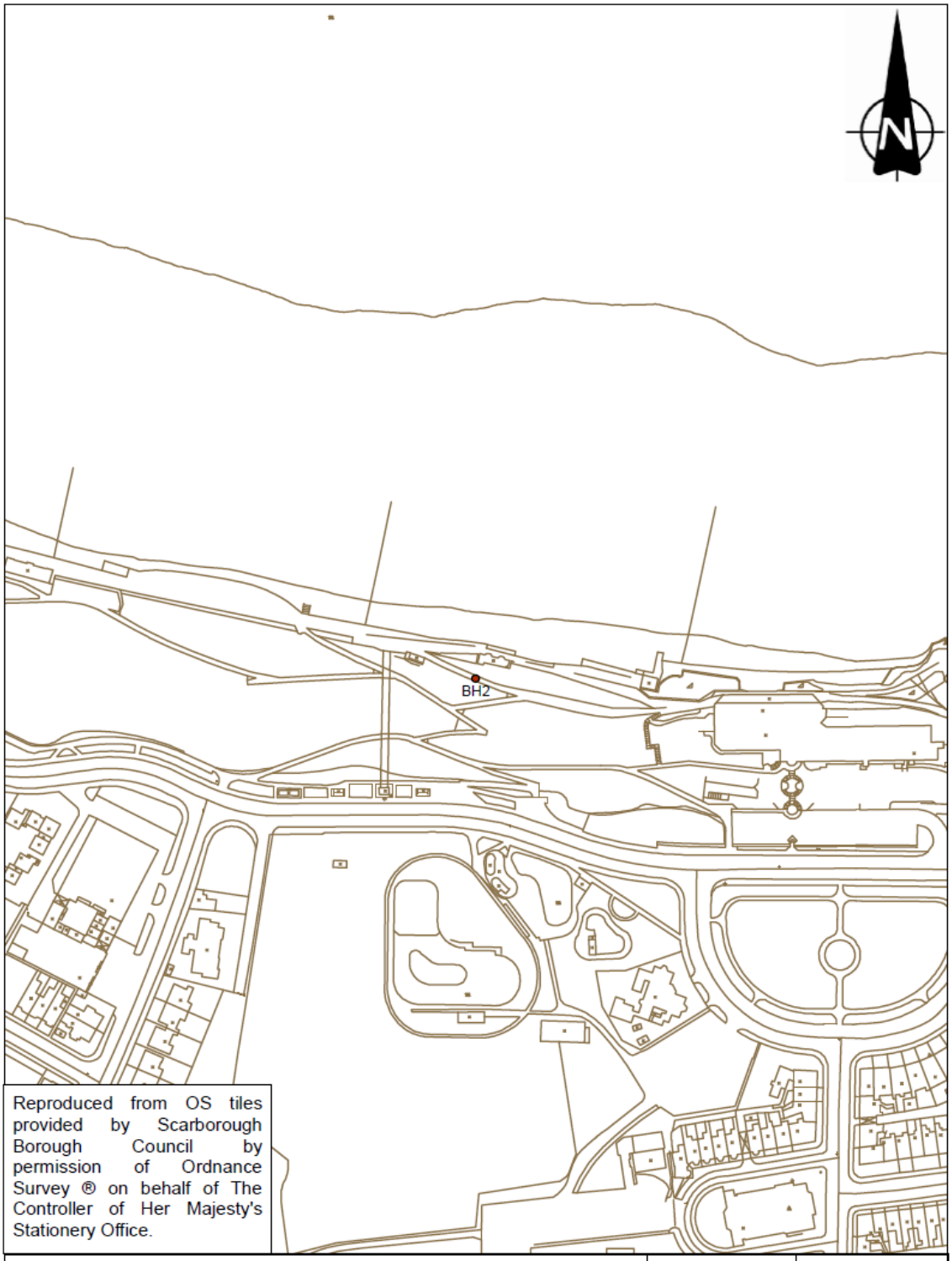
Appendix A Exploratory Holes Location Plans



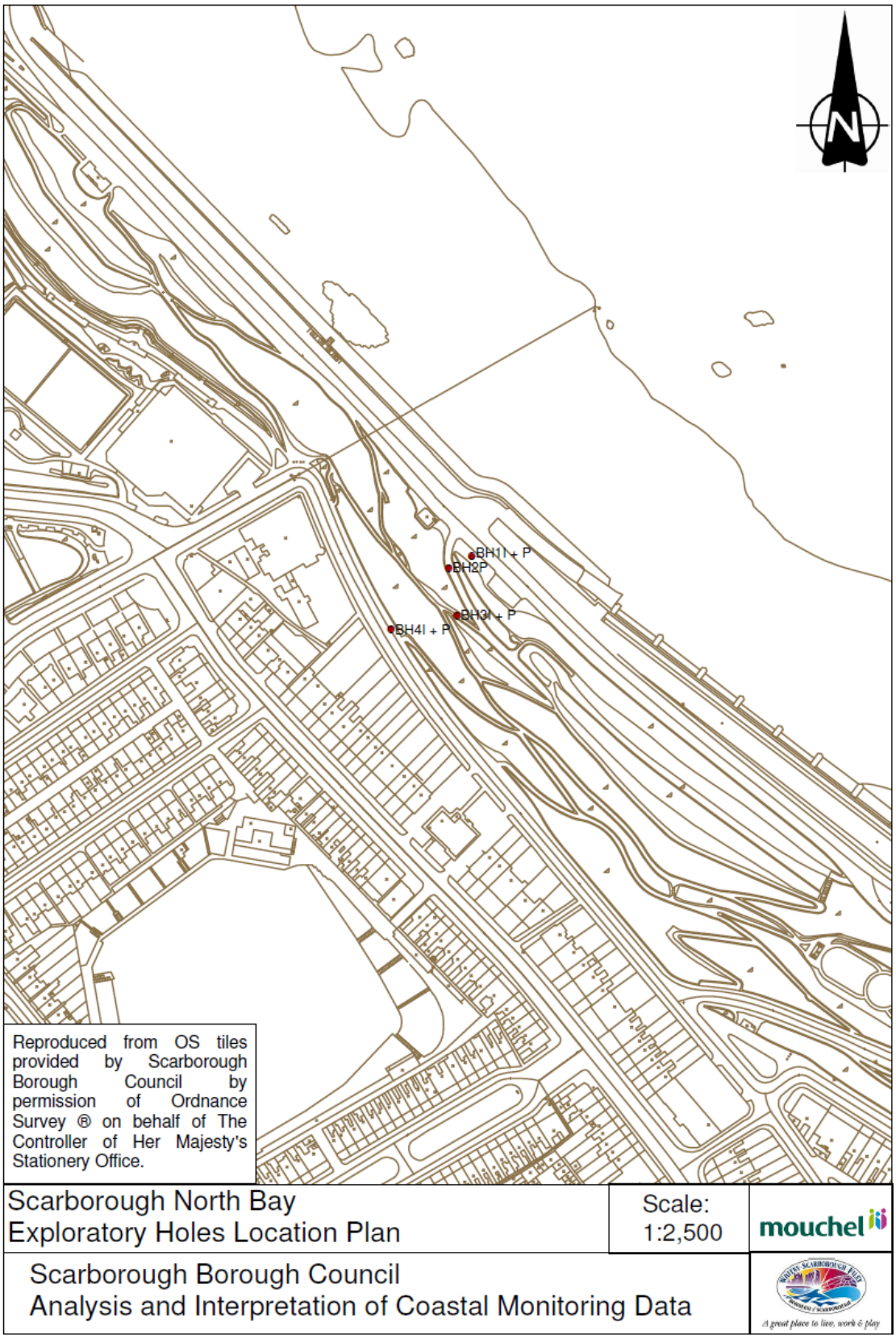
Drawing No. 1 Location Plan of Runswick Bay



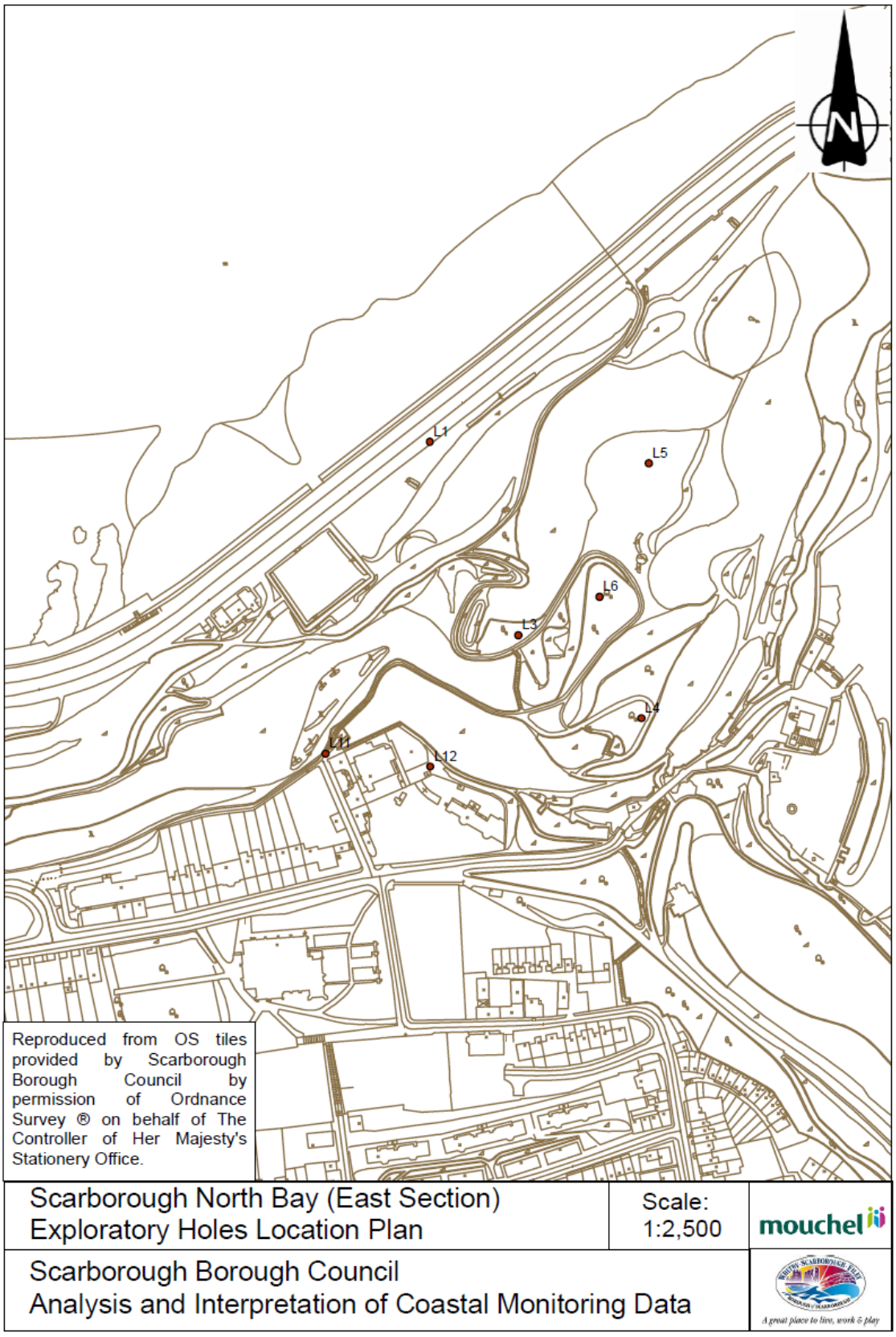
Whitby West Cliff Inclinometer Location Plan	Scale: 1:2,500	mouchel
Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data		A great place to live, work & play

Drawing No. 2 Location Plan of Whitby West Cliff

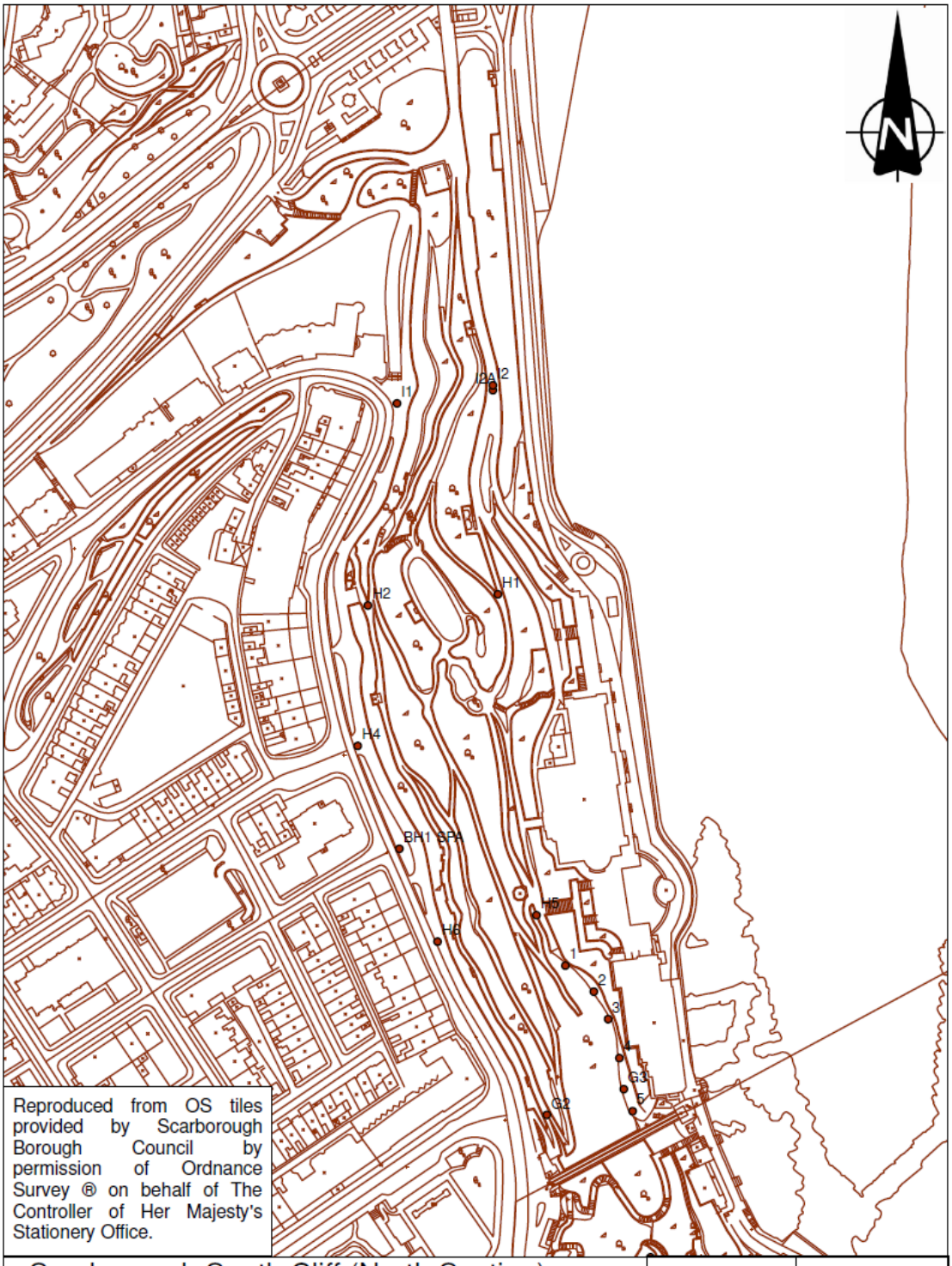
Drawing No. 3 Location Plan of Scalby Ness



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

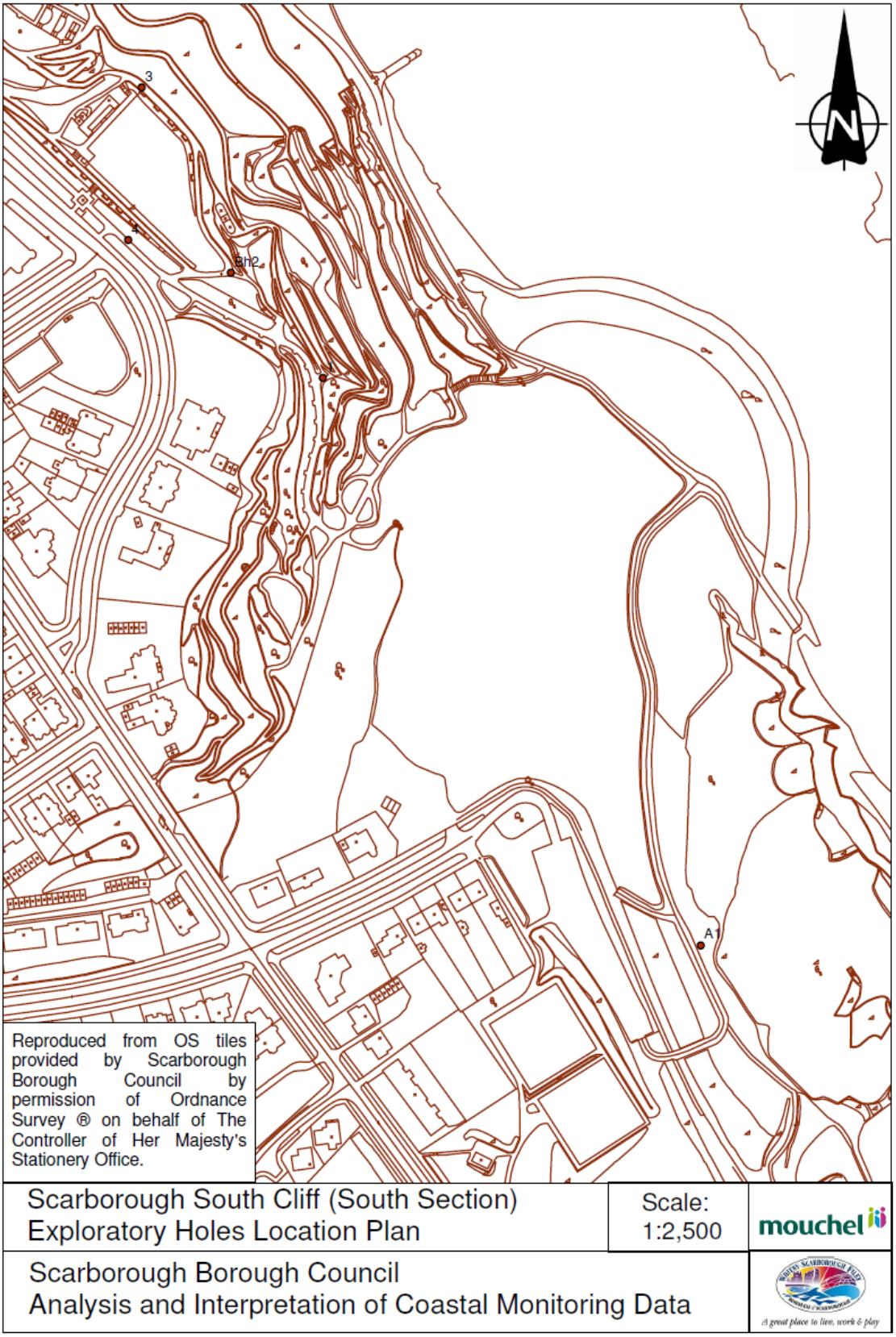


Drawing No. 5 Location Plan of Scarborough North Bay (East)

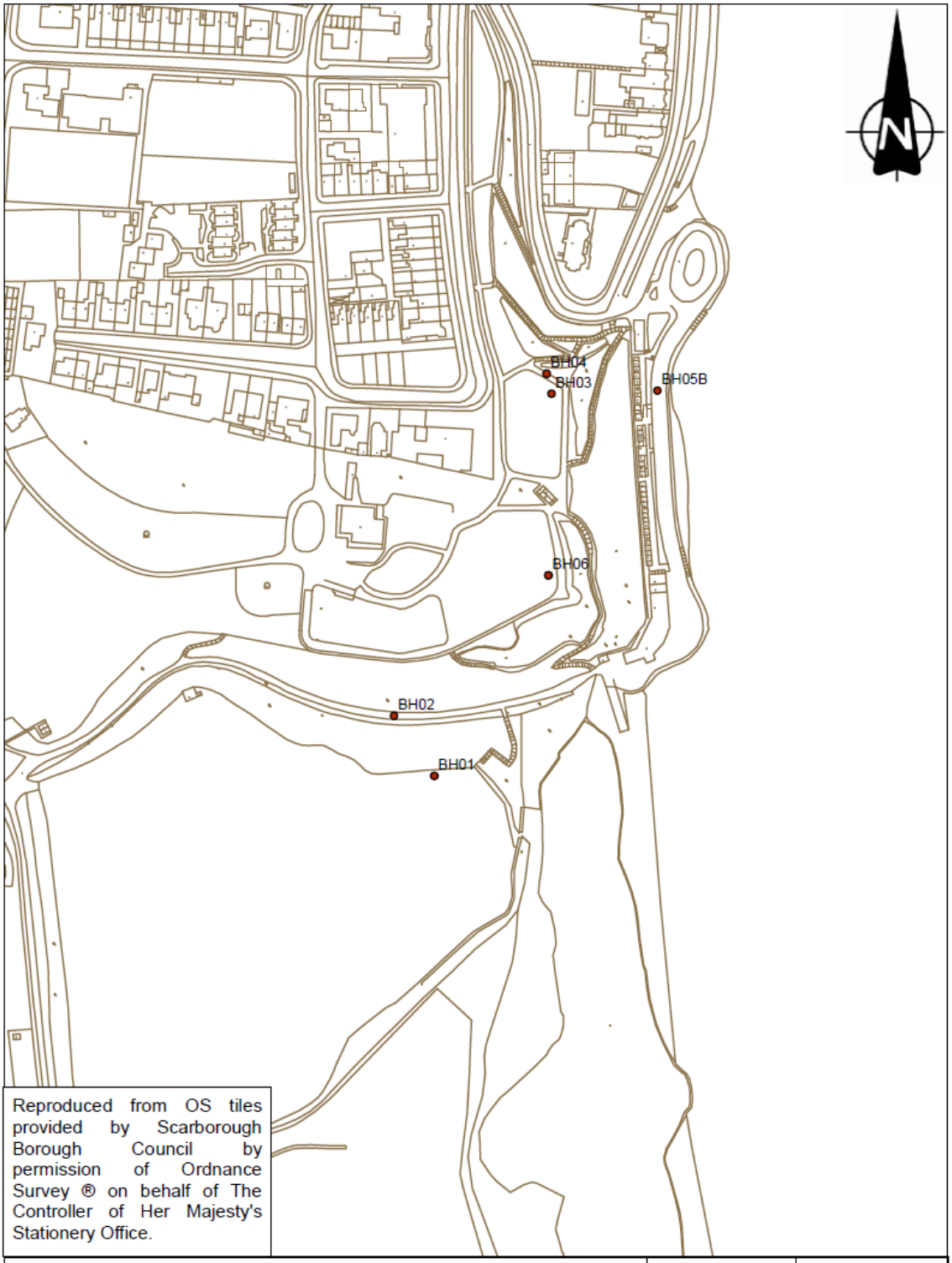


Drawing No. 6 Location Plan of Scarborough South Cliff (North)

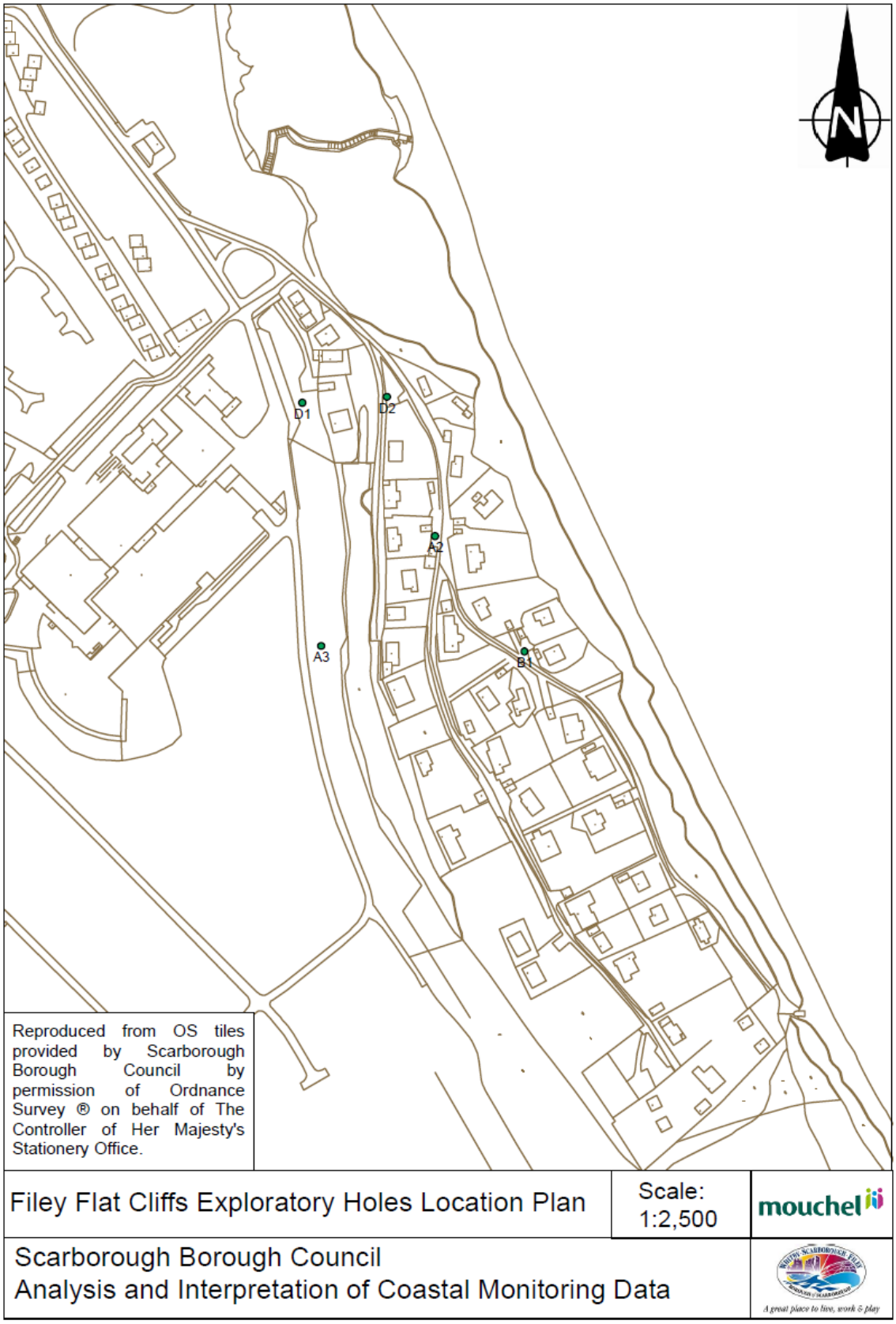
Drawing No. 7 Location Plan of Scarborough South Cliff (Central)



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



Drawing No. 9 Location Plan of Filey Town

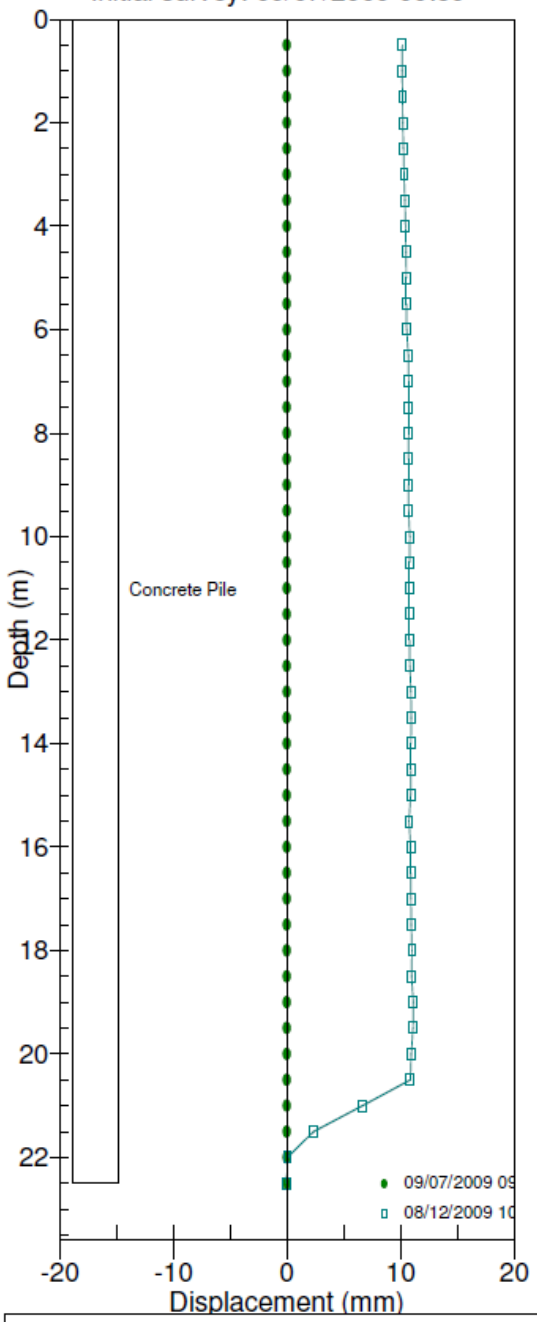


Drawing No. 10 Location Plan of Filey Flat Cliffs

Appendix B Inclinometer Data Graphs

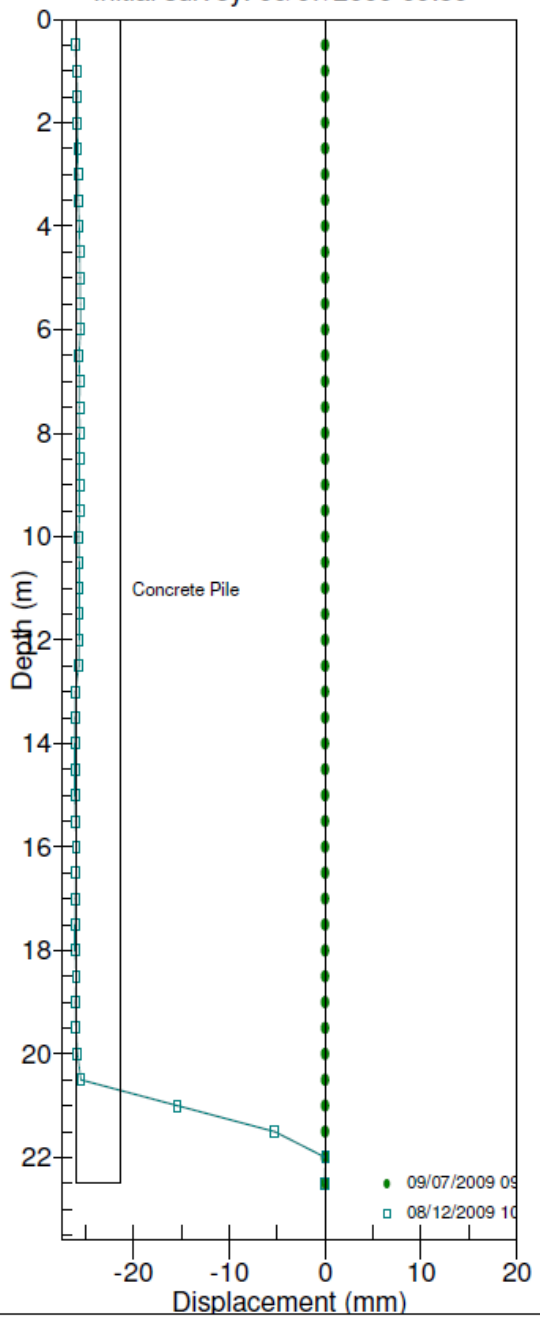
RB:A001 - A Axis Cumulative

Initial survey: 09/07/2009 09:59



RB:A001 - B Axis Cumulative

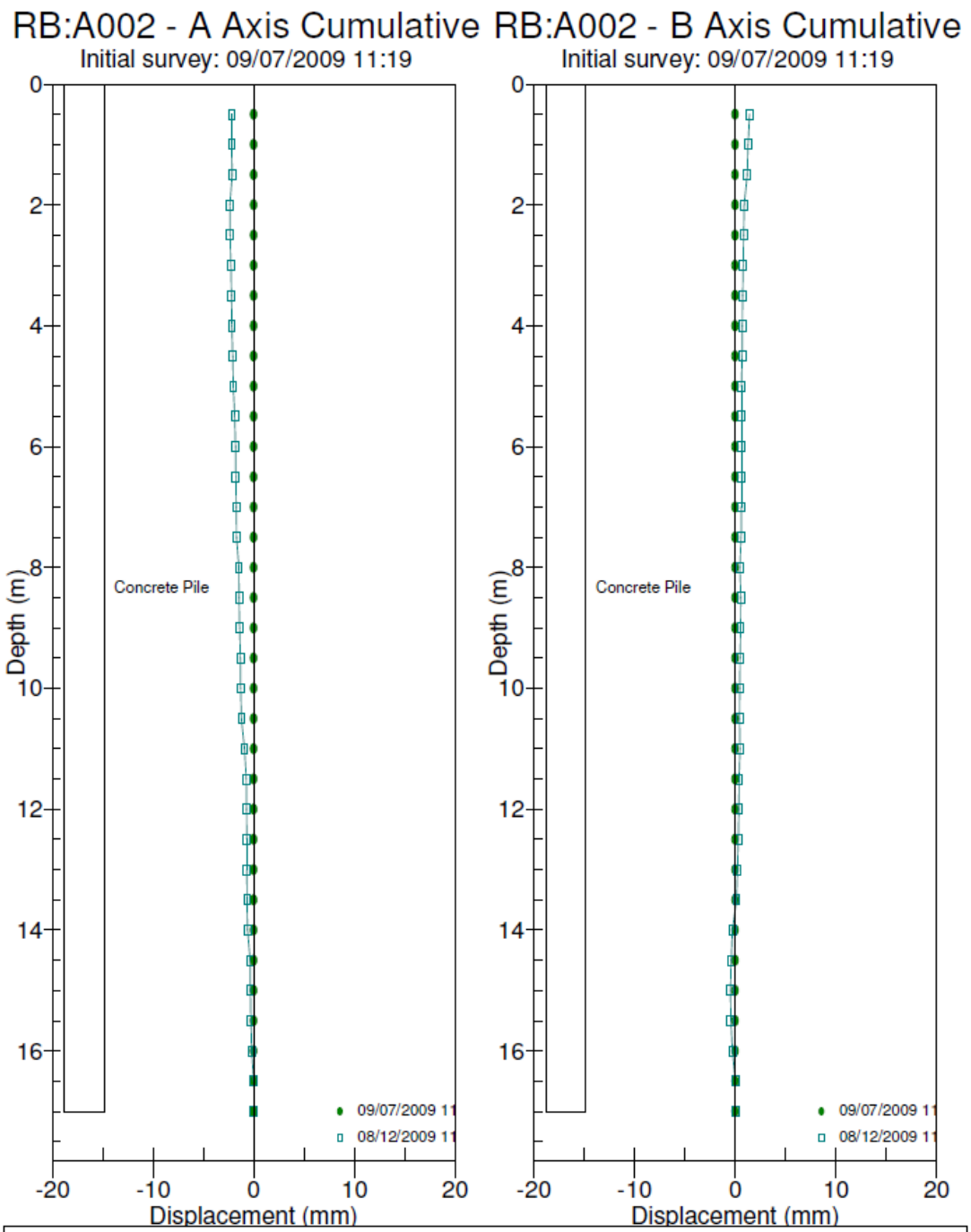
Initial survey: 09/07/2009 09:59



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

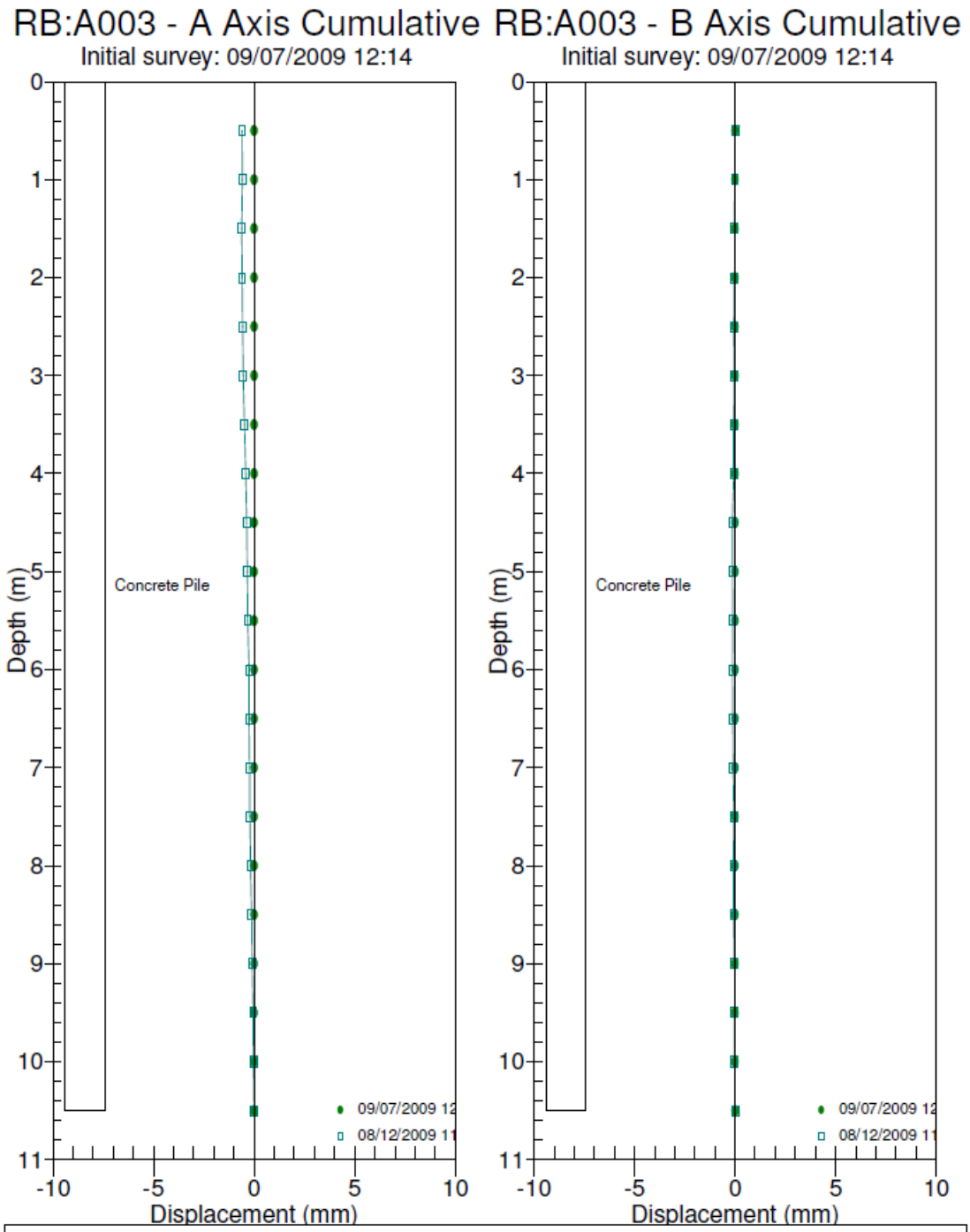
NOTE: A0 direction: East

mouchel



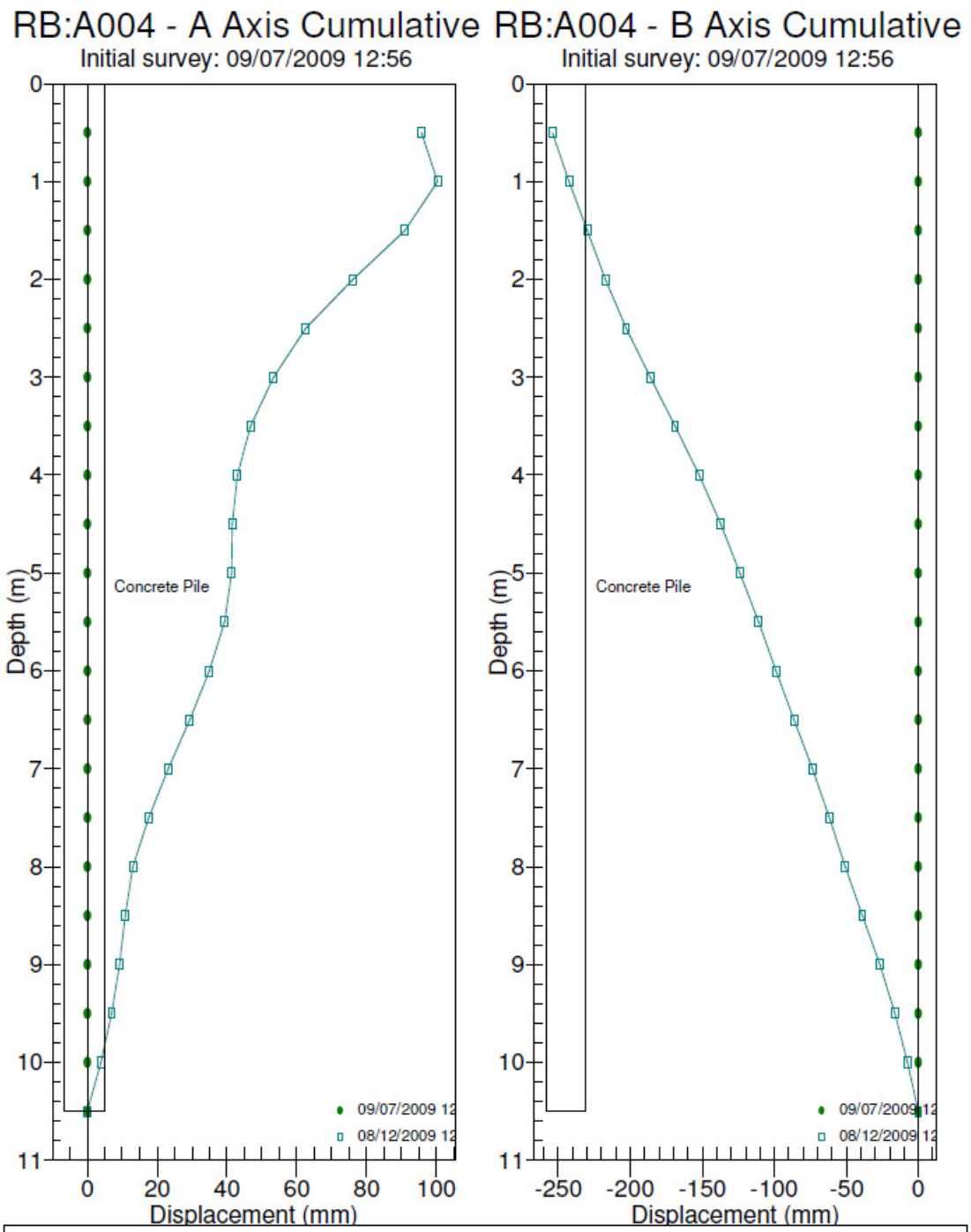
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A002
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: East



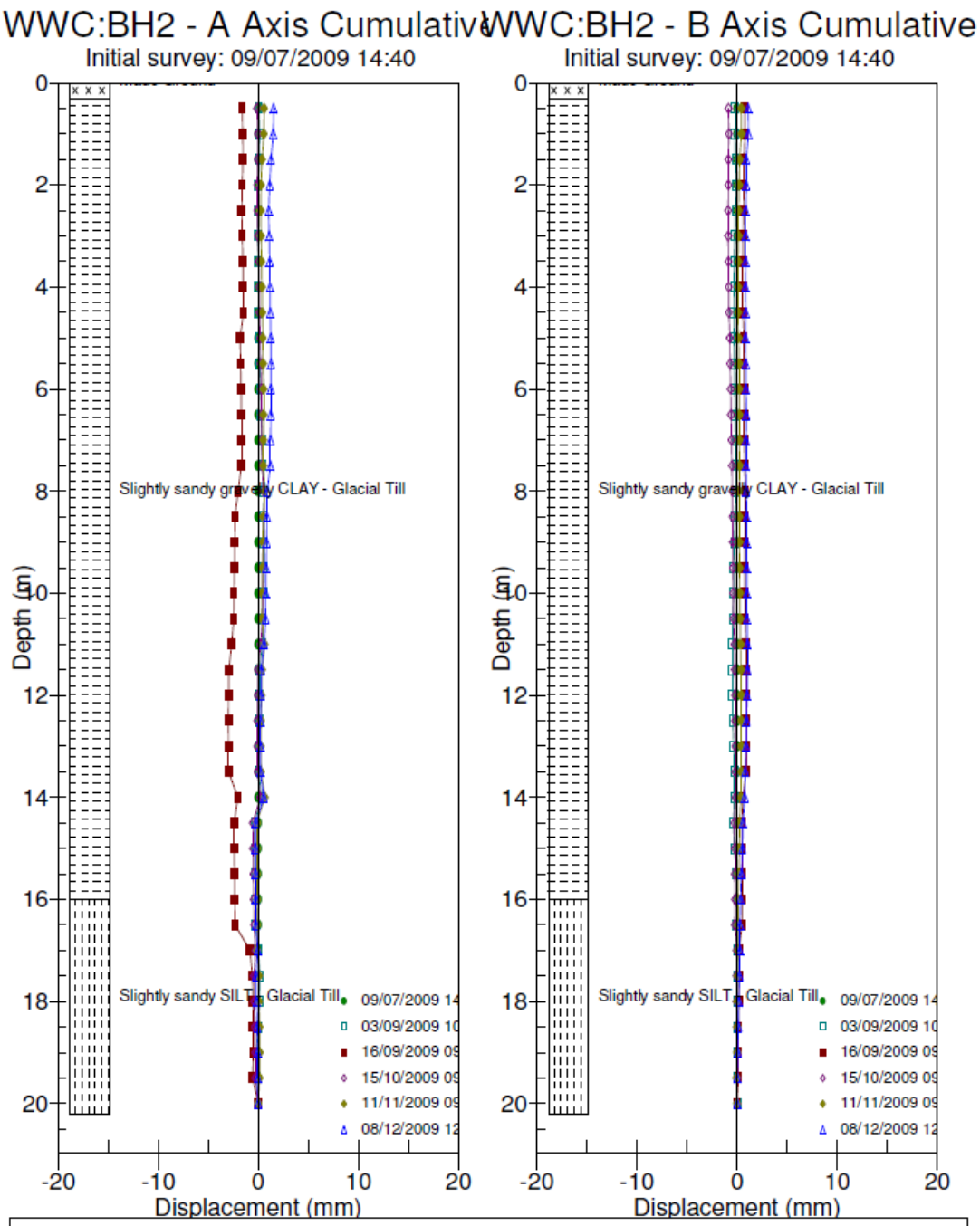
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A003
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

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

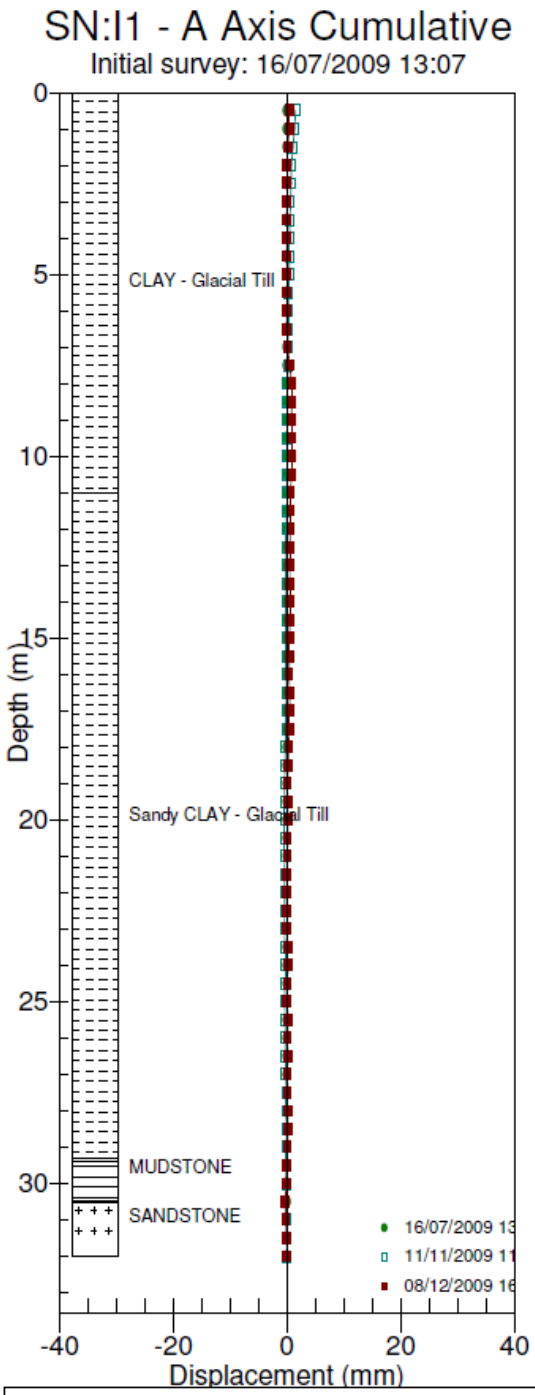
NOTE: A0 direction: East

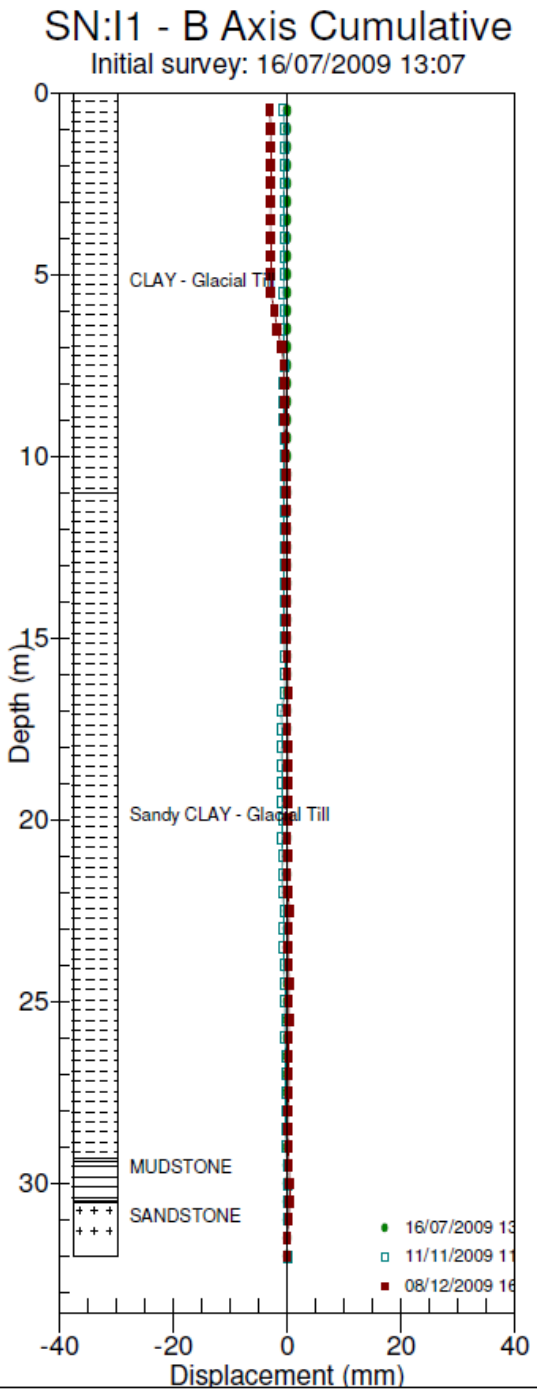


PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Whitby West Cliff
INSTALLATION: BH2
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: North

mouchel

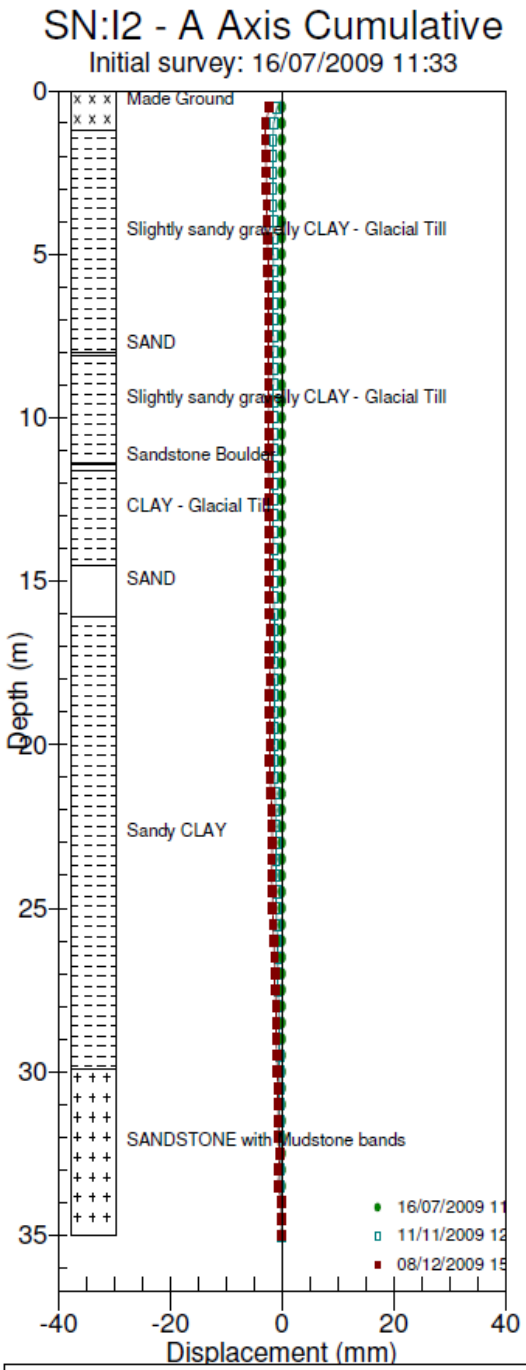


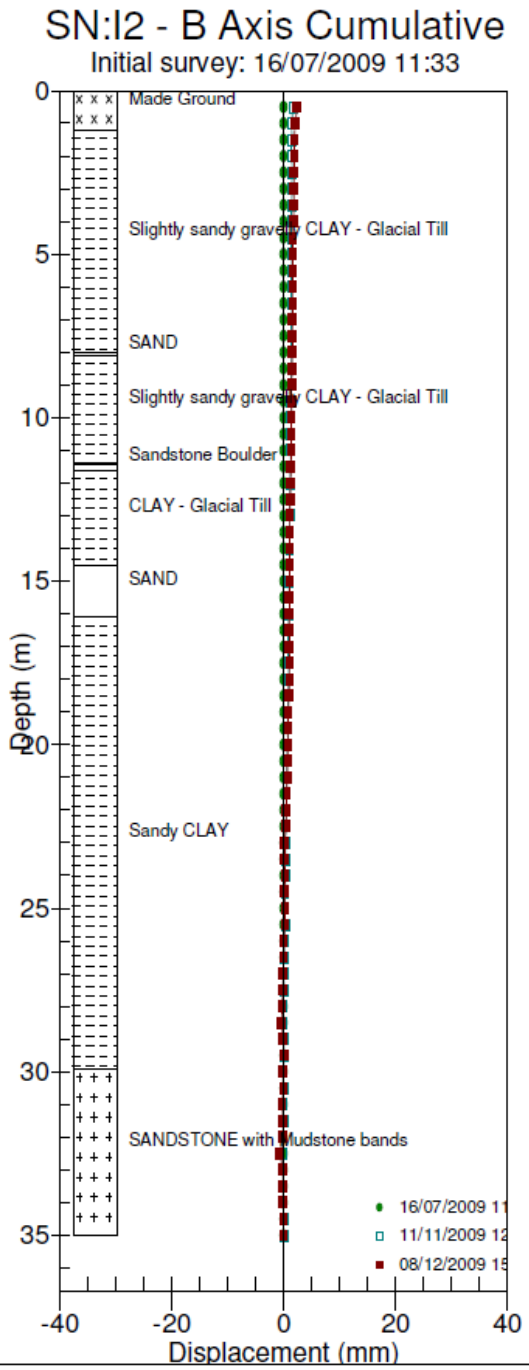


PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scalby Ness
INSTALLATION: I1
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: North

mouchel

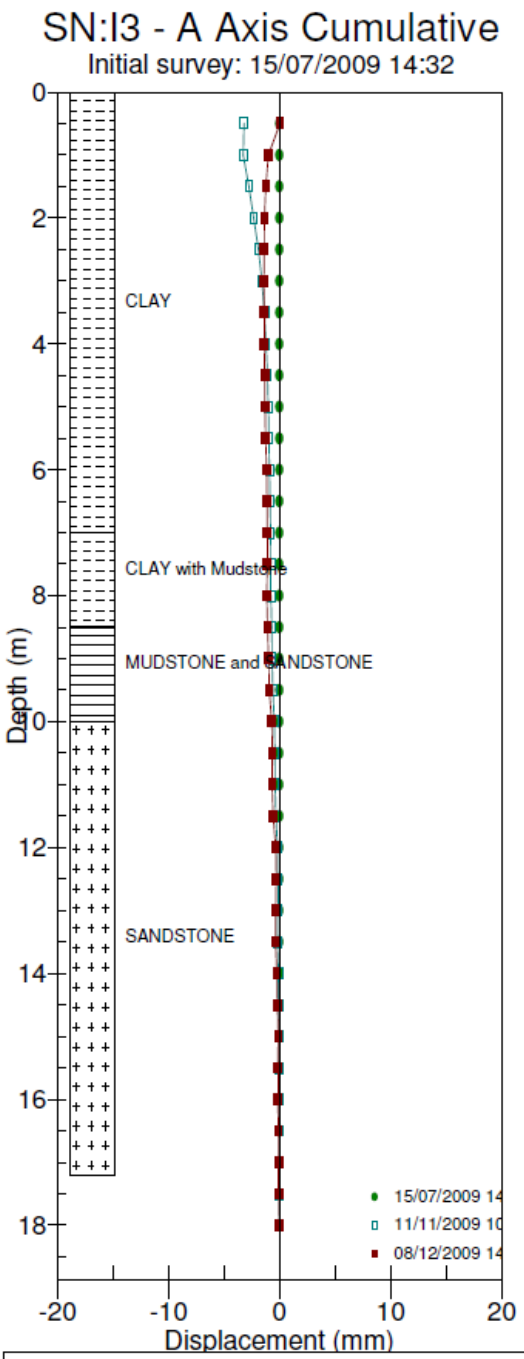


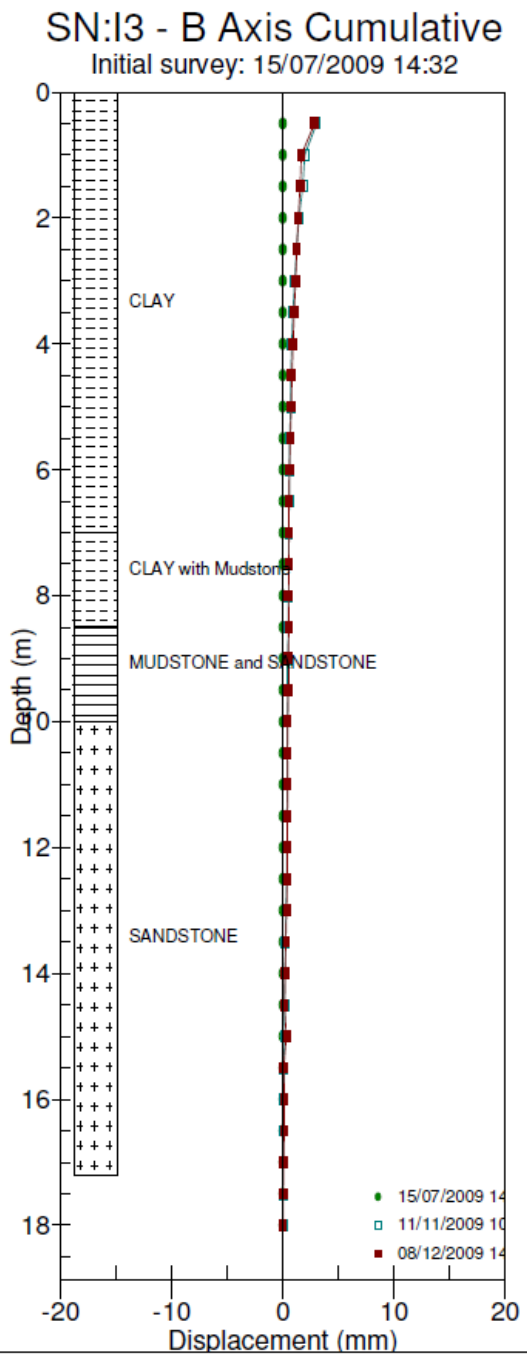


PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scalby Ness
INSTALLATION: I2
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: North East

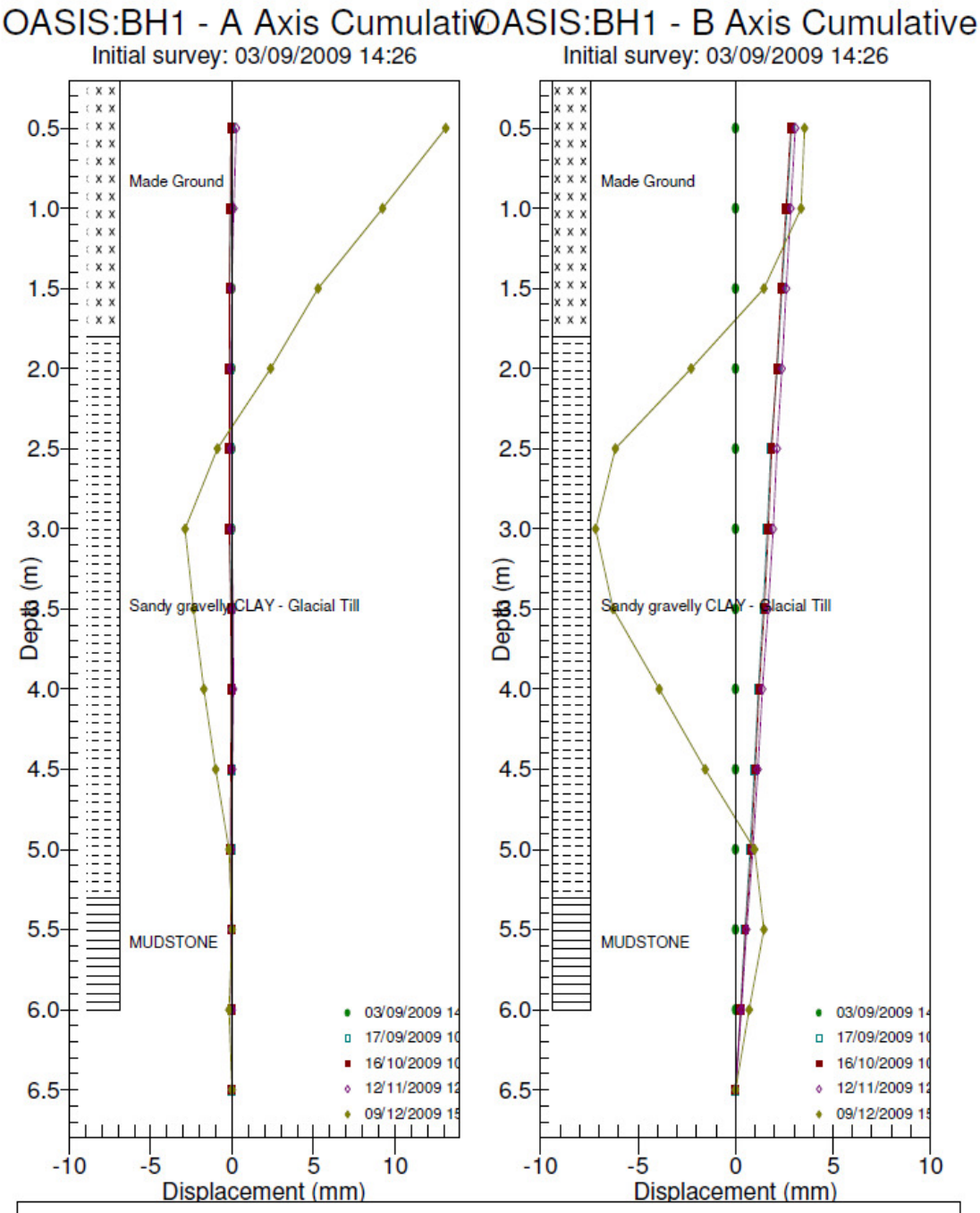
mouchel





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

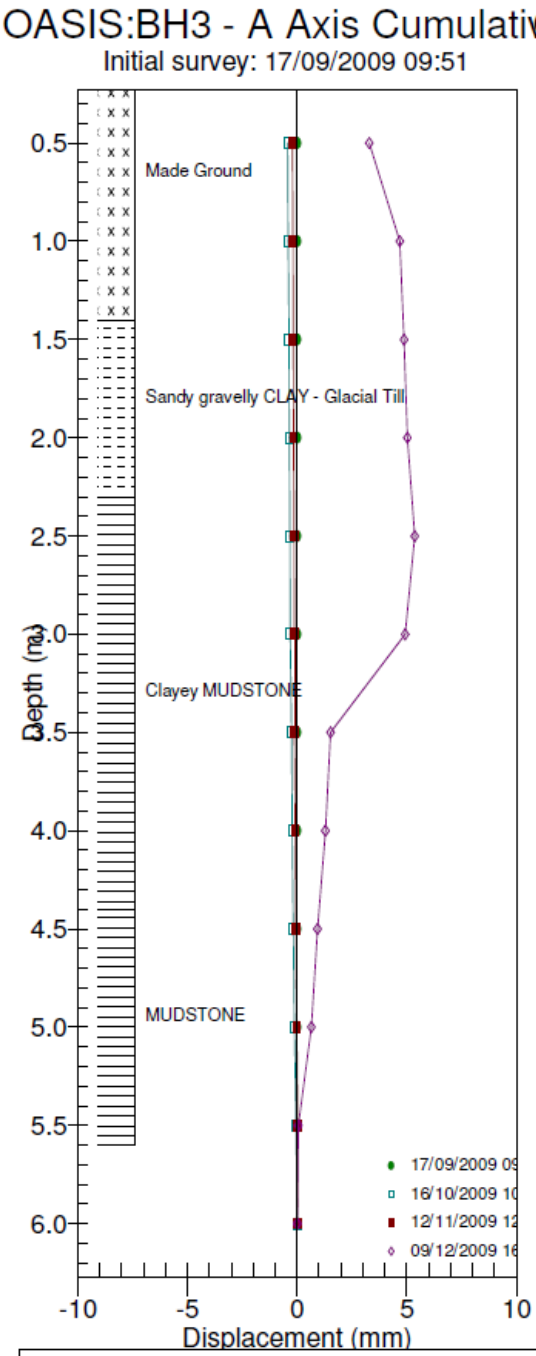
NOTE: A0 direction: East

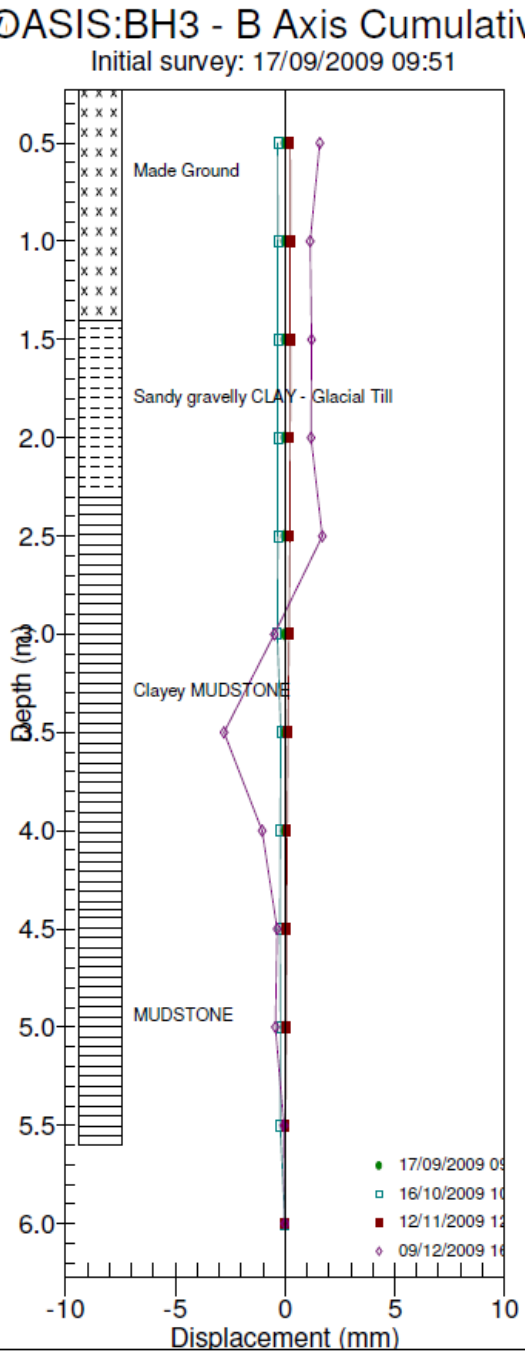


PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Oasis North Bay
INSTALLATION: BH1
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: East

mouchel

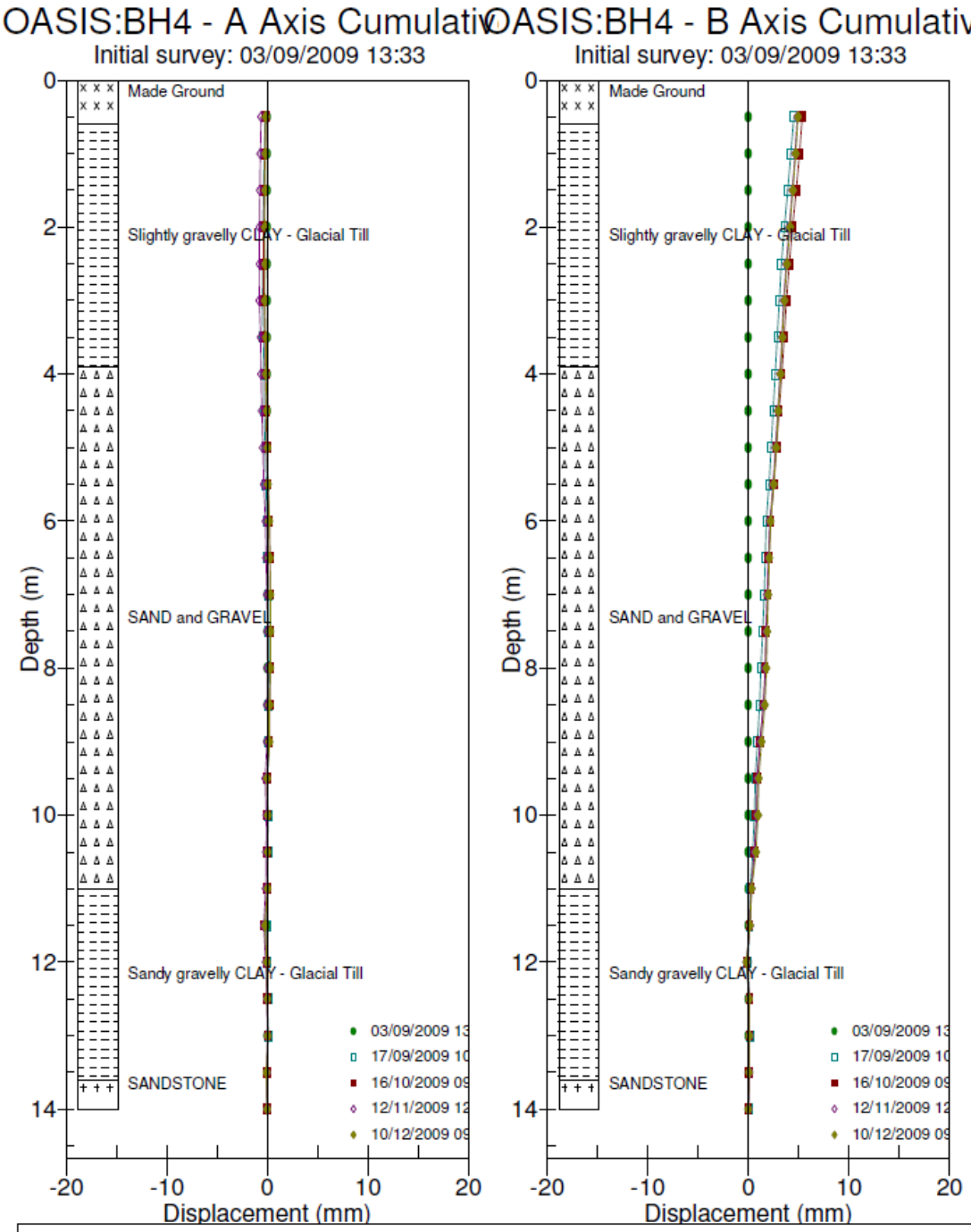




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Oasis North Bay
INSTALLATION: BH3
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: East

mouchel



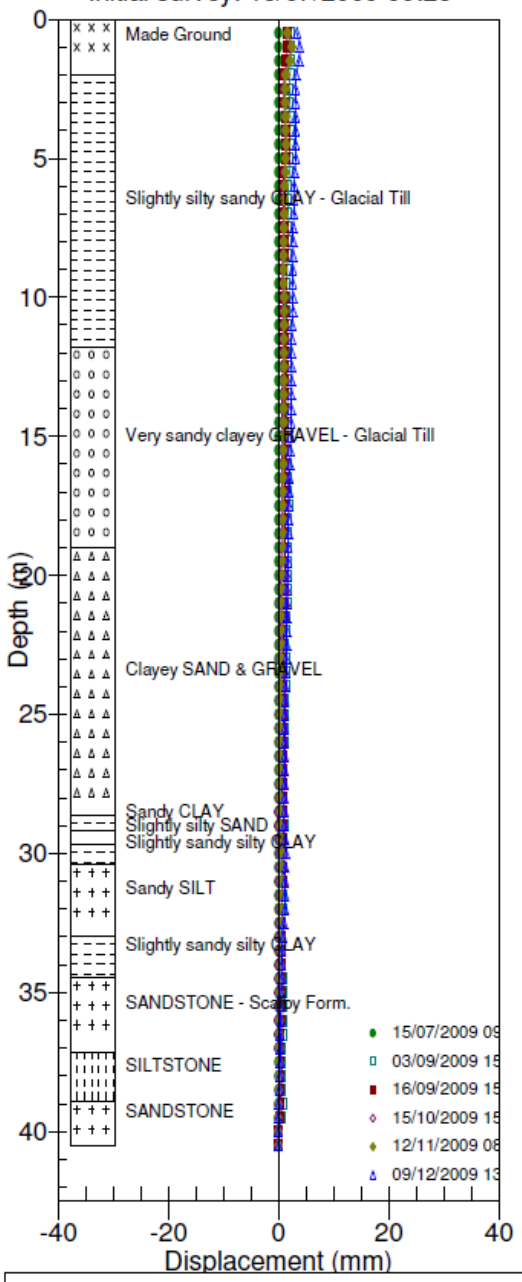
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Oasis North Bay
INSTALLATION: BH4
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: East

mouchel

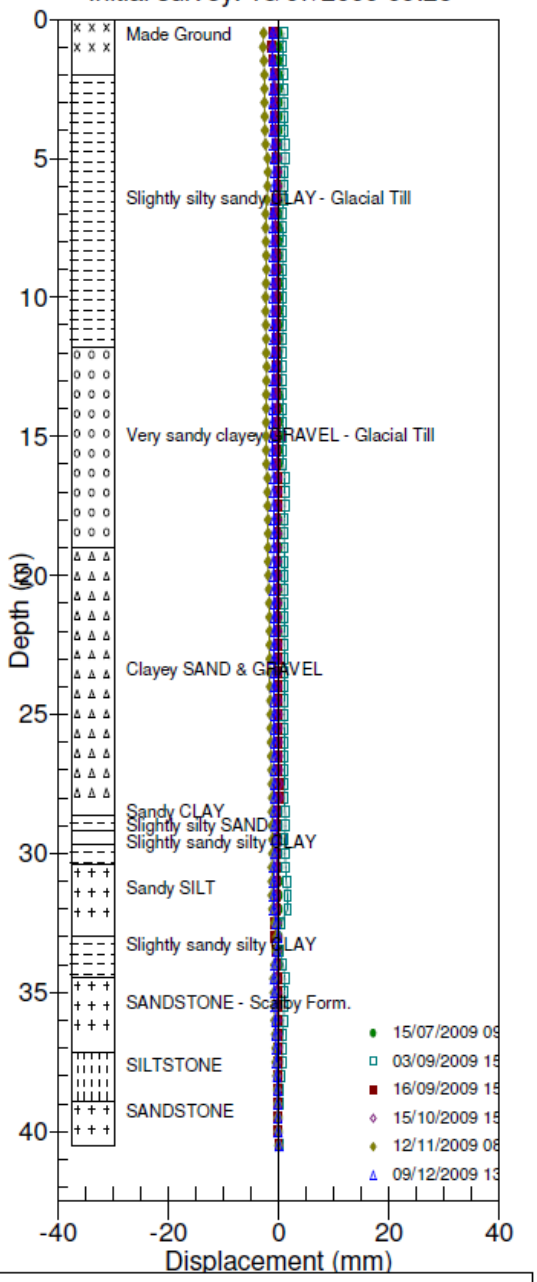
SSC:AA04 - A Axis Cumulative

Initial survey: 15/07/2009 09:26



SSC:AA04 - B Axis Cumulative

Initial survey: 15/07/2009 09:26



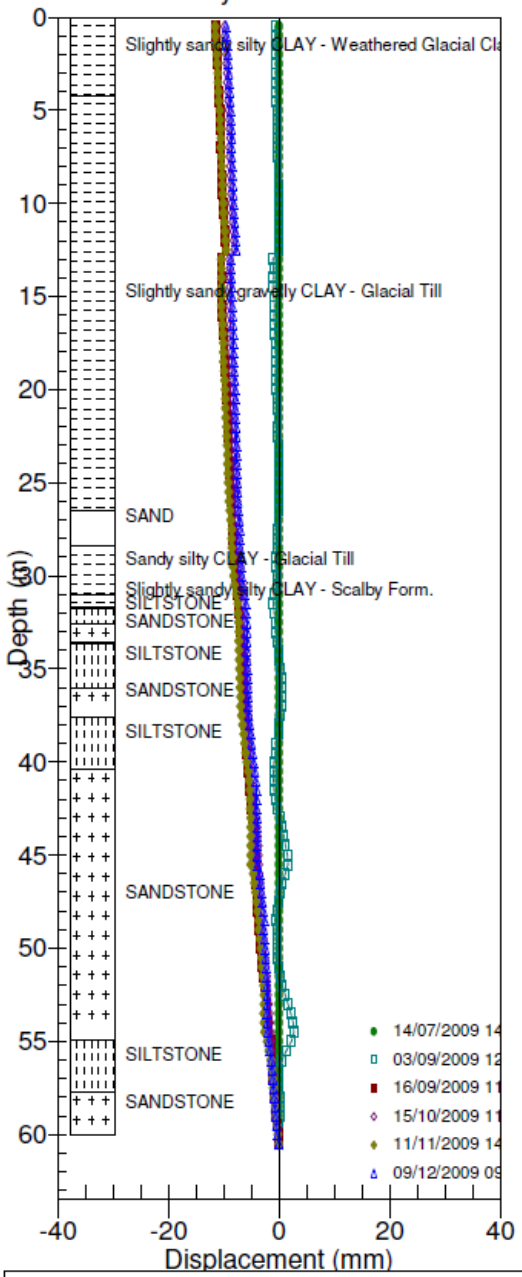
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scarborough South Cliff
INSTALLATION: AA04 (G2)
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: A0 direction: North East

mouchel

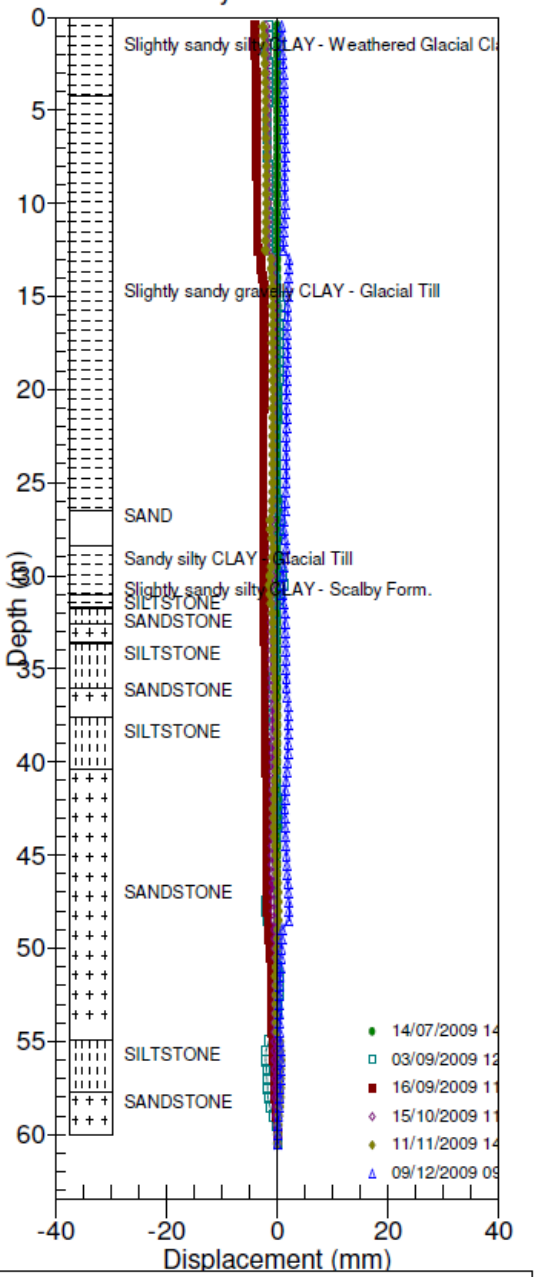
SSC:AA07 - A Axis Cumulative

Initial survey: 14/07/2009 14:12



SSC:AA07 - B Axis Cumulative

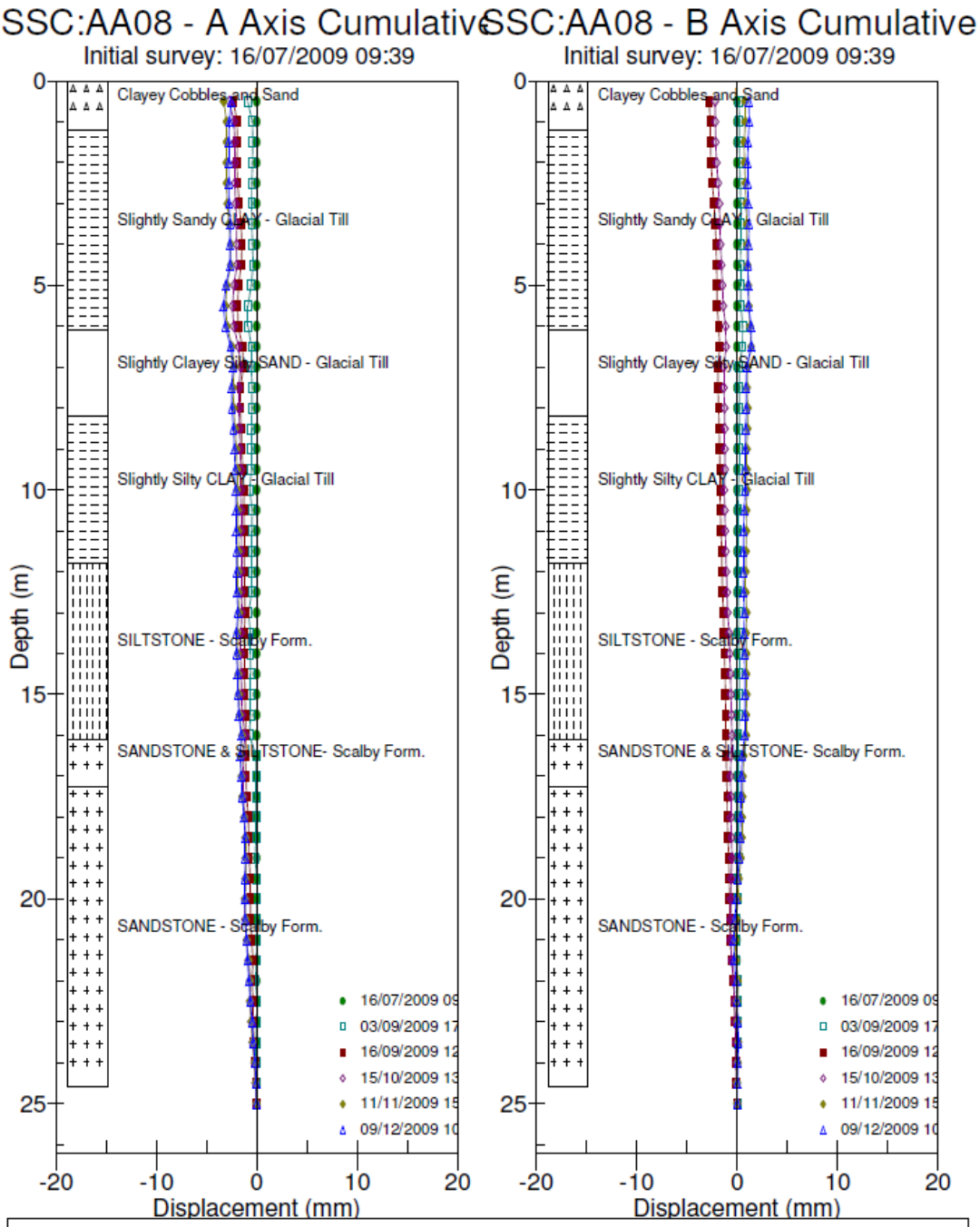
Initial survey: 14/07/2009 14:12



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

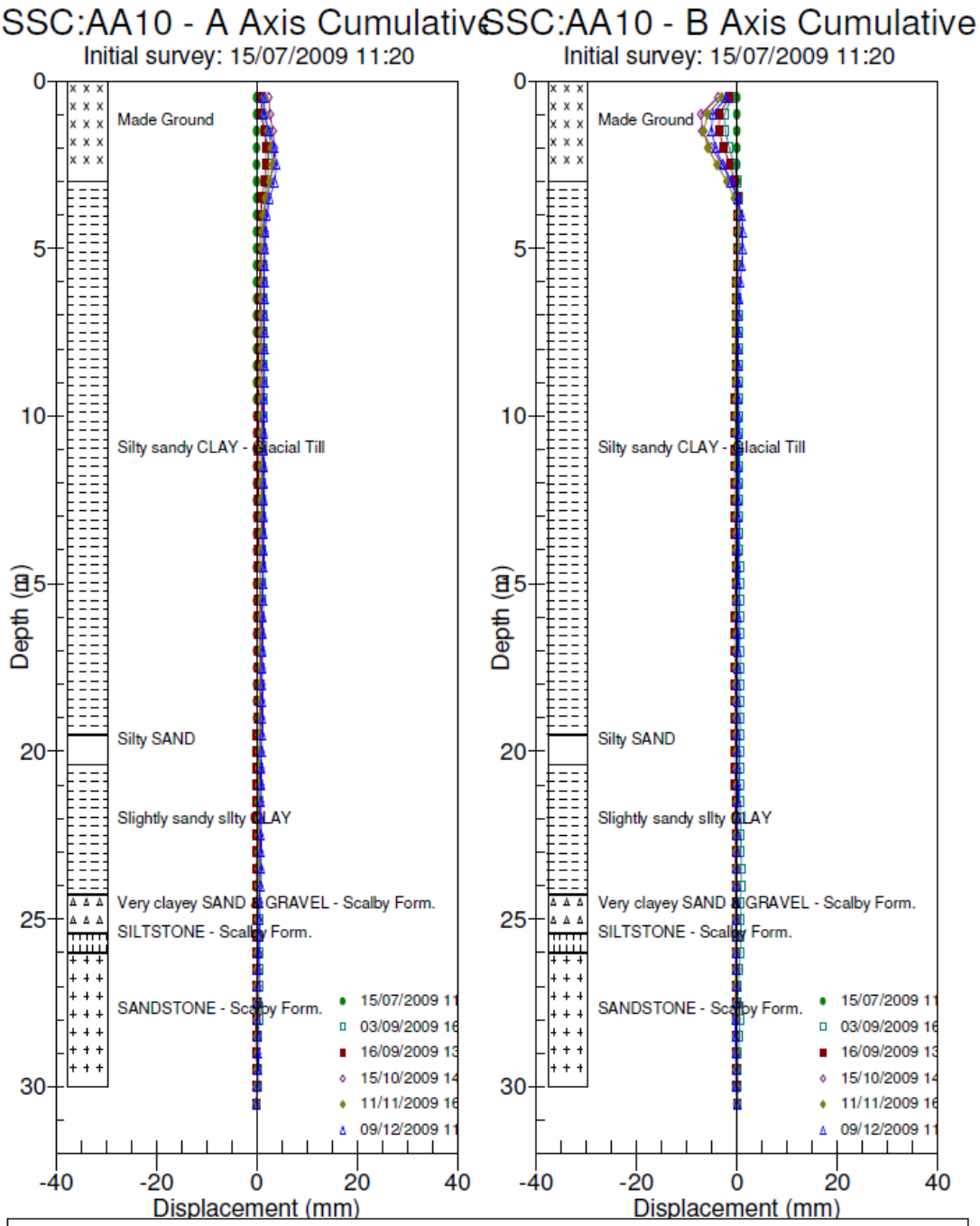
mouchel



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

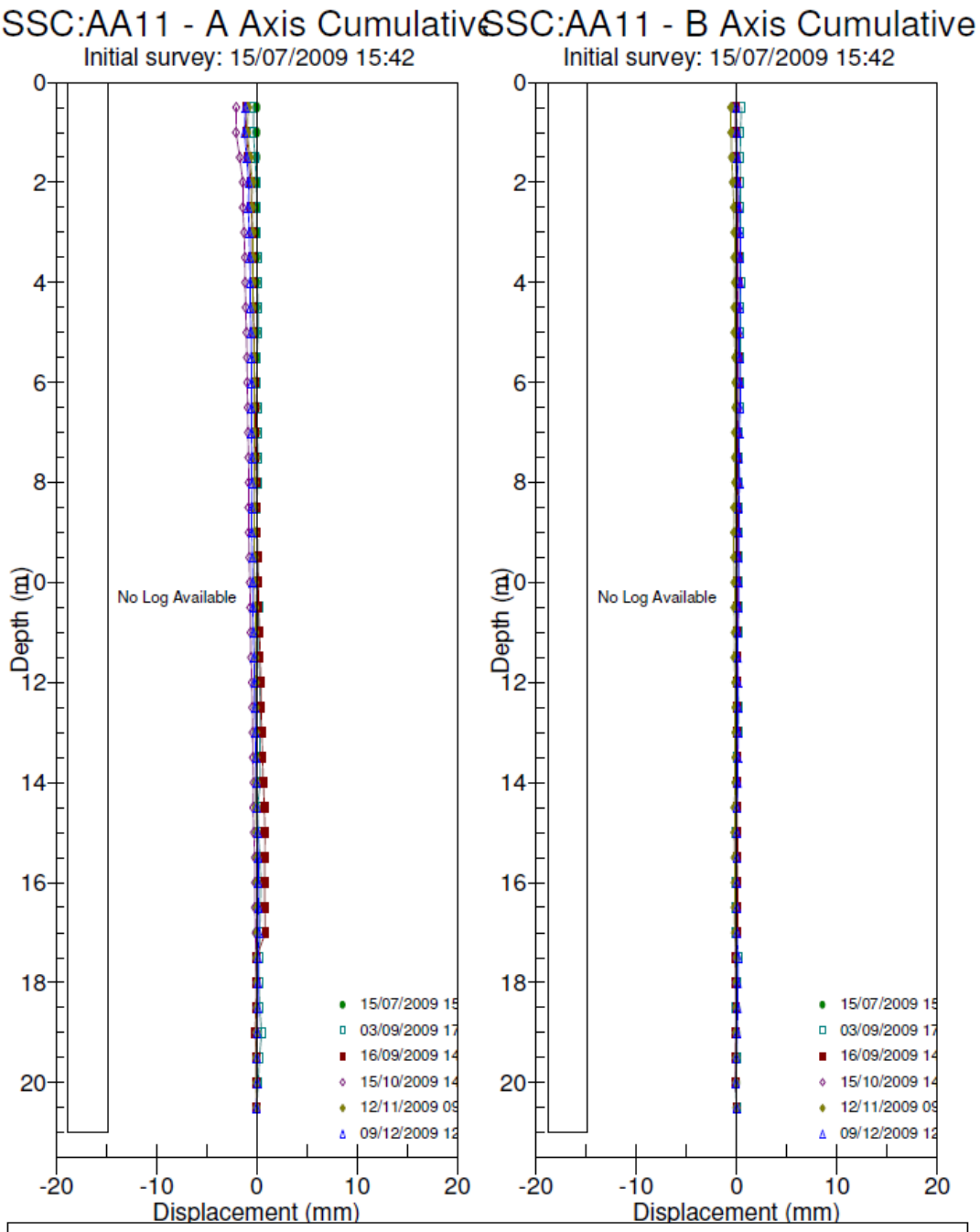
NOTE: A0 direction: East

mouchel



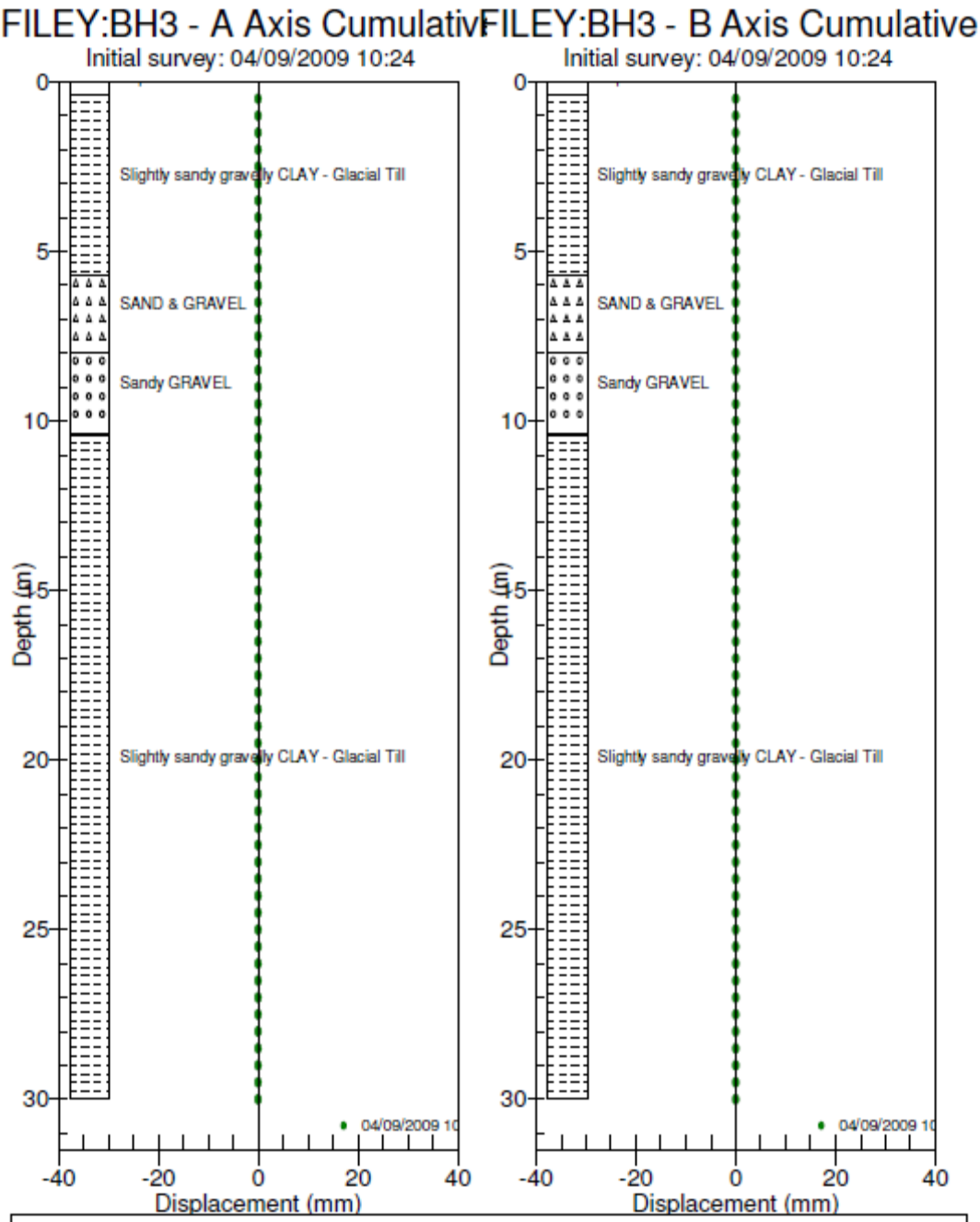
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Scarborough South Cliff
INSTALLATION: AA10 (F2)
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

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



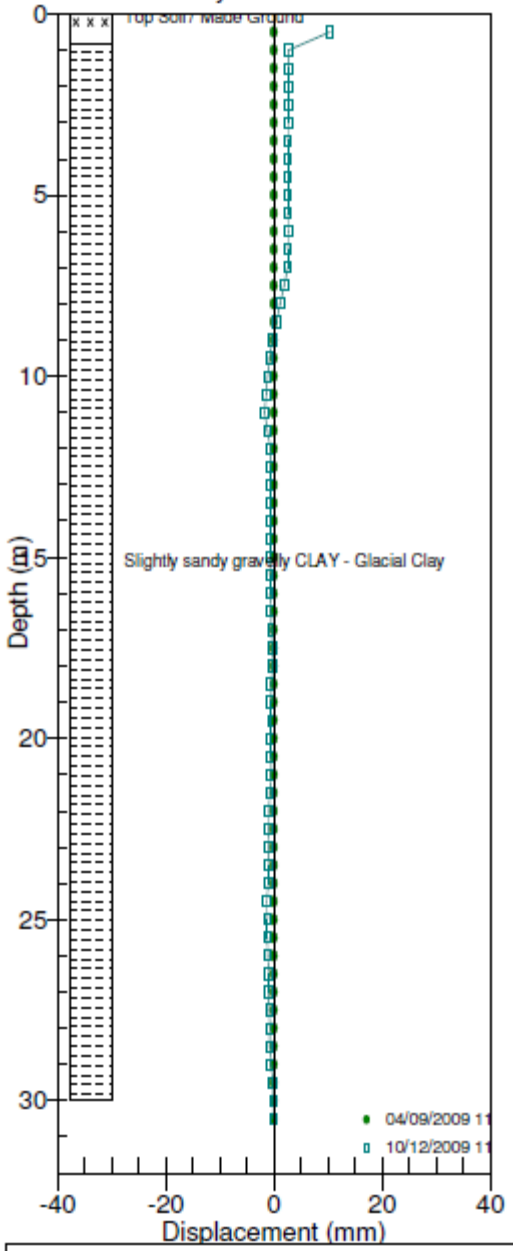
PROJECT: Ongoing Analysis of Coastal Monitoring Data
SITE: Filey Town
INSTALLATION: BH3
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

NOTE: Ao direction: North East

mouchel

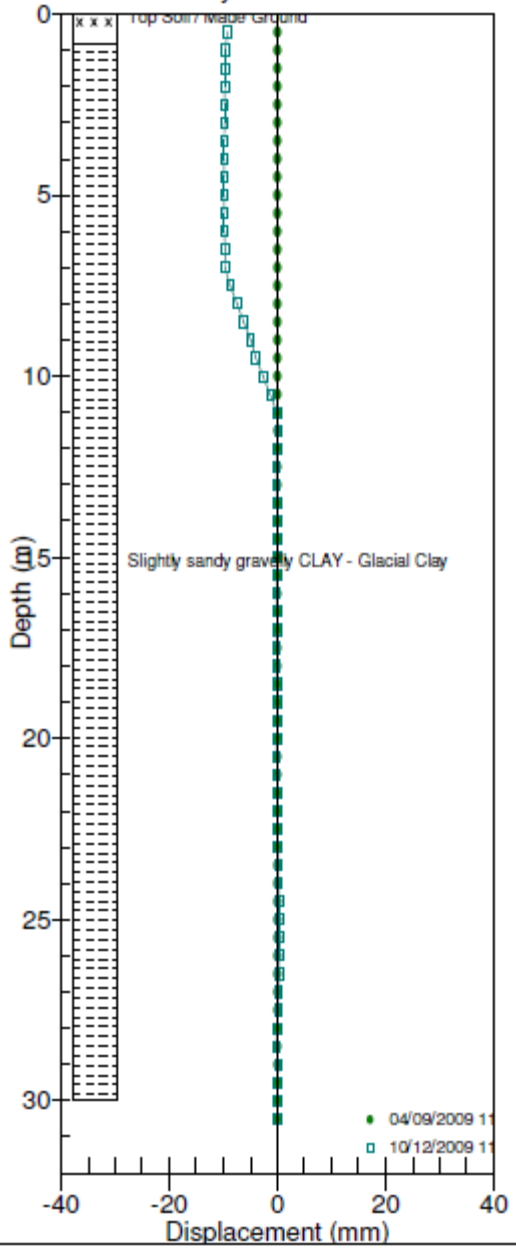
FILEY:BH6 - A Axis Cumulativ

Initial survey: 04/09/2009 11:32



FILEY:BH6 - B Axis Cumulative

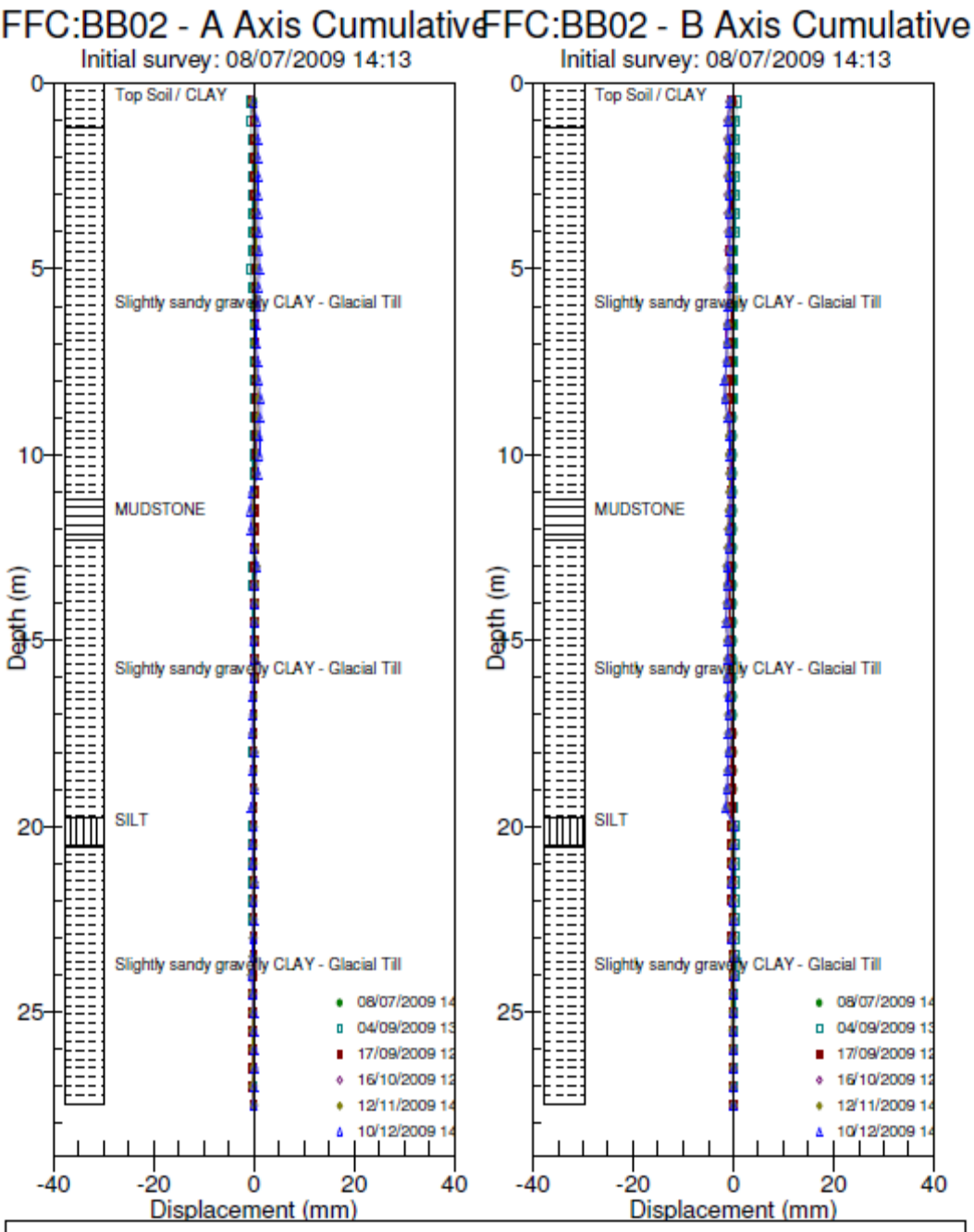
Initial survey: 04/09/2009 11:32



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

NOTE: Ao direction: North East

mouchel



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

mouchel

Appendix C Groundwater Monitoring Data

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
RUNSWICK BAY							
A001	9th July	Inclino	33.227	0.69	21.31	20.00	Concrete Pile
A002	9th July	Inclino	29.007	13.01	17.00	16.00	Concrete Pile
A003	9th July	Inclino	20.346	0.82	10.10	10.00	Concrete Pile
A004	9th July	Inclino	19.414	2.33	10.47	10.00	Concrete Pile

Groundwater Monitoring Readings - December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
RUNSWICK BAY							
A001	8th Dec	Inclino	33.227	0.72	21.40	20.00	Concrete Pile
A002	8th Dec	Inclino	29.007	13.00	16.98	16.00	Concrete Pile
A003	8th Dec	Inclino	20.346	0.84	10.24	10.00	Concrete Pile
A004	8th Dec	Inclino	19.414	2.44	10.52	10.00	Concrete Pile

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
WHITBY WEST CLIFF							
BH2	9th July	Inclino	13.78	7.73	19.90	20.00	Stiff, sandy silt

Groundwater Monitoring Readings – August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
WHITBY WEST CLIFF							
BH2	25th Aug	Inclino	13.78	6.83	19.93	20.00	Stiff, sandy silt

Groundwater Monitoring Readings – September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
WHITBY WEST CLIFF							
BH2	16th Sept	Inclino	13.78	6.70	19.90	20.00	Stiff, sandy silt

Groundwater Monitoring Readings – October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
WHITBY WEST CLIFF							
BH2	15th Oct	Inclino	13.78	6.59	19.90	20.00	Stiff, sandy silt

Groundwater Monitoring Readings – November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
WHITBY WEST CLIFF							
BH2	11th Nov	Inclino	13.78	6.14	19.90	20.00	Stiff, sandy silt

Groundwater Monitoring Readings – December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
WHITBY WEST CLIFF							
BH2	08th Dec	Inclino	13.78	5.68	19.60	20.00	Stiff, sandy silt

Groundwater Monitoring Readings – July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCALBY NESS							
I1	16th July	Inclino	35.47	6.37	32.10	31.60	Brown sandstone
I2	16th July	Inclino	34.11	0.37	35.05	34.80	Sandstone with mudstone bands
I3	16th July	Inclino	13.37	11.51	17.80	17.20	Fine to medium grained sandstone
B6	16th July	Piezo	18.55	7.63	8.42	8.55	No details
B9	16th July	Piezo	17.80	2.44	7.90	8.05	No details

Groundwater Monitoring Readings – November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCALBY NESS							
I1	11th Nov	Inclino	35.47	6.58	32.10	31.60	Brown sandstone
I2	11th Nov	Inclino	34.11	0.82	35.05	34.80	Sandstone with mudstone bands
I3	11th Nov	Inclino	13.37	11.53	17.80	17.20	Fine to medium grained sandstone
Sn1	05th Nov	Inclino	15.76	7.28	11.10	19.50	Sandstone
B6	11th Nov	Piezo	18.55	8.03	8.42	8.55	No details
B9	11th Nov	Piezo	17.80	3.53	7.90	8.05	No details

Groundwater Monitoring Readings – December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCALBY NESS							
I1	08th Dec	Inclino	35.47	3.72	32.10	31.60	Brown sandstone
I2	08th Dec	Inclino	34.11	0.96	35.10	34.80	Sandstone with mudstone bands
I3	08th Dec	Inclino	13.37	11.96	17.79	17.20	Fine to medium grained sandstone
Sn1	08th Dec	Inclino	15.76	5.68	11.20	19.50	Sandstone
B6	08th Dec	Piezo	18.55	8.43	8.43	8.55	No details
B9	08th Dec	Piezo	17.80	3.54	8.29	8.05	No details
Sn2 (a)	08th Dec	Piezo	15.48	2.85	2.85	2.50	Laminated CLAY
Sn2 (b)	08th Dec	Piezo	15.48	4.60	7.93	8.00	Slightly Sandy CLAY

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
L1 (a)	15th July	Piezo	7.03	2.00	8.00	10.00	Slightly sandy siltstone
L1 (b)	15th July	Piezo	7.03	10.27	15.04	16.00	Slightly weathered siltstone
L3 (a)	15th July	Piezo	30.78	1.41	1.41	20.70	Highly weathered sandstone
L3 (b)	15th July	Piezo	30.78	DRY	20.19	27.40	Moderately weathered sandstone to highly weathered mudstone
L5 (a)	15th July	Piezo	33.33	DRY	13.77	24.00	Highly weathered sandstone to slightly weathered siltstone
L5 (b)	15th July	Piezo	33.33	DRY	13.77	33.00	Sandstone and siltstone
L11	15th July	Inclino	55.63	7.23	14.30	14.50	Fine to medium grained sandstone
L12	15th July	Inclino	56.24	DRY	15.30	15.90	Fine to medium grained sandy siltstone

Groundwater Monitoring Readings – August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
L1 (a)	3rd Sept	Piezo	7.03	2.18	8.00	10.00	Slightly sandy siltstone
L1 (b)	3rd Sept	Piezo	7.03	5.20	15.04	16.00	Slightly weathered siltstone
L3 (a)	3rd Sept	Piezo	30.78	1.41	1.41	20.70	Highly weathered sandstone
L3 (b)	3rd Sept	Piezo	30.78	DRY	20.18	27.40	Moderately weathered sandstone to highly weathered mudstone
L5 (a)	3rd Sept	Piezo	33.33	Not read, Fouled	-	24.00	Highly weathered sandstone to slightly weathered siltstone
L5 (b)	3rd Sept	Piezo	33.33	Ditto	-	33.00	Sandstone and siltstone
L11	3rd Sept	Inclino	55.63	2.57	14.30	14.50	Fine to medium grained sandstone
L12	3rd Sept	Inclino	56.24	15.50	15.50	15.90	Fine to medium grained sandy siltstone

Groundwater Monitoring Readings – September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
L1 (a)	17th Sept	Piezo	7.03	2.24	8.10	10.00	Slightly sandy siltstone
L1 (b)	17th Sept	Piezo	7.03	5.06	15.10	16.00	Slightly weathered siltstone
L3 (a)	17th Sept	Piezo	30.78	1.39	1.40	20.70	Highly weathered sandstone
L3 (b)	17th Sept	Piezo	30.78	DRY	20.18	27.40	Moderately weathered sandstone to highly weathered mudstone
L5 (a)	17th Sept	Piezo	33.33	Not read, Fouled	-	24.00	Highly weathered sandstone to slightly weathered siltstone
L5 (b)	17th Sept	Piezo	33.33	Ditto	-	33.00	Sandstone and siltstone
L11	17th Sept	Inclino	55.63	2.48	14.30	14.50	Fine to medium grained sandstone
L12	17th Sept	Inclino	56.24	15.50	15.50	15.90	Fine to medium grained sandy siltstone

Groundwater Monitoring Readings – October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
L1 (a)	16th Oct	Piezo	7.03	2.10	8.10	10.00	Slightly sandy siltstone
L1 (b)	16th Oct	Piezo	7.03	4.80	14.90	16.00	Slightly weathered siltstone
L3 (a)	16th Oct	Piezo	30.78	1.39	1.43	20.70	Highly weathered sandstone
L3 (b)	16th Oct	Piezo	30.78	DRY	20.20	27.40	Moderately weathered sandstone to highly weathered mudstone
L4	16th Oct	Inclino	47.44	DRY	17.55	44.70	
L5 (a)	16th Oct	Piezo	33.33	DRY	13.76	24.00	Highly weathered sandstone to slightly weathered siltstone
L5 (b)	16th Oct	Piezo	33.33	DRY	13.76	33.00	Sandstone and siltstone
L11	16th Oct	Inclino	55.63	5.40	14.30	14.50	Fine to medium grained sandstone
L12	16th Oct	Inclino	56.24	14.05	15.50	15.90	Fine to medium grained sandy siltstone

Groundwater Monitoring Readings – November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
L1 (a)	12th Nov	Piezo	7.03	2.27	8.10	10.00	Slightly sandy siltstone
L1 (b)	12th Nov	Piezo	7.03	4.63	14.90	16.00	Slightly weathered siltstone
L3 (a)	12th Nov	Piezo	30.78	20.2	1.43	20.70	Highly weathered sandstone
L3 (b)	12th Nov	Piezo	30.78	1.44	1.44	27.40	Moderately weathered sandstone to highly weathered mudstone
L4	05th Nov	Inclino	47.44	10.68	10.70	44.70	Sandstone /Siltstone/ Mudstone
L5 (a)	12th Nov	Piezo	33.33	DRY	13.8	24.00	Highly weathered sandstone to slightly weathered siltstone
L5 (b)	12th Nov	Piezo	33.33	DRY	13.8	33.00	Sandstone and siltstone
L6	05th Nov	Inclino	35.74	DRY	17.40	30.10	Siltstone & Sandstone
L11	12th Nov	Inclino	55.63	5.85	14.30	14.50	Fine to medium grained sandstone
L12	12th Nov	Inclino	56.24	14.97	15.50	15.90	Fine to medium grained sandy siltstone

Groundwater Monitoring Readings – December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
L1 (a)	10th Dec	Piezo	7.03	2.40	8.03	10.00	Slightly sandy siltstone
L1 (b)	10th Dec	Piezo	7.03	4.60	15.06	16.00	Slightly weathered siltstone
L3 (a)	10th Dec	Piezo	30.78	DRY	20.16	20.70	Highly weathered sandstone
L3 (b)	10th Dec	Piezo	30.78	1.43	1.43	27.40	Moderately weathered sandstone to highly weathered mudstone
L4	10th Dec	Inclino	47.44	DRY	17.6	44.70	Sandstone /Siltstone/ Mudstone
L5 (a)	10th Dec	Piezo	33.33	DRY	13.75	24.00	Highly weathered sandstone to slightly weathered siltstone
L5 (b)	10th Dec	Piezo	33.33	DRY	13.75	33.00	Sandstone and siltstone
L6	10th Dec	Inclino	35.74	DRY	13.78	30.10	Siltstone & Sandstone
L11	10th Dec	Piezo	55.63	2.46	14.35	14.50	Fine to medium grained sandstone
L12	10th Dec	Piezo	56.24	DRY	15.28	15.90	Fine to medium grained sandy siltstone

Groundwater Monitoring Readings – August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
BH1P	3rd Sept	Piezo	7.90	3.54	4.97	4.97	-
BH1I	3rd Sept	Inclino	7.90	3.30	6.10	6.10	Mudstone
BH2P	3rd Sept	Piezo	9.55	Flooded	-	1.50	Made Ground
BH3P	3rd Sept	Piezo	17.80	Flooded	-	5.40	Mudstone
BH3I	3rd Sept	Inclino	17.80	Seized cover	-	5.60	Mudstone
BH4P	3rd Sept	Piezo	31.10	DRY	13.10	13.10	Gravely CLAY
BH4I	3rd Sept	Inclino	31.10	13.60	13.60	14.20	Sandstone

Groundwater Monitoring Readings – September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
BH1P	17th Sept	Piezo	7.90	3.60	4.92	4.97	-
BH1I	17th Sept	Inclino	7.90	3.30	6.10	6.10	Mudstone
BH2P	17th Sept	Piezo	9.55	DRY	1.10	1.50	Made Ground
BH3P	17th Sept	Piezo	17.80	3.97	4.57	5.40	Mudstone
BH3I	17th Sept	Inclino	17.80	1.88	5.74	5.60	Mudstone
BH4P	17th Sept	Piezo	31.10	DRY	13.10	13.10	Gravely CLAY
BH4I	17th Sept	Inclino	31.10	13.71	13.71	14.20	Sandstone

Groundwater Monitoring Readings – October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
BH1P	16th Oct	Piezo	7.90	3.60	4.92	4.97	-
BH1I	16th Oct	Inclino	7.90	3.30	6.10	6.10	Mudstone
BH2P	16th Oct	Piezo	9.55	DRY	1.10	1.50	Made Ground
BH3P	16th Oct	Piezo	17.80	3.90	4.57	5.40	Mudstone
BH3I	16th Oct	Inclino	17.80	1.98	5.74	5.60	Mudstone
BH4P	16th Oct	Piezo	31.10	DRY	13.10	13.10	Gravely CLAY
BH4I	16th Oct	Inclino	31.10	13.40	13.71	14.20	Sandstone

Groundwater Monitoring Readings – November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
BH1P	12th Nov	Piezo	7.90	3.61	4.92	4.97	-
BH1I	12th Nov	Inclino	7.90	3.45	6.10	6.10	Mudstone
BH2P	12th Nov	Piezo	9.55	1.06	1.10	1.50	Made Ground
BH3P	12th Nov	Piezo	17.80	3.94	4.57	5.40	Mudstone
BH3I	12th Nov	Inclino	17.80	2.11	5.74	5.60	Mudstone
BH4P	12th Nov	Piezo	31.10	DRY	13.10	13.10	Gravely CLAY
BH4I	12th Nov	Inclino	31.10	13.6	13.71	14.20	Sandstone

Groundwater Monitoring Readings – December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' NORTH BAY							
BH1P	9th Dec	Piezo	7.90	3.57	4.96	4.97	-
BH1I	9th Dec	Inclino	7.90	3.20	6.18	6.10	Mudstone
BH2P	9th Dec	Piezo	9.55	DRY	1.10	1.50	Made Ground
BH3P	9th Dec	Piezo	17.80	3.91	4.48	5.40	Mudstone
BH3I	9th Dec	Inclino	17.80	1.76	5.80	5.60	Mudstone
BH4P	10th Dec	Piezo	31.10	13.10	13.10	13.10	Gravely CLAY
BH4I	10th Dec	Inclino	31.10	13.10	13.94	14.20	Sandstone

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
AA01 (I1)	15th July	Inclino	47.95	43.00	65.10	65.00	Sandstone
AA02 (H4)	15th July	Inclino	53.85	DRY	61.30	61.50	Sandstone
AA03 (H6)	15th July	Inclino	55.76	49.57	54.40	54.50	Sandstone
AA04 (G2)	15th July	Inclino	47.62	40.10	40.60	39.50	Sandstone and siltstone
AA10 (F2)	15th July	Inclino	34.98	23.40	30.50	29.50	Sandstone and siltstone
AA11 (F4)	15th July	Inclino	N/A	16.02	20.20	19.50	No details
AA09 (E3)	15th July	Inclino	58.06	33.81	48.50	48.00	Sandstone and siltstone
AA05 (E5)	15th July	Inclino	63.06	42.34	54.80	53.50	Sandstone and siltstone
AA08 (D3)	15th July	Inclino	38.43	21.35	25.02	24.60	Fine sandstone
AA06 (D1)	15th July	Inclino	64.1	32.20	46.50	46.40	Silty mudstone
AA07 (Bh2)	15th July	Inclino	56.33	46.20	60.00	60.00	Fine to coarse grained sandstone
I2	15th July	Piezo	22.69	21.55	31.00	31.10	Clayey fine sand

Groundwater Monitoring Readings - August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
AA01 (I1)	4th Sept	Inclino	47.95	44.84	65.10	65.00	Sandstone
AA02 (H4)	4th Sept	Inclino	53.85	45.00	61.30	61.50	Sandstone
AA03 (H6)	4th Sept	Inclino	55.76	48.66	54.40	54.50	Sandstone
AA04 (G2)	25th Aug	Inclino	47.62	39.50	40.60	39.50	Sandstone and siltstone
AA10 (F2)	25th Aug	Inclino	34.98	19.85	30.50	29.50	Sandstone and siltstone
AA11 (F4)	25th Aug	Inclino	N/A	15.90	20.20	19.50	No details
AA09 (E3)	4th Sept	Inclino	58.06	29.25	48.50	48.00	Sandstone and siltstone
AA05 (E5)	4th Sept	Inclino	63.06	42.41	54.80	53.50	Sandstone and siltstone
AA08 (D3)	25th Aug	Inclino	38.43	21.40	25.02	24.60	Fine sandstone
AA06 (D1)	25th Aug	Inclino	64.1	32.20	46.50	46.40	Silty mudstone
AA07 (Bh2)	25th Aug	Inclino	56.33	45.64	60.00	60.00	Fine to coarse grained sandstone
I2	25th Aug	Piezo	22.69	21.30	31.00	31.10	Clayey fine sand

Groundwater Monitoring Readings - September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
AA01 (I1)	17th Sept	Inclino	47.95	46.20	65.10	65.00	Sandstone
AA02 (H4)	17th Sept	Inclino	53.85	45.17	61.30	61.50	Sandstone
BH1 SPA (Top)	17th Sept	Piezo	55.00	13.27	13.60	13.60	Sandy Clay
AA03 (H6)	17th Sept	Inclino	55.76	49.25	54.40	54.50	Sandstone
AA04 (G2)	17th Sept	Inclino	47.62	39.50	39.50	39.50	Sandstone and siltstone
AA10 (F2)	16th Sept	Inclino	34.98	19.61	30.50	29.50	Sandstone and siltstone
AA11 (F4)	16th Sept	Inclino	N/A	15.90	20.20	19.50	No details
AA09 (E3)	16th Sept	Inclino	58.06	29.71	48.50	48.00	Sandstone and siltstone
AA05 (E5)	17th Sept	Inclino	63.06	42.35	54.80	53.50	Sandstone and siltstone
AA08 (D3)	16th Sept	Inclino	38.43	21.33	25.02	24.60	Fine sandstone
AA06 (D1)	17th Sept	Inclino	64.1	33.14	46.50	46.40	Silty mudstone
AA07 (Bh2)	17th Sept	Inclino	56.33	46.53	60.00	60.00	Fine to coarse grained sandstone
I2	16th Sept	Piezo	22.69	21.41	31.00	31.10	Clayey fine sand

Groundwater Monitoring Readings - October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
AA01 (I1)	15th Oct	Inclino	47.95	46.85	65.10	65.00	Sandstone
AA02 (H4)	15th Oct	Inclino	53.85	46.02	61.30	61.50	Sandstone
BH1 SPA (Top)	15th Oct	Piezo	55.00	12.60	12.78	13.60	Sandy Clay
AA03 (H6)	15th Oct	Inclino	55.76	49.63	54.40	54.50	Sandstone
AA04 (G2)	15th Oct	Inclino	47.62	39.97	39.50	39.50	Sandstone and siltstone
AA10 (F2)	15th Oct	Inclino	34.98	16.21	30.50	29.50	Sandstone and siltstone
AA11 (F4)	15th Oct	Inclino	N/A	15.91	20.20	19.50	No details
AA09 (E3)	15th Oct	Inclino	58.06	26.54	48.50	48.00	Sandstone and siltstone
AA05 (E5)	15th Oct	Inclino	63.06	42.35	54.80	53.50	Sandstone and siltstone
AA08 (D3)	15th Oct	Inclino	38.43	21.10	25.02	24.60	Fine sandstone
AA06 (D1)	15th Oct	Inclino	64.1	31.95	46.50	46.40	Silty mudstone
AA07 (Bh2)	15th Oct	Inclino	56.33	45.41	60.00	60.00	Fine to coarse grained sandstone
I2	15th Oct	Piezo	22.69	21.40	31.00	31.10	Clayey fine sand

Groundwater Monitoring Readings - November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
AA01 (I1)	12th Nov	Inclino	47.95	DRY to 50m	65.10	65.00	Sandstone
AA02 (H4)	12th Nov	Inclino	53.85	DRY to 50m	61.30	61.50	Sandstone
BH1 SPA (Top)	12th Nov	Piezo	55.00	12.6	12.78	13.60	Sandy CLAY
AA03 (H6)	12th Nov	Inclino	55.76	DRY to 50m	54.40	54.50	Sandstone
AA04 (G2)	11th Nov	Inclino	47.62	DRY	39.50	39.50	Sandstone and siltstone
AA10 (F2)	11th Nov	Inclino	34.98	21.2	30.50	29.50	Sandstone and siltstone
AA11 (F4)	11th Nov	Inclino	N/A	15.34	20.20	19.50	No details
AA09 (E3)	12th Nov	Inclino	58.06	29.9	48.50	48.00	Sandstone and siltstone
AA05 (E5)	12th Nov	Inclino	63.06	42.3	54.80	53.50	Sandstone and siltstone
AA08 (D3)	11th Nov	Inclino	38.43	21.42	25.02	24.60	Fine sandstone
AA06 (D1)	12th Nov	Inclino	64.1	31.86	46.50	46.40	Silty mudstone
AA07 (Bh2)	11th Nov	Inclino	56.33	45.5	60.00	60.00	Fine to coarse grained sandstone
I2	12th Nov	Piezo	22.69	21.76	31.00	31.10	Clayey fine sand

Groundwater Monitoring Readings - December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
AA01 (I1)	9th Dec	Inclino	47.95	DRY	>50.00	65.00	Sandstone
AA02 (H4)	9th Dec	Inclino	53.85	DRY	>50 00	61.50	Sandstone
BH1 SPA (Top)	9th Dec	Piezo	55.00	13.59	13.59	13.60	Sandy CLAY
AA03 (H6)	9th Dec	Inclino	55.76	47.95	>50 00	54.50	Sandstone
AA04 (G2)	9th Dec	Inclino	47.62	DRY	40.30	39.50	Sandstone and siltstone
AA10 (F2)	9th Dec	Inclino	34.98	17.05	31.44	29.50	Sandstone and siltstone
AA11 (F4)	9th Dec	Inclino	N/A	14.48	20.27	19.50	No details
AA09 (E3)	9th Dec	Inclino	58.06	17.02	48.40	48.00	Sandstone and siltstone
AA05 (E5)	9th Dec	Inclino	63.06	42.41	>50.00	53.50	Sandstone and siltstone
AA08 (D3)	9th Dec	Inclino	38.43	21.22	24.97	24.60	Fine sandstone
AA06 (D1)	9th Dec	Inclino	64.1	32.61	46.50	46.40	Silty mudstone
AA07 (Bh2)	9th Dec	Inclino	56.33	45.46	>50.00	60.00	Fine to coarse grained sandstone
I2	9th Dec	Piezo	22.69	21.26	31.04	31.10	Clayey fine sand

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
I2A	15th July	Piezo	22.69	19.00	19.00	19.00	Clayey coarse sand
H2 (a)	15th July	Piezo	46.52	29.20	29.20	30.00	Silty fine and medium sand
H2 (b)	15th July	Piezo	46.52	34.30	37.50	38.50	Silty fine and medium sand
H1 (a)	15th July	Piezo	26.45	DRY	15.30	15.75	Gravel in a clayey silty sand
H1 (b)	15th July	Piezo	26.45	DRY	4.28	36.00	Fine to coarse sand and gravel
H5	15th July	Piezo	23.35	1.64	6.91	9.70	Firm to stiff sandy silty clay
1 Spa	15th July	Piezo	N/A	12.92	13.90	13.90	No details
2 Spa	15th July	Piezo	N/A	9.10	12.80	12.80	No details
3 Spa	15th July	Piezo	N/A	6.69	11.48	11.48	No details
4 Spa	15th July	Piezo	N/A	6.48	7.27	7.27	No details
G3	15th July	Piezo	18.15	4.88	6.17	6.17	Medium coarse gravel

Groundwater Monitoring Readings - August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
I2A	25th Aug	Piezo	22.69	18.94	19.00	19.00	Clayey coarse sand
H2 (a)	25th Aug	Piezo	46.52	29.20	29.20	30.00	Silty fine and medium sand
H2 (b)	25th Aug	Piezo	46.52	34.53	37.50	38.50	Silty fine and medium sand
H1 (a)	25th Aug	Piezo	26.45	DRY	15.30	15.75	Gravel in a clayey silty sand
H1 (b)	25th Aug	Piezo	26.45	DRY	4.28	36.00	Fine to coarse sand and gravel
H5	25th Aug	Piezo	23.35	2.40	8.91	9.70	Firm to stiff sandy silty clay
1 Spa	25th Aug	Piezo	N/A	13.50	13.90	13.90	No details
2 Spa	25th Aug	Piezo	N/A	9.04	12.80	12.80	No details
3 Spa	25th Aug	Piezo	N/A	6.70	11.48	11.48	No details
4 Spa	25th Aug	Piezo	N/A	6.30	7.27	7.27	No details
G3	25th Aug	Piezo	18.15	5.25	6.17	6.17	Medium coarse gravel

Groundwater Monitoring Readings - September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
I2A	16th Sept	Piezo	22.69	16.81	18.81	19.00	Clayey coarse sand
H2 (a)	17th Sept	Piezo	46.52	29.20	29.20	30.00	Silty fine and medium sand
H2 (b)	17th Sept	Piezo	46.52	34.79	37.50	38.50	Silty fine and medium sand
H1 (a)	16th Sept	Piezo	26.45	DRY	15.20	15.75	Gravel in a clayey silty sand
H1 (b)	16th Sept	Piezo	26.45	DRY	4.60	36.00	Fine to coarse sand and gravel
H5	16th Sept	Piezo	23.35	3.30	9.70	9.70	Firm to stiff sandy silty clay
1 Spa	17th Sept	Piezo	N/A	12.21	13.90	13.90	No details
2 Spa	17th Sept	Piezo	N/A	9.16	12.80	12.80	No details
3 Spa	17th Sept	Piezo	N/A	6.71	11.48	11.48	No details
4 Spa	17th Sept	Piezo	N/A	6.74	7.27	7.27	No details
G3	17th Sept	Piezo	18.15	5.30	6.17	6.17	Medium coarse gravel

Groundwater Monitoring Readings - October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
I2A	15th Oct	Piezo	22.69	18.95	18.81	19.00	Clayey coarse sand
H2 (a)	15th Oct	Piezo	46.52	29.24	29.20	30.00	Silty fine and medium sand
H2 (b)	15th Oct	Piezo	46.52	34.50	37.50	38.50	Silty fine and medium sand
H1 (a)	15th Oct	Piezo	26.45	DRY	15.20	15.75	Gravel in a clayey silty sand
H1 (b)	15th Oct	Piezo	26.45	DRY	4.60	36.00	Fine to coarse sand and gravel
H5	15th Oct	Piezo	23.35	3.30	9.70	9.70	Firm to stiff sandy silty clay
1 Spa	15th Oct	Piezo	N/A	10.70	13.90	13.90	No details
2 Spa	15th Oct	Piezo	N/A	10.2	12.80	12.80	No details
3 Spa	15th Oct	Piezo	N/A	6.70	11.48	11.48	No details
4 Spa	15th Oct	Piezo	N/A	6.85	7.27	7.27	No details
G3	15th Oct	Piezo	18.15	4.50	6.17	6.17	Medium coarse gravel

Groundwater Monitoring Readings - November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
I2A	12th Nov	Piezo	22.69	18.97	18.81	19.00	Clayey coarse sand
H2 (a)	12th Nov	Piezo	46.52	DRY	29.20	30.00	Silty fine and medium sand
H2 (b)	12th Nov	Piezo	46.52	34.23	37.50	38.50	Silty fine and medium sand
H1 (a)	12th Nov	Piezo	26.45	DRY	15.70	15.75	Gravel in a clayey silty sand
H1 (b)	12th Nov	Piezo	26.45	DRY	4.30	36.00	Fine to coarse sand and gravel
H5	12th Nov	Piezo	23.35	3.6	9.70	9.70	Firm to stiff sandy silty clay
1 Spa	12th Nov	Piezo	N/A	10.01	13.90	13.90	No details
2 Spa	12th Nov	Piezo	N/A	9.1	12.80	12.80	No details
3 Spa	12th Nov	Piezo	N/A	6.7	11.48	11.48	No details
4 Spa	12th Nov	Piezo	N/A	6.75	7.27	7.27	No details
G3	12th Nov	Piezo	18.15	4.7	6.17	6.17	Medium coarse gravel

Groundwater Monitoring Readings - December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
I2A	9th Dec	Piezo	22.69	18.94	18.94	19.00	Clayey coarse sand
H2 (a)	9th Dec	Piezo	46.52	DRY	29.20	30.00	Silty fine and medium sand
H2 (b)	9th Dec	Piezo	46.52	34.36	37.43	38.50	Silty fine and medium sand
H1 (a)	-	Piezo	26.45	-	No longer Monitored	15.75	Gravel in a clayey silty sand
H1 (b)	-	Piezo	26.45	-	No longer Monitored	36.00	Fine to coarse sand and gravel
H5	9th Dec	Piezo	23.35	3.53	8.90	9.70	Firm to stiff sandy silty clay
1 Spa	9th Dec	Piezo	N/A	8.48	14.20	13.90	No details
2 Spa	9th Dec	Piezo	N/A	7.83	12.20	12.80	No details
3 Spa	9th Dec	Piezo	N/A	6.60	12.07	11.48	No details
4 Spa	9th Dec	Piezo	N/A	6.51	7.42	7.27	No details
G3	9th Dec	Piezo	18.15	5.11	5.22	6.17	Medium coarse gravel

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
5 Spa	15th July	Piezo	N/A	DRY	8.80	8.80	No details
G1 (a)	15th July	Piezo	55.48	36.40	36.40	36.60	Clayey silty coarse sand
G1 (b)	15th July	Piezo	55.48	DRY	2.10	16.80	Clayey fine to coarse gravel
E2 (a)	15th July	Slip Indicator	51.81	3.80	17.70	19.00	Slightly clayey slightly silty fine sand
E2 (b)	15th July	Piezo	51.81	1.29	8.20	8.85	Sandy silty clay
D2 (a)	15th July	Piezo	46.54	6.12	19.09	19.00	Firm silty sandy clay
D2 (b)	15th July	Piezo	46.54	1.10	5.04	5.00	Clayey fine to coarse sand
Bh3 (a)	15th July	Piezo	53.83	37.56	42.40	45.40	Slightly sandy mudstone
Bh3 (b)	15th July	Piezo	53.83	9.94	12.30	12.45	Stiff sandy, silty clay
Bh4 (a)	15th July	Piezo	59.00	8.40	30.85	30.85	Firm to stiff, sandy silty clay
Bh4 (b)	15th July	Piezo	59.00	8.56	33.90	33.90	Firm to stiff, sandy silty clay

Groundwater Monitoring Readings - August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
5 Spa	25th Aug	Piezo	N/A	8.75	8.80	8.80	No details
G1 (a)	25th Aug	Piezo	55.48	36.40	36.40	36.60	Clayey silty coarse sand
G1 (b)	25th Aug	Piezo	55.48	DRY	2.00	16.80	Clayey fine to coarse gravel
E2 (a)	3rd Sept	Slip Indicator	51.81	3.80	17.70	19.00	Slightly clayey slightly silty fine sand
E2 (b)	3rd Sept	Piezo	51.81	1.37	8.20	8.85	Sandy silty clay
D2 (a)	3rd Sept	Piezo	46.54	6.14	19.00	19.00	Firm silty sandy clay
D2 (b)	3rd Sept	Piezo	46.54	1.07	5.04	5.00	Clayey fine to coarse sand
Bh3 (a)	3rd Sept	Piezo	53.83	39.40	42.40	45.40	Slightly sandy mudstone
Bh3 (b)	3rd Sept	Piezo	53.83	10.00	12.30	12.45	Stiff sandy, silty clay
Bh4 (a)	3rd Sept	Piezo	59.00	8.18	30.85	30.85	Firm to stiff, sandy silty clay
Bh4 (b)	3rd Sept	Piezo	59.00	8.33	33.90	33.90	Firm to stiff, sandy silty clay

Groundwater Monitoring Readings - September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
5 Spa	17th Sept	Piezo	N/A	8.68	8.90	8.80	No details
G1 (a)	17th Sept	Piezo	55.48	36.40	36.40	36.60	Clayey silty coarse sand
G1 (b)	17th Sept	Piezo	55.48	DRY	2.00	16.80	Clayey fine to coarse gravel
E2 (a)	16th Sept	Slip Indicator	51.81	4.40	18.60	19.00	Slightly clayey slightly silty fine sand
E2 (b)	16th Sept	Piezo	51.81	1.38	8.20	8.85	Sandy silty clay
D2 (a)	16th Sept	Piezo	46.54	9.20	19.00	19.00	Firm silty sandy clay
D2 (b)	16th Sept	Piezo	46.54	1.02	5.00	5.00	Clayey fine to coarse sand
Bh3 (a)	17th Sept	Piezo	53.83	39.12	42.40	45.40	Slightly sandy mudstone
Bh3 (b)	16th Sept	Piezo	53.83	9.88	12.40	12.45	Stiff sandy, silty clay
Bh4 (a)	16th Sept	Piezo	59.00	8.40	27.60	30.85	Firm to stiff, sandy silty clay
Bh4 (b)	16th Sept	Piezo	59.00	8.40	33.45	33.90	Firm to stiff, sandy silty clay

Groundwater Monitoring Readings - October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
5 Spa	15th Oct	Piezo	N/A	DRY	8.90	8.80	No details
G1 (a)	15th Oct	Piezo	55.48	36.24	36.40	36.60	Clayey silty coarse sand
G1 (b)	15th Oct	Piezo	55.48	DRY	2.00	16.80	Clayey fine to coarse gravel
E2 (a)	15th Oct	Slip Indicator	51.81	4.45	18.60	19.00	Slightly clayey slightly silty fine sand
E2 (b)	15th Oct	Piezo	51.81	1.45	8.20	8.85	Sandy silty clay
D2 (a)	15th Oct	Piezo	46.54	6.20	19.00	19.00	Firm silty sandy clay
D2 (b)	15th Oct	Piezo	46.54	1.05	5.00	5.00	Clayey fine to coarse sand
Bh3 (a)	15th Oct	Piezo	53.83	39.59	42.40	45.40	Slightly sandy mudstone
Bh3 (b)	15th Oct	Piezo	53.83	9.93	12.40	12.45	Stiff sandy, silty clay
Bh4 (a)	15th Oct	Piezo	59.00	8.82	27.60	30.85	Firm to stiff, sandy silty clay
Bh4 (b)	15th Oct	Piezo	59.00	9.05	33.45	33.90	Firm to stiff, sandy silty clay

Groundwater Monitoring Readings - November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
5 Spa	12th Nov	Piezo	N/A	DRY	8.90	8.80	No details
G1 (a)	12th Nov	Piezo	55.48	36.44	36.40	36.60	Clayey silty coarse sand
G1 (b)	12th Nov	Piezo	55.48	DRY	2.00	16.80	Clayey fine to coarse gravel
E2 (a)	12th Nov	Slip Indicator	51.81	4.62	18.60	19.00	Slightly clayey slightly silty fine sand
E2 (b)	12th Nov	Piezo	51.81	1.51	8.20	8.85	Sandy silty clay
D2 (a)	12th Nov	Piezo	46.54	6.09	19.00	19.00	Firm silty sandy clay
D2 (b)	11th Nov	Piezo	46.54	1.14	5.00	5.00	Clayey fine to coarse sand
Bh3 (a)	11th Nov	Piezo	53.83	41.47	42.40	45.40	Slightly sandy mudstone
Bh3 (b)	11th Nov	Piezo	53.83	10.02	12.40	12.45	Stiff sandy, silty clay
Bh4 (a)	11th Nov	Piezo	59.00	8.26	27.60	30.85	Firm to stiff, sandy silty clay
Bh4 (b)	11th Nov	Piezo	59.00	8.06	33.45	33.90	Firm to stiff, sandy silty clay

Groundwater Monitoring Readings - December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
5 Spa	9th Dec	Piezo	N/A	DRY	9.53	8.80	No details
G1 (a)	9th Dec	Piezo	55.48	36.40	36.40	36.60	Clayey silty coarse sand
G1 (b)	9th Dec	Piezo	55.48	DRY	2.10	16.80	Clayey fine to coarse gravel
E2 (a)	9th Dec	Slip Indicator	51.81	4.68	16.65	19.00	Slightly clayey slightly silty fine sand
E2 (b)	9th Dec	Piezo	51.81	1.68	8.20	8.85	Sandy silty clay
D2 (a)	9th Dec	Piezo	46.54	6.10	19.05	19.00	Firm silty sandy clay
D2 (b)	9th Dec	Piezo	46.54	1.03	5.04	5.00	Clayey fine to coarse sand
Bh3 (a)	9th Dec	Piezo	53.83	39.59	42.46	45.40	Slightly sandy mudstone
Bh3 (b)	9th Dec	Piezo	53.83	9.96	12.28	12.45	Stiff sandy, silty clay
Bh4 (a)	9th Dec	Piezo	59.00	7.26	27.70	30.85	Firm to stiff, sandy silty clay
Bh4 (b)	9th Dec	Piezo	59.00	7.34	33.40	33.90	Firm to stiff, sandy silty clay

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
Bh1 (a)	15th July	Piezo	49.77	DRY	30.60	30.60	Silty sandstone
Bh1 (b)	15th July	Piezo	49.77	12.58	19.90	19.90	Stiff, sandy, silty clay

Groundwater Monitoring Readings - August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
Bh1 (a)	3rd Sept	Piezo	49.77	Flooded	30.60	30.60	Silty sandstone
Bh1 (b)	3rd Sept	Piezo	49.77	Flooded	19.90	19.90	Stiff, sandy, silty clay

Groundwater Monitoring Readings - September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
Bh1 (a)	16th Sept	Piezo	49.77	DRY	30.60	30.60	Silty sandstone
Bh1 (b)	16th Sept	Piezo	49.77	12.86	16.70	19.90	Stiff, sandy, silty clay

Groundwater Monitoring Readings - October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
Bh1 (a)	15th Oct	Piezo	49.77	DRY	30.60	30.60	Silty sandstone
Bh1 (b)	165h Oct	Piezo	49.77	12.94	16.70	19.90	Stiff, sandy, silty clay
A1	15th Oct	Inclino	58.28	Not Found	-	30.50	Mudstone

Groundwater Monitoring Readings - November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
Bh1 (a)	11th Nov	Piezo	49.77	DRY	30.60	30.60	Silty sandstone
Bh1 (b)	11th Nov	Piezo	49.77	12.42	16.70	19.90	Stiff, sandy, silty clay
A1	05th Nov	Inclino	58.28	9.06	9.06	30.50	Mudstone

Groundwater Monitoring Readings - December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
SCARBORO' SOUTH CLIFF							
Bh1 (a)	9th Dec	Piezo	49.77	DRY	30.70	30.60	Silty sandstone
Bh1 (b)	9th Dec	Piezo	49.77	11.14	16.70	19.90	Stiff, sandy, silty clay
A1	10th Dec	Inclino	58.28	5.35	9.21	30.50	Mudstone
BH01 SPA (a)	9th Dec	Piezo	N/A	9.90	12.57	13.00	Gravel
BH01 SPA (b)	9th Dec	Piezo	N/A	3.90	3.90	4.00	Made Ground

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FILEY TOWN							
BH1	8th July	Piezo	28.768	13.06	13.65	14.00	Sandy gravely CLAY
BH2	8th July	Piezo	16.942	0.56	2.00	2.00	Clayey sandy gravel
BH4	8th July	Piezo	27.07	Not Found	-	9.00	slightly sandy, slightly gravely CLAY
BH5B	8th July	Piezo	7.541	6.04	6.18	6.45	Gravely fine to coarse sand – Made Ground
BH3	8th July	Inclino	27.098	16.25	30.00	29.70	Stiff, slightly sandy, slightly gravely CLAY
BH6	8th July	Inclino	27.33	Not Found	-	30.00	Stiff, slightly sandy, gravely CLAY

Groundwater Monitoring Readings - December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FILEY TOWN							
BH1	10th Dec	Piezo	28.768	13.31	13.87	14.00	Sandy gravely CLAY
BH2	10th Dec	Piezo	16.942	-	Blocked with spoil at 100mm approx.	2.00	Clayey sandy gravel
BH4	10th Dec	Piezo	27.07	3.84	9.30	9.00	slightly sandy, slightly gravely CLAY
BH5B	10th Dec	Piezo	7.541	5.85	6.20	6.45	Gravely fine to coarse sand – Made Ground
BH3	10th Dec	Inclino	27.098	16.33	18.35	29.70	Stiff, slightly sandy, slightly gravely CLAY
BH6	10th Dec	Inclino	27.33	9.20	30.60	30.00	Stiff, slightly sandy, gravely CLAY

Groundwater Monitoring Readings - July 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FLAT CLIFFS							
BB01 (D2)	8th July	Inclino	25.54	DRY	14.20	22.50	Firm slightly sandy, slightly gravely CLAY
BB02 (A2)	8th July	Inclino	17.93	1.59	28.10	28.85	Firm slightly sandy, slightly gravely CLAY
B1	8th July	Piezo	15.64	2.06	23.38	24.50	Fine to medium SAND with clay bands
D1	8th July	Piezo	36.09	16.37	20.48	20.50	Stiff slightly sandy gravely CLAY
A3	8th July	Piezo	36.77	18.04	30.40	30.50	Firm slightly sandy gravely CLAY

Groundwater Monitoring Readings - August 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FLAT CLIFFS							
BB01 (D2)	25th August	Inclino	25.54	DRY	14.20	22.50	Firm slightly sandy, slightly gravely CLAY
BB02 (A2)	25th August	Inclino	17.93	1.76	28.10	28.85	Firm slightly sandy, slightly gravely CLAY
B1	25th August	Piezo	15.64	2.03	23.38	24.50	Fine to medium SAND with clay bands
D1	25th August	Piezo	36.09	16.60	20.48	20.50	Stiff slightly sandy gravely CLAY
A3	25th August	Piezo	36.77	17.94	30.40	30.50	Firm slightly sandy gravely CLAY

Groundwater Monitoring Readings - September 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FLAT CLIFFS							
BB01 (D2)	17th Sept	Inclino	25.54	DRY	14.20	22.50	Firm slightly sandy, slightly gravely CLAY
BB02 (A2)	17th Sept	Inclino	17.93	1.43	27.50	28.85	Firm slightly sandy, slightly gravely CLAY
B1	17th Sept	Piezo	15.64	2.29	23.35	24.50	Fine to medium SAND with clay bands
D1	17th Sept	Piezo	36.09	16.81	20.36	20.50	Stiff slightly sandy gravely CLAY
A3	17th Sept	Piezo	36.77	18.02	30.39	30.50	Firm slightly sandy gravely CLAY

Groundwater Monitoring Readings - October 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FLAT CLIFFS							
BB01 (D2)	16th Oct	Inclino	25.54	DRY	14.20	22.50	Firm slightly sandy, slightly gravely CLAY
BB02 (A2)	16th Oct	Inclino	17.93	1.58	27.50	28.85	Firm slightly sandy, slightly gravely CLAY
B1	16th Oct	Piezo	15.64	1.30	23.35	24.50	Fine to medium SAND with clay bands
D1	16th Oct	Piezo	36.09	16.95	20.36	20.50	Stiff slightly sandy gravely CLAY
A3	16th Oct	Piezo	36.77	18.15	30.39	30.50	Firm slightly sandy gravely CLAY

Groundwater Monitoring Readings - November 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FLAT CLIFFS							
BB01 (D2)	12th Nov	Inclino	25.54	DRY	14.20	22.50	Firm slightly sandy, slightly gravely CLAY
BB02 (A2)	12th Nov	Inclino	17.93	1.9	27.50	28.85	Firm slightly sandy, slightly gravely CLAY
B1	12th Nov	Piezo	15.64	2.42	23.35	24.50	Fine to medium SAND with clay bands
D1	12th Nov	Piezo	36.09	18.06	20.36	20.50	Stiff slightly sandy gravely CLAY
A3	12th Nov	Piezo	36.77	18.61	30.39	30.50	Firm slightly sandy gravely CLAY

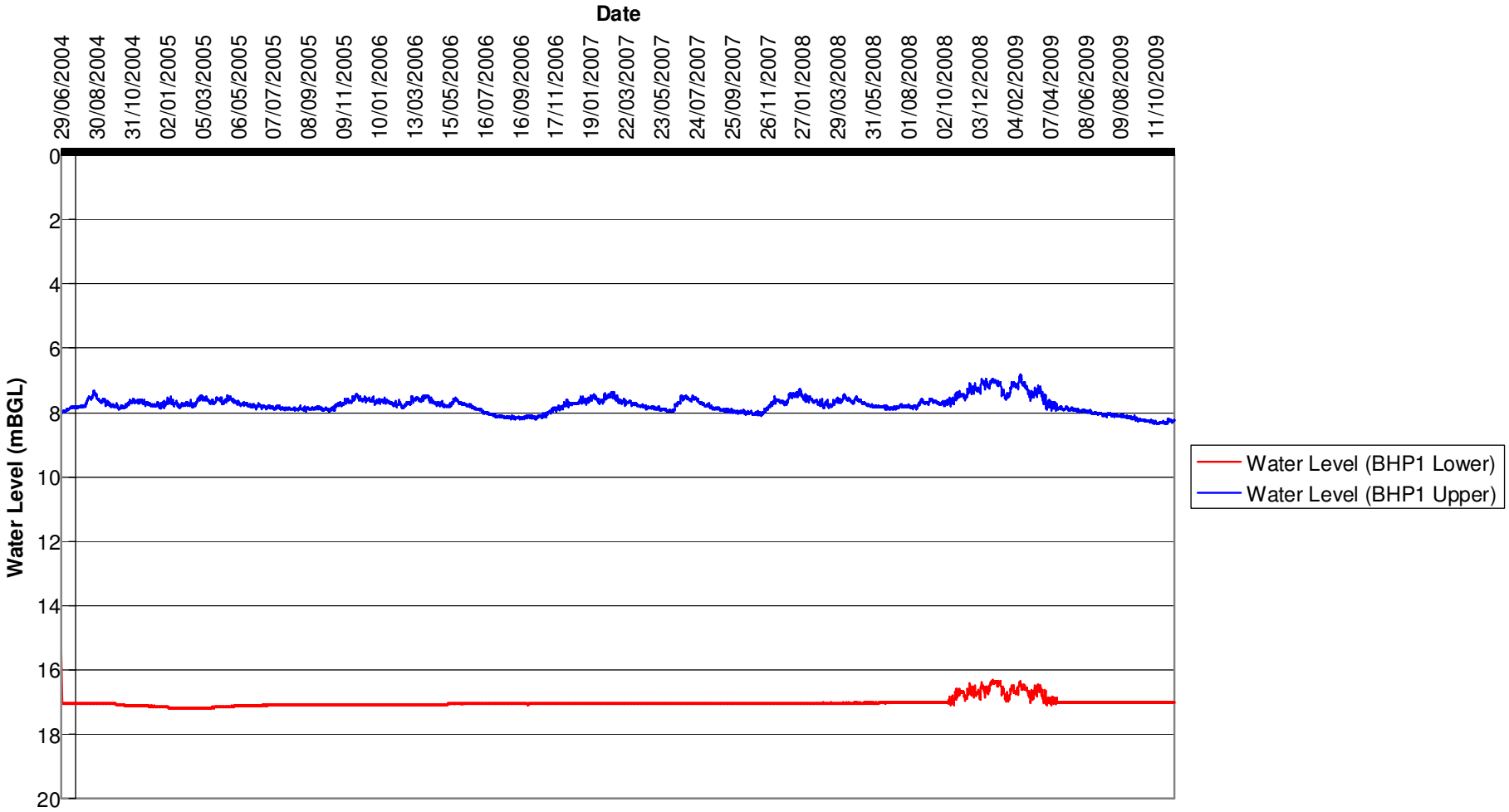
Groundwater Monitoring Readings - December 2009

SITE Exploratory hole No.	Date (2009)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
FLAT CLIFFS							
BB01 (D2)	10th Dec	Inclino	25.54	DRY	14.33	22.50	Firm slightly sandy, slightly gravely CLAY
BB02 (A2)	10th Dec	Inclino	17.93	1.77	27.50	28.85	Firm slightly sandy, slightly gravely CLAY
B1	10th Dec	Piezo	15.64	2.32	23.40	24.50	Fine to medium SAND with clay bands
D1	10th Dec	Piezo	36.09	4.24	20.50	20.50	Stiff slightly sandy gravely CLAY
A3	10th Dec	Piezo	36.77	18.27	30.50	30.50	Firm slightly sandy gravely CLAY

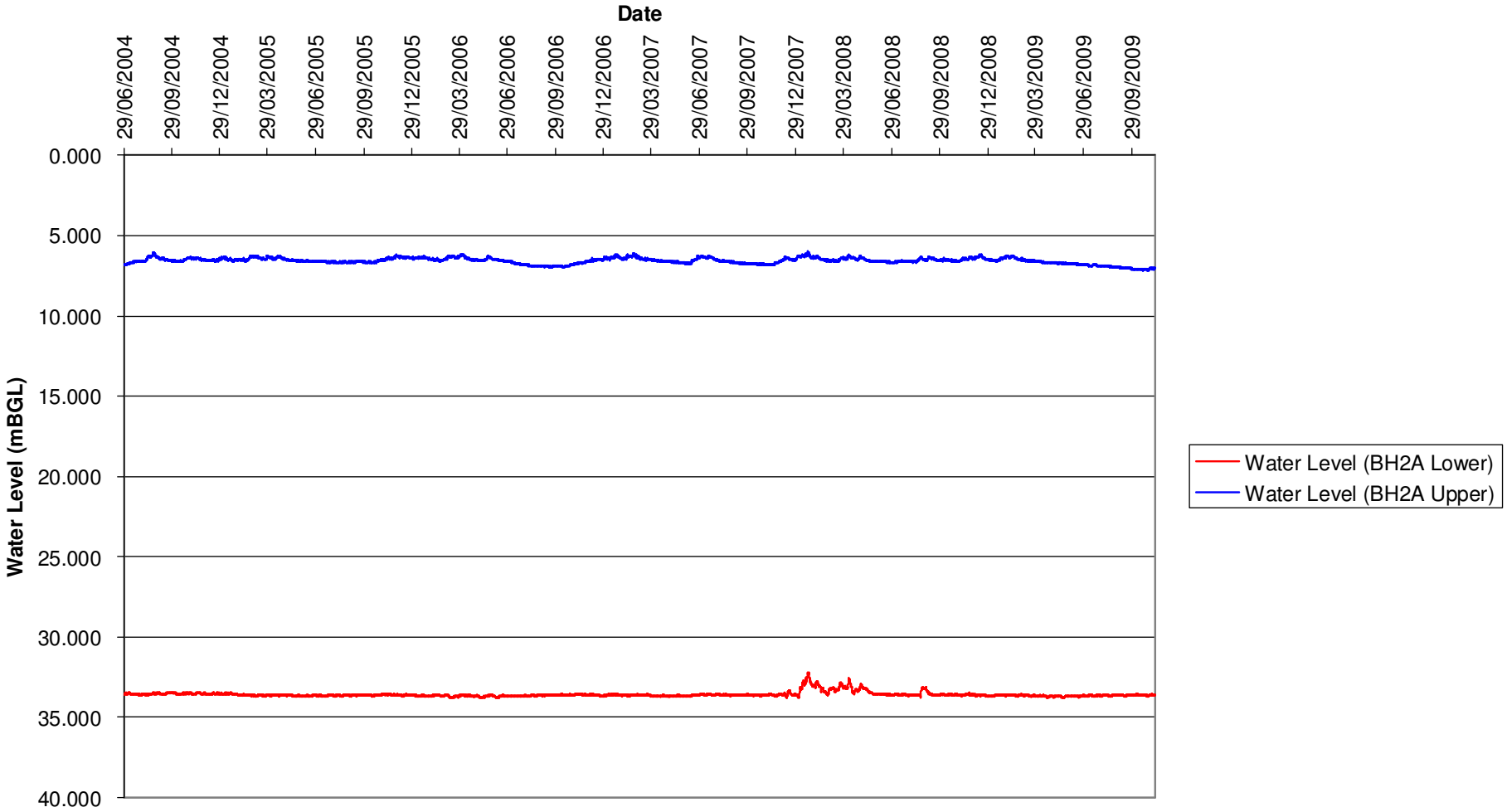
N/A - Not Available
Piezo - Piezometer
Inclino – Inclinometer

Automated Piezometer Groundwater Monitoring Readings

SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



SCALBY NESS (AUTOMATED) GROUNDWATER LEVELS



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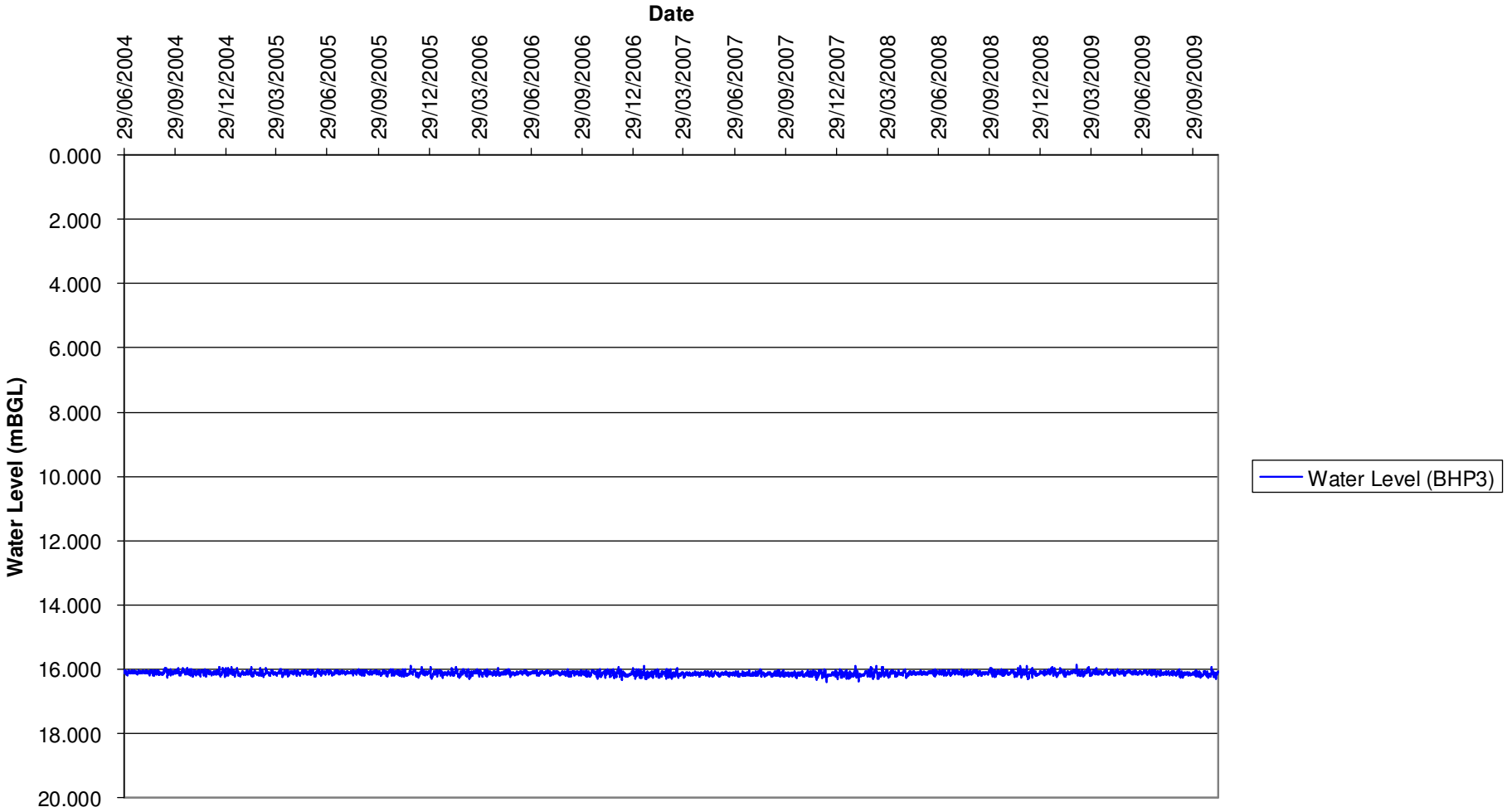

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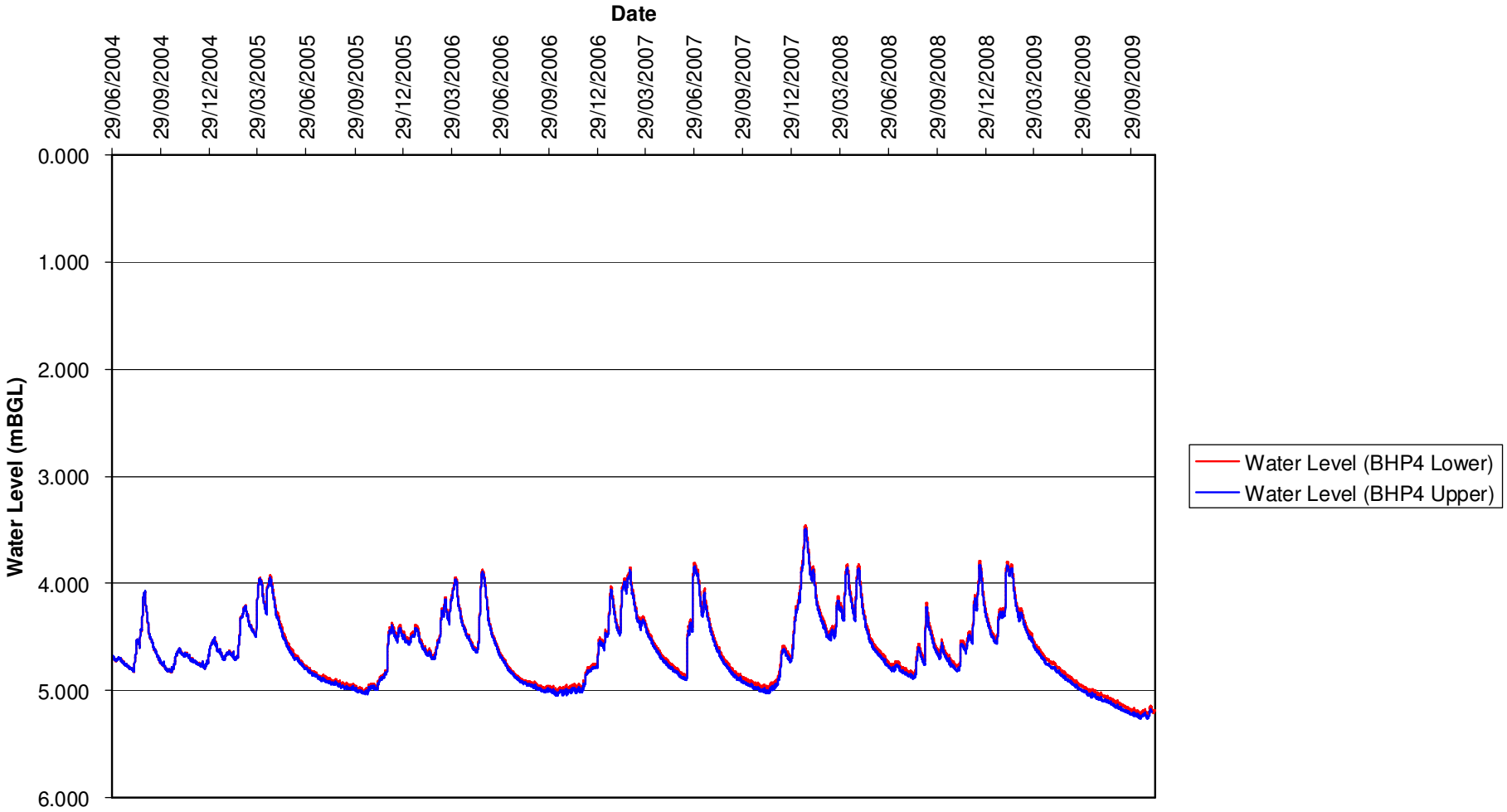

Appendix D Survey Data

Initial Monitoring of Survey Points – 22nd July 2009

Whitby West Cliff					
BH2	Easting	Northing	Height (m)	Slope Distance	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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 - 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	8.319	8.311	8.310	8.313	8.315	8.309
MP2	7.869	7.874	7.870	7.870	7.871	7.870
MP3	8.655	8.657	8.643	8.657	8.655	8.657
MP4	12.623	12.612	12.617	12.613	12.618	12.623
MP5	11.657	11.665	11.658	11.656	11.663	11.657
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	3.15	3.15	3.15	3.15	3.15	3.15
MP2	4.30	4.30	4.30	4.30	4.30	4.30
MP3	2.66	2.65	2.65	2.65	2.65	2.65
MP4	4.18	4.18	4.18	4.18	4.18	4.18

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	7.206	7.204	7.207	7.211	7.200	7.207
MP2	6.079	6.081	6.082	6.079	6.082	6.078
MP3	9.117	9.114	9.112	9.110	9.112	9.112
MP4	10.317	10.320	10.323	10.319	10.318	10.320
MP5	9.246	9.246	9.241	9.247	9.251	9.252
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	10.724	10.724	10.719	10.726	10.723	10.721
MP2	12.989	12.983	12.990	12.978	12.989	12.999
MP3	10.254	10.260	10.264	10.262	10.265	10.266
MP4	13.849	13.855	13.848	13.848	13.856	13.849
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	12.050	12.050	12.039	12.050	12.047	12.046
MP2	6.004	5.997	6.000	5.997	6.000	6.006
MP3	7.211	7.236	7.219	7.225	7.223	7.219
MP4						

Appendix E 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 South Cliff I1 (AA01)

Plate 29 Scarborough South Cliff H4 (AA02)

Plate 30 Scarborough South Cliff BH1 SPA (Top)

Plate 31 Scarborough South Cliff H6 (AA03)

Plate 32 Scarborough South Cliff G2 (AA04)

Plate 33 Scarborough South Cliff F2 (AA10)

Plate 34 Scarborough South Cliff F4 (AA11)

Plate 35 Scarborough South Cliff E3 (AA09)

Plate 36 Scarborough South Cliff E5 (AA05)

Plate 37 Scarborough South Cliff D3 (AA08)

Plate 38 Scarborough South Cliff D1 (AA06)

Plate 39 Scarborough South Cliff Bh2 (AA07)

Plate 40 Scarborough South Cliff I2

Plate 41 Scarborough South Cliff I2A

Plate 42 Scarborough South Cliff H2

Plate 43 Scarborough South Cliff H1

Plate 44 Scarborough South Cliff H5

Plate 45 Scarborough South Cliff 1 Spa

Plate 46 Scarborough South Cliff 2 Spa

Plate 47 Scarborough South Cliff 3 Spa

Plate 48 Scarborough South Cliff 4 Spa

Plate 49 Scarborough South Cliff G3

Plate 50 Scarborough South Cliff 5 Spa

Plate 51 Scarborough South Cliff F5

Plate 52 Scarborough South Cliff F3

Plate 53 Scarborough South Cliff E2

Plate 54 Scarborough South Cliff E1

Plate 55 Scarborough South Cliff E4

Plate 56 Scarborough South Cliff D2

Plate 57 Scarborough South Cliff Bh3

Plate 58 Scarborough South Cliff Bh4

Plate 59 Scarborough South Cliff Bh1

Plate 60 Scarborough South Cliff A1 (AA12)

Plate 61 Scarborough South Cliff H4 (AA02) Survey Points

Plate 62 Scarborough South Cliff H4 (AA02) Survey Points

Plate 63 Scarborough South Cliff E3 (AA09) Survey Points

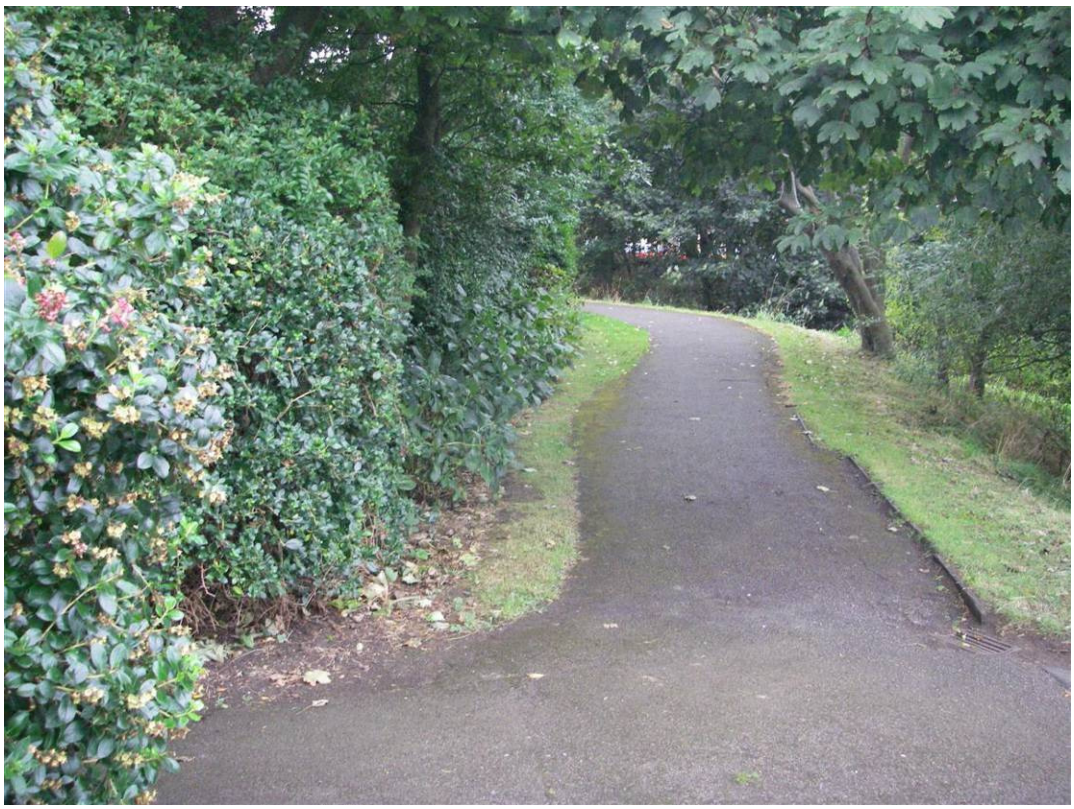

Plate 64 Scarborough South Cliff E3 (AA09) Survey Points

Plate 65 Scarborough South Cliff E3 (AA09) Survey Points

Plate 66 Scarborough South Cliff BH2 (AA12) Survey Points

Plate 67 Scarborough South Cliff BH2 (AA12) Survey Points

Plate 68 Scarborough South Cliff Promenade showing signs of subsidence.

Plate 69 Scarborough South Cliff Promenade showing signs of subsidence.

Plate 70 Filey Town BH01

Plate 71 Filey Town BH02

Plate 72 Filey Town BH03

Plate 73 Filey Town BH04

Plate 74 Filey Town BH05B

Plate 75 Filey Town BH06

Plate 76 Filey Flat Cliffs A2 (BB02)

Plate 77 Filey Flat Cliffs B1

Plate 78 Filey Flat Cliffs D1

Plate 79 Filey Flat Cliffs A3

Appendix F Site Photographs of Runswick Bay

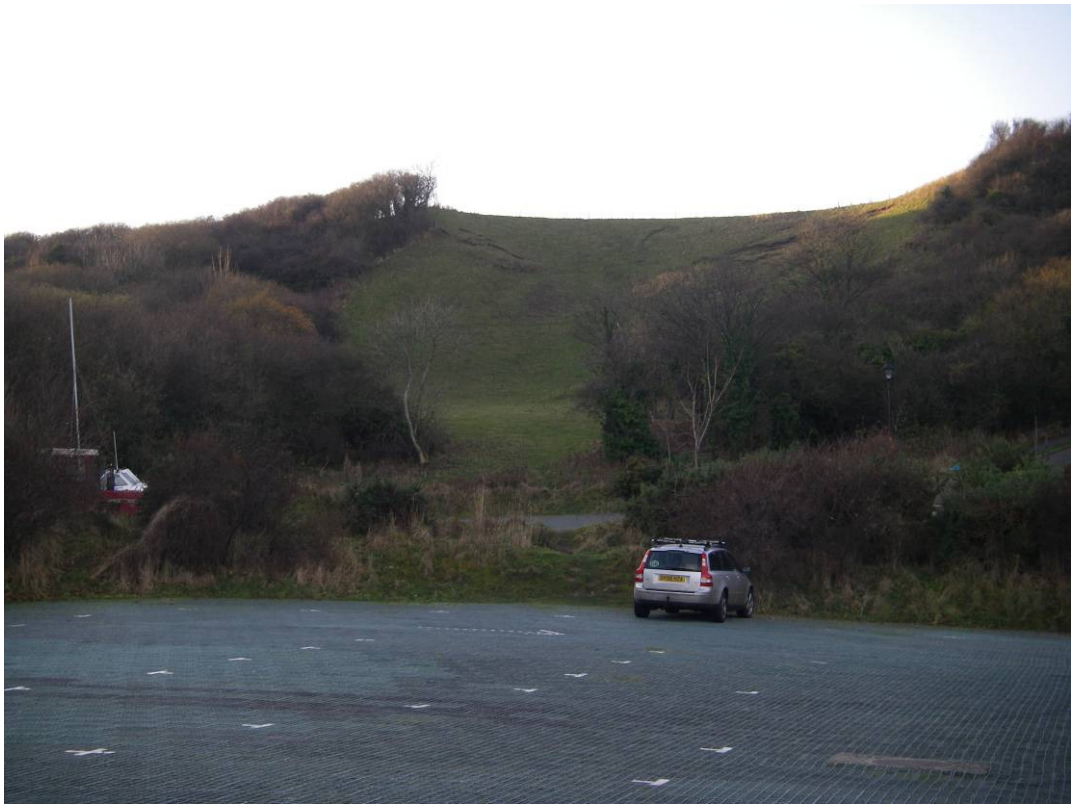

Plate 1 Site view showing slope morphology looking west towards Ings End.

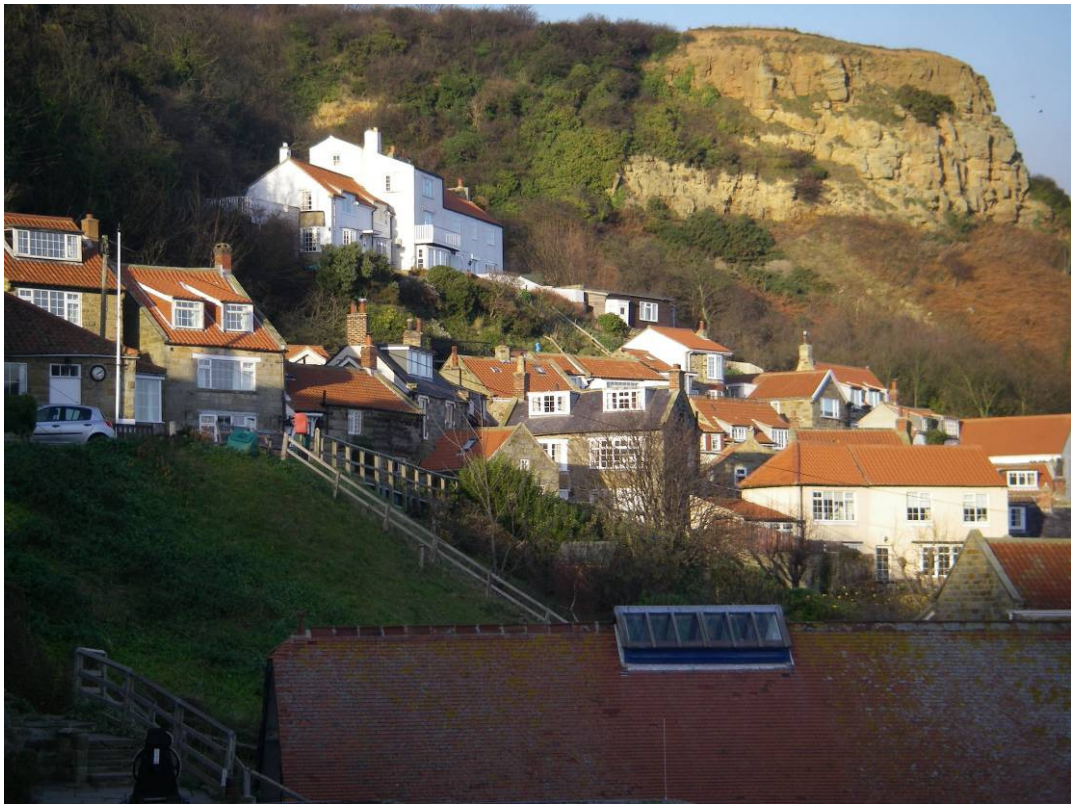

Plate 2 Site view looking north towards Cauldron Cliff.

Plate 3 Site view looking towards only access road.

Plate 4 Site view looking south-south east across rock armour revetment towards the Dother Pits.

Appendix G Site Photographs of Whitby West Cliff

Plate 5 Site view looking east along West Cliff towards The Spa.

Plate 6 Site view looking west along West Cliff towards Sandsend.

Plate 7 Site view of West Cliff slopes looking west.

Plate 8 Site view of West Cliff slopes looking east.

Appendix H Site Photographs of Scalby Ness

Plate 9 Site view looking north across Scalby Beck from the Upper Plateau.

Plate 10 Site view looking north across Scalby Beck from the Upper Plateau.

Plate 11 Site view looking south across Upper Plateau showing slope crest and residential properties.

Plate 12 Site view of Behaviour Unit II showing over steepened back-scarp below Upper Plateau.

Plate 13 Site view looking north at Scalby Beck showing rock outcrops.

Plate 14 Site view of slopes showing mid-slope back rotated block and surface tension cracking.

Appendix I Site Photographs of Scarborough North Bay

Plate 15 Site view of The Holms towards Castle Cliff.

Plate 16 Site view of The Holms looking up towards Scarborough Castle.

Plate 17 Site view of The Holms looking up towards Castle by The Sea.

Plate 18 Site view of the Castle from Castle by The Sea. (Note retaining walls in the mid-ground).

Plate 19 Site view of The Holms with Castle Cliff in the background.

Plate 20 Site view of The Holms

Appendix J Site Photographs of Scarborough South Cliff

Plate 21 Site view looking south towards Holbeck Gardens and Holbeck Cliff.

Plate 22 Site view showing steep slope angles above South Bay Pool Cliff.

Plate 23 Site view of Italian Gardens showing bench-cut paths and slope angles.

Plate 24 Site view looking north at arcuate embayment at South Cliff Gardens.

Plate 25 Site view looking south at arcuate embayment at South Cliff Gardens.

Plate 26 Site view looking south at the cliff railway and slopes of Prince of Wales Cliff.

Plate 27 Site view of slope crest retaining walls at Prince of Wales Cliff.

Plate 28 Site view looking south across Spa Cliff showing steep slope angles and bench-cut paths.

Plate 29 Site view looking north across Spa Chalet Cliff showing steep slope angles and bench-cut paths.

Plate 30 Site view of retaining wall and slope failure behind The Spa on Spa Cliff.

Appendix K Site Photographs of Filey Town and Brigg

Plate 42 Site view of Crescent Hill from Glen Gardens.

Plate 31 Site view of slopes at Crescent Hill.

Plate 32 Site view of slopes behind chalets on Royal Parade.

Plate 33 Site view looking north across Glen Gardens.

Plate 34 Site view looking down Martin's Ravine. (Note stream on right-hand side).

Plate 35 Site view looking up Martin's Ravine. (Remediated slopes on left).

Plate 36 Site view of coastal slopes immediately south of Martin's Ravine.

Plate 37 Site view of Filey Brigg looking west.

Plate 38 Site view of gullying and slumping of glacial tills at Filey Brigg.

Plate 39 Site view looking east at slumped glacial tills at Filey Brigg.

Appendix L Site Photographs of Filey Flat Cliffs

Plate 40 Site view looking north across Filey Bay towards Filey Brigg.

Plate 41 Site view looking south across Filey Bay towards Flamborough Head.

Plate 42 Site view of tension cracks in access road into Flat Cliffs.

Plate 43 Site view of leaning timber garage at No. 5 Flat Cliffs; seaward of coastal slopes.

Plate 44 Site view of property on ‘level’ mid-slope bench with steep back slopes in background.

Plate 45 Site view looking down slope from ‘level’ mid-slope bench.