Ongoing Analysis and Interpretation of Coastal Monitoring Data

Review of Runswick Bay / Knipe Point Monitoring

Geotechnical Interpretative Report

June 2010

Document Ref. No. 721229/023-024/GIR/001/Final

Prepared by

mouchel

York House
Thornfield Business Park
Standard Way
Northallerton
North Yorkshire
DL6 2XQ
UK

T 01609 766667
F 01609 766624

Produced for

Scarborough Borough Council
Town Hall
St. Nicholas Street
Scarborough
North Yorkshire
YO11 2HG

A great place to live, work & play

Document Control Sheet

Project Title	Ongoing Analysis and Interpretation of Coastal Monitoring Data
Report Title	Review of Runswick Bay / Knipe Point Monitoring Geotechnical Interpretative Report
Report Reference	721229/023-024/GIR/001/Final
Version	B
Issue Date	June 2010

Record of Issue

Version	Status	Author + Date	Check + Date	Authorised + Date
A	Draft	P. Robinson	Dr. J Maund	Dr. J Maund
B	Final			
		07/06/2010	07/06/2010	07/06/2010

Distribution

Organisation	Contact	Format	Copies
Scarborough Borough Council	Mr R Siddle	CD & Hardcopy	1
Mouchel Ltd	Dr. J Maund	Electronic	1
Mouchel Ltd	Northallerton Library	Hard	1

DISCLAIMER

This report is presented to Scarborough Borough Council in respect of the Ongoing Analysis and Interpretation of Coastal Monitoring Data and may not be used or relied on by any other person or by the client in relation to any other matters not covered specifically by the scope of this Report.

Notwithstanding anything to the contrary contained in the report, Mouchel Limited is obliged to exercise reasonable skill, care and diligence in the performance of the services required by Scarborough Borough Council and Mouchel Limited shall not be liable except to the extent that it has failed to exercise reasonable skill, care and diligence, and this report shall be read and construed accordingly.

This report has been prepared by Mouchel Limited. No individual is personally liable in connection with the preparation of this report. By receiving this report and acting on it, the client or any other person accepts that no individual is personally liable whether in contract, tort, for breach of statutory duty or otherwise.

Mouchel has used reasonable skill, care and diligence in any interpretation of the records made available by Scarborough Borough Council (i.e. ground investigation, rainfall information and other data) however, the inherent variability of ground conditions allows only definition of the actual conditions at the location and depths of exploratory holes and samples/tests there from, while at intermediate locations conditions can only be inferred.

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

Contents

Tables

Figures

Appendices

EXECUTIVE SUMMARY

In October 2008, Mouchel were instructed by 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. 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.

In response to ground movements in on-site instrumentation at Runswick Bay, recommendations for further, more frequent monitoring events were instructed to be instigated by SBC. The increased monitoring regime is to provide data for a six months period in order to better understand the nature of ground movements at this site. The site of Knipe Point has been introduced into the monitoring regime as a new instruction beginning in March 2010 up to December 2012.

This report presents the data recorded from additional monitoring at the sites of **Runswick Bay and Knipe Point in early May 2010**. The monitoring of each site has been issued as a separate instruction from SBC to be undertaken at similar intervals to the original regime. However, since the monitoring began later than the regime initially established, this report relates only to the sites of Runswick Bay and Knipe Point.

At Knipe Point a new mudslide was identified mid-slope below monitoring point H06I in April 2010 although little or no ground movements have been identified by the remaining, installed instrumentation during the period of monitoring so far undertaken. The walkover survey of May 2010 noted the continued development of the mudslide and related groundwater issues from the slope. Monitoring data from the piezometers is limited as borehole instrumentation in BH02 to BH04 have been damaged by sub-surface ground movements at various depths. Cliff recession rates have abated in line with reduced monthly rainfall along the three headscarps under observation.

At Runswick Bay, ground movements were observed in installations A001 and A004 of up to 15mm in May 2010.

A summary of observations made from the start of monitoring (July 2009) and those made since the last monitoring event of May 2010 are presented in Table 1.

Table 1 Summary of Site Observations

SITE	Observations made since last Monitoring Event (May 2010)*	Total observed movement since first Monitoring Event (July 2009)
Runswick Bay	A001 shows 2-3mm movement from 22.0 to 20.0 metres depth. A004 shows 5mm movement from 10.0m depth, reaching a maximum of 15mm at 2.0m depth. Groundwater relatively static	5mm movement indicated in A001 between 22.0 and 20.0 metres depth. 5mm movement indicated in A004 from 10.0m depth increasing to 15mm at 2.0m depth. Groundwater relatively static
Knipe Point	Reduction in cliff recession rates along headscarps 'New' mid-slope mudslide observed in April 2010 below Knipe Point Headscarp at monitoring point H06I still active	Since February 2010 - Continued recession of Cornellian and Knipe Point headscarps. Limited (14mm) recession noted along A165*

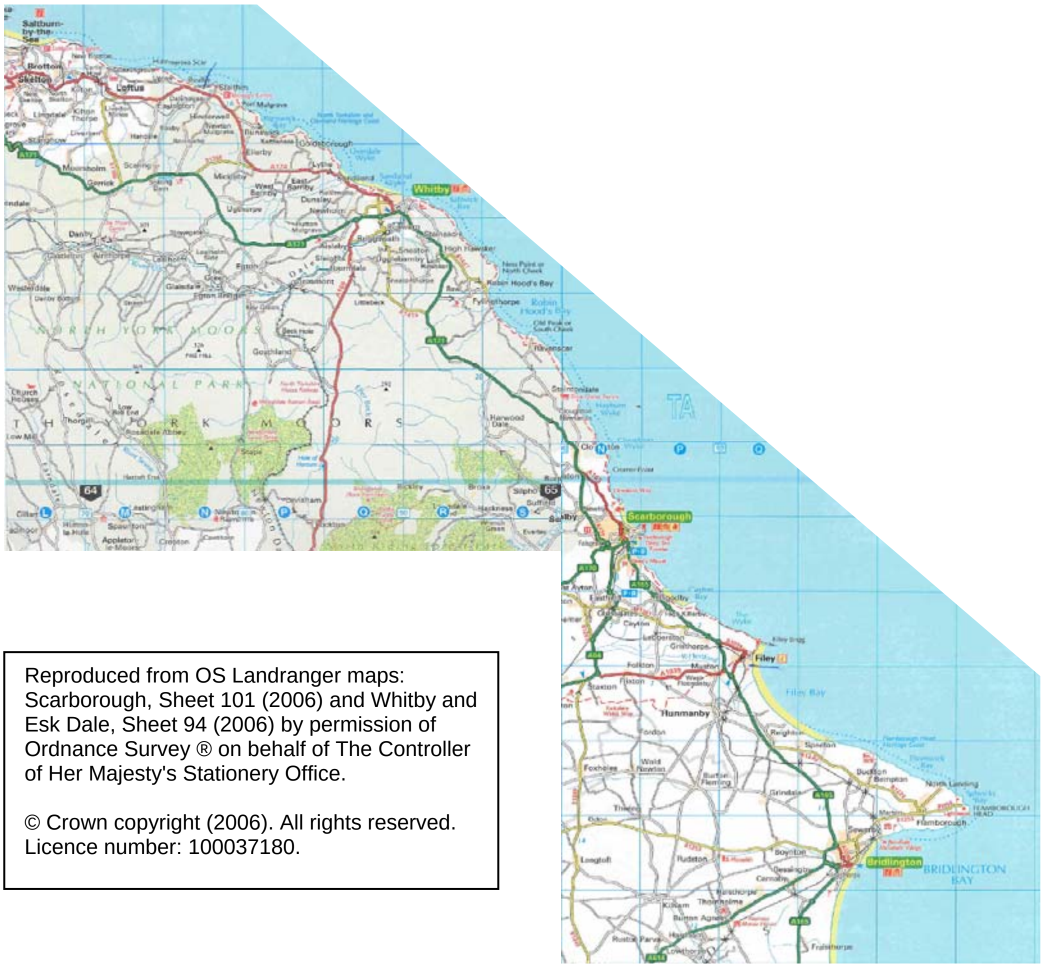
* - Landslip along A165 in January 2010 is outside of monitoring area.

1 Introduction

1.1 Description of the Project

The extent of the monitoring area (Figure 1) considered for the ongoing analysis is along the full length of Scarborough Borough Council's coastline from Staithes to Speeton. Through the Shoreline Management Plan 2007 (SMP2) and 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.

Figure 1 Scheme Location



Reproduced from OS Landranger maps: Scarborough, Sheet 101 (2006) and Whitby and Esk Dale, Sheet 94 (2006) by permission of Ordnance Survey ® on behalf of The Controller of Her Majesty's Stationery Office.

The ongoing analyses undertaken in accordance with previously detailed recommendations of monitoring frequency were begun in July 2009.

Runswick Bay has been included for monitoring from February through to July 2010 due to suspected ground movements observed within inclinometers A001 and A004 from monitoring data in December 2009. SBC initially instructed Mouchel that the site at Knipe Point and recession point sites along with that at Killerby have been removed from our remit until further notice and are not under consideration for this analysis at the time of writing this report. However, Mouchel is now monitoring Knipe Point at monthly intervals from March to August, in October and, from December 2010 at six monthly intervals up to June 2012.

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

Site location plans are presented as Figures 2 and 3 within the relevant chapters and exploratory holes location plans, identifying the locations of instrumentation, are presented in Appendix A.

1.2 Installation Monitoring Procedures

1.2.1 Inclinometers

The initial monitoring event for the Ongoing Monitoring Regime was begun during early 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.

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

Where the instrument tubing is proved to be intact, a Vertical Digital Inclinometer probe (using a Bluetooth system (MkII) with a TDS Recon 200 PDA) is lowered to the base of the tubing, allowing the probe to temperature stabilise and measurements are recorded at half metre intervals as the probe is raised. Readings of inclination are recorded in two directions (A0 and A180) within the inclinometer tube; A0 being the principal direction of interest in ground movements 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.

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.

1.2.2 Piezometers and Slip Indicators

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

1.3 Interpretation Views

1.3.1 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.

1.3.2 Incremental Displacement

Another form of data presentation is the Incremental Displacement plot. This shows displacement over each probe length during the period since the initial reading sets. Unlike the Cumulative Displacement plot, operator error or instrument malfunction do not accumulate, as the data are plotted from reading to reading (i.e. delta previous not delta datum).

1.3.3 Absolute Position

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

1.4 Rainfall Data

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

Departures from this monitoring regime were evident where remedial works had not been undertaken at a site, where there were significant 'gaps' in monitoring data from a site and following periods of heavy and prolonged rainfall. The definition of '*significant rainfall*' has been developed through the analysis of rainfall data records (made available by the EA and SBC) and quantified within the context of the effects of such an event on the present monitoring regime frequency. A definition of heavy / prolonged rainfall events was investigated in terms of determining statistically derived values of daily rainfall per month for the period 1995/8 to 2008/9. Limiting values of rainfall in terms of how much rainfall, within a 24 hour period, can occur before advising that site inspections should be undertaken were identified. To this end, having reviewed the rainfall data, the 75^{th} percentile was calculated as a threshold value. This showed that 75% of daily rainfall was below this value and the remaining 25% of rainfall exceeded this amount.

In the event that the 75^{th} percentile of daily rainfall values (a period of heavy / prolonged rainfall) are exceeded, it was recommended to carry out monitoring one week after the end of the rainfall event and at monthly intervals thereafter for three months. Further to the heavy rainfall experienced in December 2009, these recommendations were followed by SBC as Mouchel were invited to undertake additional monitoring events in order to comply with monitoring recommendations. The additional monitoring suites are to be undertaken for January and March 2010.

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 has been presented in Mouchel Report '*Definition of Heavy and / or Prolonged Rainfall* – 721229/004/GIR/001/FINAL'.

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 Site Walk-over

An initial site walkover was undertaken by a geotechnical engineer from Mouchel on 28th 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 existing 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.

2.1.3 Topography and Geomorphology

The village of Runswick is situated at the foot of a steep, 80 metre high bank and has a long history of slope instability. It occupies the northern end of the bay in a confined site bounded by Nettledale Beck to the south and Runswick Beck to the north.

The geological structure of the bay is inferred to be derived from a shallow syncline trending north-south and shallowing westwards away from the coastline. This feature forms a buried glacial channel extending some distance inland. The southern side of the village comprises the main access road with car parking facilities beyond as far as Nettledale Beck. This area is founded upon the glacial till deposits which appear actively unstable, based on the surface morphology. Beyond Runswick Beck which forms the northern limit of the village lies sheer cliff headland of Middle Jurassic sandstones and ironstones which lie unconformably on Lower Jurassic shales. These shales form a wave cut platform below the foot of the cliffs at the north end of the bay.

2.1.4 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, pp9-10.* Additional reports were provided by SBC for further consultation by Mouchel for the Ongoing Analysis. All of this data has been placed on an Arcview GIS layer for ease of use and availability.

2.2 Stratigraphy

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

2.3 Groundwater Regime

Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of North East Yorkshire has classified the area as a Non-Aquifer because of 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.

2.4.2 History of Monitoring

Data provided by SBC indicated, from reports, that there had been several ground investigations undertaken at Runswick including those between 1967 and 1998. However, although details of the specific ground investigations are not available, the locations, depths, general stratigraphy, water regime and general remarks for boreholes drilled were derived from numerous records held by SBC.

Coastal protection and slope stabilisation incorporating remediation works to the sea wall and car park areas was completed by April 2001. In March 2000, 4no inclinometers were installed into piles to a maximum depth of 20 metres within bored pile portal frame shear keys. These instruments had been periodically monitored from this date onwards although monitoring records were only available from March 2000 to July 2002 and for 20th November 2008. The instruments may have been monitored through the intervening periods although data was not made available to confirm this.

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. Taking into consideration the findings of the *Condition Survey Report,* the monitoring regime consists of the existing inclinometers (A001, A002, A003 and A004) located along the edge of the main access road leading down into Runswick village. The instruments were monitored using a Vertical Digital Bluetooth Inclinometer system (MkII) and a TDS Recon 200 PDA. Groundwater was measured using a dip meter.

In light of the suspected ground movements reported from previous monitoring visits (December 2009 and January 2010), it was recommended that the Runswick Bay site should be monitored more frequently, on a monthly basis, for a minimum period of six months. With additional monitoring events, this would provide monitoring data (covering the period December 2009 to July 2010) with which to more confidently identify and interpret the nature and rates of ground movements occurring at Runswick Bay.

2.5.3 Ongoing Monitoring Results

Inclinometer Readings

Inclinometer readings have been undertaken in accordance with the procedures detailed in Section 1.3 of this report. Monitoring at Runswick Bay has taken place on numerous occasions, the first in July, December 2009 and monthly from January to May 2010.

The initial visit collected 'baseline' readings against which all successive readings are compared. The latest readings indicate some movement has occurred within inclinometers installed in A001 and A004. Within A001, 3mm of incremental movement is indicated between 22.0 and 20.0 metres depth and in A004; 5mm incremental 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 have been recorded on five occasions between the 16th June 2009 and 9th February 2010. A comparison of the readings shows very little change in groundwater levels occurring over this period. Where fluctuations in borehole water levels have been recorded, these are probably in response to changing groundwater levels. Groundwater readings are presented in Appendix C.

2.6 Conclusions

Inclinometer instrumentation was installed within the 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 the piles caused by ground movements. Within Report 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 related to any general ground movements indicated by instrument readings.

Successive readings from December 2009 indicated that some movement had occurred within inclinometers installed in boreholes A001 and A004. Within A001, 5mm of movement was indicated at the base between 22.0 and 20.0 metres depth and in A004; 5mm movement was indicated from 10.0m depth increasing to 15mm at 2.0m depth. Readings from January to March 2010 indicated this pattern of movement to be repeated, although to a lesser degree of 2-3mm between 22.0 and 20.0 metres depth.

The data recorded in April 2010 has again followed a similar pattern to that previously identified of 5mm of movement at the base between 22.0 and 20.0 metres depth. In each installation the ground movements were indicated as taking place in a down slope direction. Inclinometer data from A002 and A003 has so far indicated that no ground movements have taken place in and around the vicinity of these instruments.

Groundwater levels recorded from the inclinometers have remained relatively stable since monitoring began in June 2009. These results would be expected given that the instruments are installed within concrete piles of unknown diameters and as such are 'isolated' to some degree from the natural groundwater regime prevailing at this site.

Successive inclinometer readings taken from December 2009 to March 2010 indicate some movement had occurred within inclinometers installed in A001 and A004. Within A001, 5mm of movement was indicated between 22.0 and 20.0 metres depth, reducing to 2-3mm in the March readings and since increasing to 5mm for April readings. In A004; 5mm movement had been recorded from 10.0m depth increasing to 15mm at 2.0m depth. Readings recorded through to April 2010 plot as identical readings when compared to the 'baseline' reading of July 2009. By replacing this initial reading with the reading from December 2009, successive readings plot as a straight line and hence do not indicate ground movements. This comparison would indicate that there may be an anomaly in the 'baseline' readings of July 2009 which is showing 'apparent' ground movements occurring at the stated depths. It is recommended that this instrument continues to be monitored in order to build on the data already recorded. When applying the same procedure of referencing data to December 2009 readings for A001, the modified results continue to show ground movements at identical depths. In each installation the ground movements were indicated as taking place in a down slope direction. The results from monitoring inclinometers A002 and A003 continue to show that no movement has taken place within the vicinity of these instruments.

3 Knipe Point

3.1 Site Location and Description

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

Figure 3: Site Location

3.1.1 *Historic Review of Problems*

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

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

3.1.2 Site Walk-over

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

3.1.3 Topography and Geomorphology

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

3.1.4 Existing Information

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

3.2 Stratigraphy

The 1:50,000 British Geological Survey (BGS) Sheet 54 Solid & Drift, Scarborough indicates that the site is underlain by superficial deposits of glacial till (Quaternary), underlain by Oxford Clay of up to 36-76m in thickness. This overlies 3-13m of Osgodby Formation calcareous sandstone above a thin (1.5-3m) layer of undifferentiated Cayton Clay Formation and Cornbrash Formation consisting of limestones and mudstones. An unconformity is encountered, beneath which there is 60 metres of the Scalby Formation mudstones and sandstones. Outcrops of strata generally young in a southerly direction, trending north west to south east. A fault trending NNW-SSE dissects the point, truncating the aforementioned strata. The tip of the point comprises the Gristhorpe and Lebberston Members (limestones and mudstones) of the Cloughton Formation.

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

3.4.2 History of Monitoring

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

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

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

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

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

3.5 Monitoring Regime

3.5.1 Recommended Monitoring Regime

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

3.5.2 Ongoing Monitoring Regime

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

3.5.3 Ongoing Monitoring Results

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

Groundwater Readings

Groundwater readings are presented in Appendix D

Survey Point Readings

A survey of the recession survey points is undertaken at regular intervals as described in section 3.5.1. The results are presented in Appendix E.

Weather Records

Continuous rainfall, air and ground temperatures are recorded on site by an automatic weather station located within the residential area of the site. A photograph of this equipment is presented in Appendix G, Plate 17.

3.6 Conclusions

Knipe Point was introduced into the coastal monitoring programme in March 2010 as a new instruction. A comparison of previously recorded data, collected on behalf of SBC, from February with that of March 2010 indicates that a landward retreat of the Cornelian Bay headscarp is ongoing with made ground failures prevalent as the disappearance and re-positioning of markers C1 to C8 indicates. Also, the fence posts to properties No.s 5 and 6 have been moved landward as recent cliff recession continues to undermine the boundary fence posts. Recent reports and monitoring data on recession rates, available from the National Trust, have also detailed the rates of landward degradation of the headscarps of Cornelian Bay and Knipe Point.

A photographic record of the site, presented in Appendix H, shows the degradation of the headscarps under observation particularly the areas around monitoring points C1 to 8 and H04I to 11I. At Cornelian headscarp most of the original monitoring points have been lost to cliff recession, C1 and C4 are still used although C8 has been repositioned inland and measurements are taken in a northerly and easterly direction. Recession at C8 continues in a northerly direction although eastwards recession rates appear to have abated, the reduction would seem to be related to drier weather conditions. The slopes are evidently less active with a reduction in ground movements and mudslides as shown in photographs of the site (see Appendix H, Plates 3 to 6). Knipe Point headscarp also shows a continuation of recession rates at a greatly reduced intensity between monitoring points H04I and H11I. This section of cliff has been the most active in terms of recession rates, leading to the demolition of several properties as the cliff edge has receded landward. Since this regime of monitoring began in February, recession rates between these points of -5mm to -62mm have been recorded. The greater loss was at H11I which coincides with groundwater seepage, present approximately 5 metres below ground level (Appendix H, Plate 9), have lead to the development of a mudslide and headscarp recession. However, since the previous monitoring event of April 2010, recession rates have been restricted to -3mm observed at H11I with no recession evident elsewhere along this scarp.

During the survey of April 2010 a ‘fresh’ mudslide was observed on the slopes of Knipe Point immediately below monitoring point H06I. During the site monitoring of May this mudslide was observed to have developed further and was approximately 10 metres below ground level, extending further down the slopes (Appendix G, Plates 7 & 8). Ground water seepages were observed to be active from this point in the slope and continue to be coincident with the mudslide.

No further cliff recession has been observed along the A165 headscarp. Comparisons of data from several monitoring points with February, March and that of April 2010 are not entirely consistent as they have been taken by different engineers. Some changes in the methods and manner of data collection are inevitable which can lead to the resulting anomalies. Since the closure of this road, any such failures at this location do not pose an immediate, pending danger to the public or to assets. The headscarp along this section is currently separated from the public and the thoroughfare by a thick blackthorn hedge.

In mid-February 2010, a small landslip, which coincided with periods of heavy snowfall and freeze / thaw conditions, occurred along the Cayton Bay headscarp adjacent to the Former A165. The slope failure resulted in this section of road to be permanently closed to traffic. To date there has been no further development of this slope failure although this feature is located outside of Mouchel’s remit of the Knipe Point site.

4 References

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data*, Feasibility Report into the Replacement of Damaged Monitoring Equipment" 721229/017/GIR/002/FINAL, September 2009

Mouchel Report "Ongoing *Analysis and Interpretation of Coastal Monitoring Data. Initial Review of Full Suite Monitoring" 721229/002/GIR/002/Draft*, October 2009.

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data*, *Initial Review of Restricted Suite Monitoring*" 721229/002/GIR/003/FINAL, October 2009

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data*, *Second Review of Restricted Suite Monitoring*" 721229/002/GIR/004/FINAL, October 2009

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data, Third Review of Restricted Suite Monitoring*" 721229/002/GIR/005/FINAL, November 2009

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data, Fourth Review of Restricted Suite Monitoring*" 721229/002/GIR/006/FINAL, December 2009

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data, "Definition of Heavy / Prolonged Rainfall Events*" 721229/004/GIR/001/FINAL, January 2010

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data, Second Review of Full Suite Monitoring*" 721229/002/GIR/007/FINAL, January 2010

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data*, First Additional Full Suite Monitoring" 721229/021/GIR/001/FINAL, February 2010

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data, Fifth Review of Restricted Suite Monitoring*" 721229/002/GIR/008/FINAL, December 2010

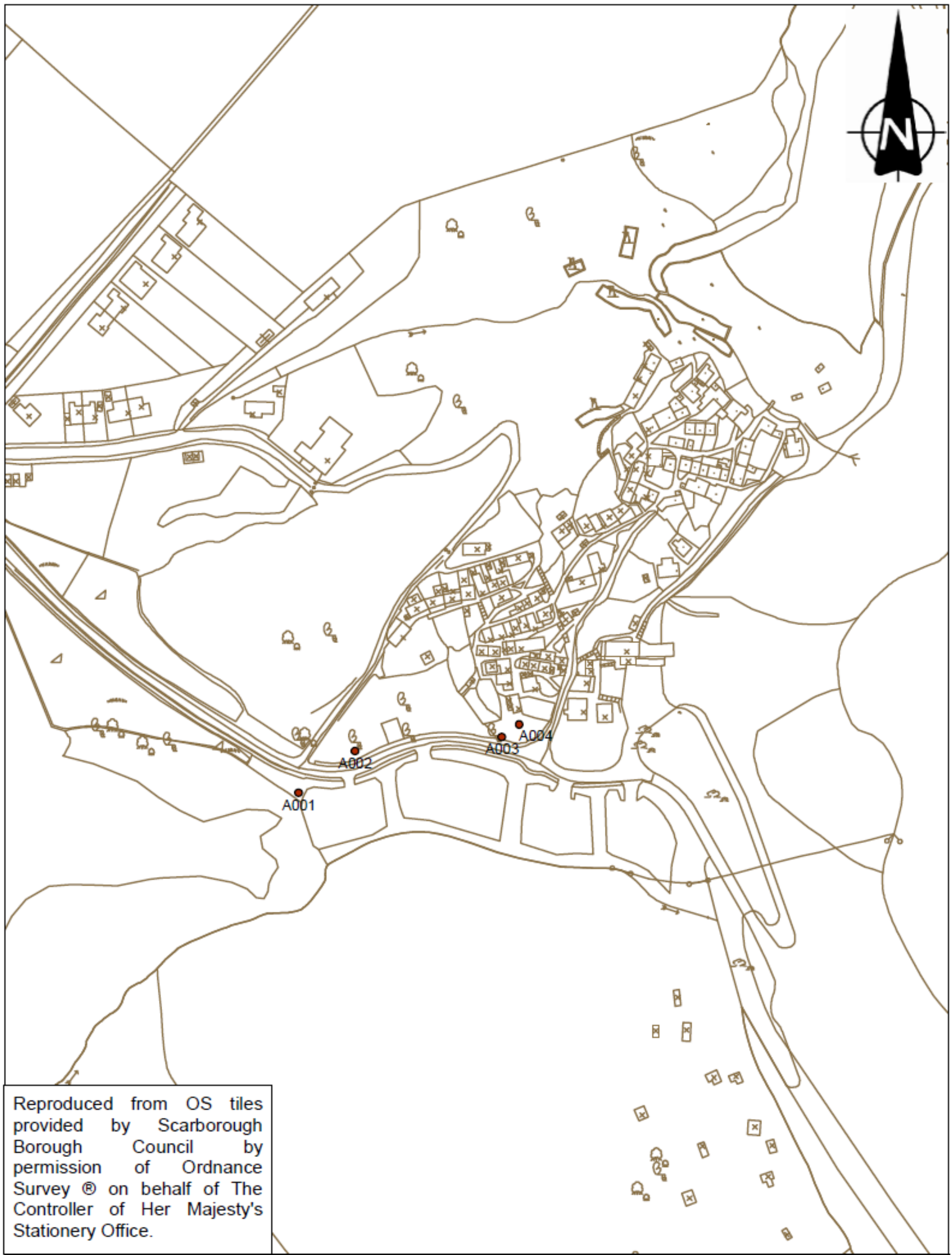
Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data*, Second Additional Full Suite Monitoring" 721229/021/GIR/002/FINAL, April 2010

Mouchel Report *"Ongoing Analysis and Interpretation of Coastal Monitoring Data, Sixth Review of Restricted Suite Monitoring*" 721229/002/GIR/009/FINAL, May 2010

Scarborough Borough Council Records.

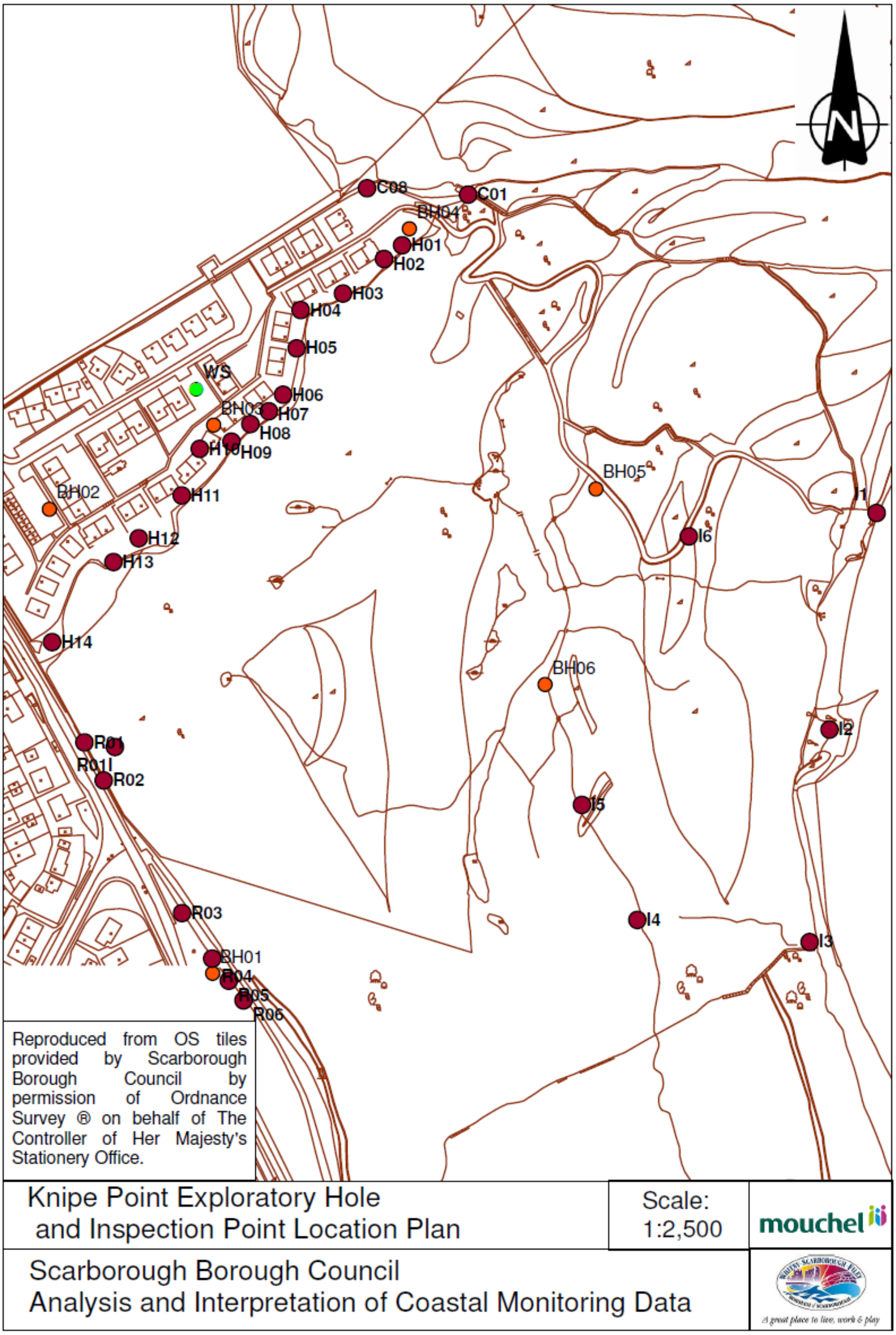
Spark, B W (1981) Geomorphology - 2nd Edition. Longman.

Appendix A Exploratory Holes Location Plans



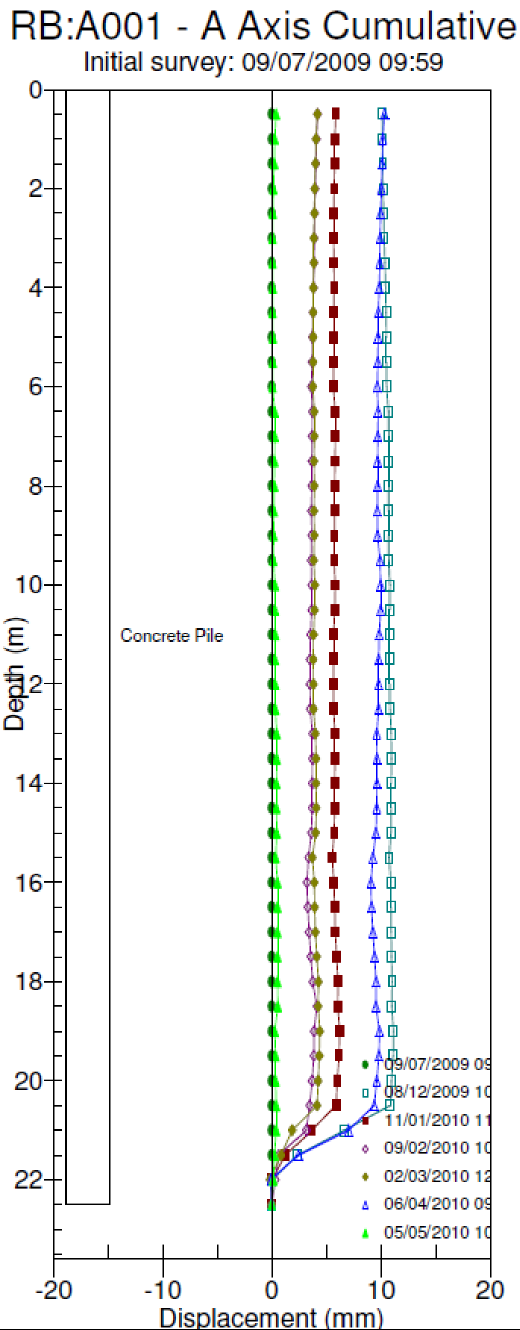
Runswick Bay Inclinometer Location Plan	Scale: 1:2,500	mouchel
Scarborough Borough Council Analysis and Interpretation of Coastal Monitoring Data		A great place to live, work & play

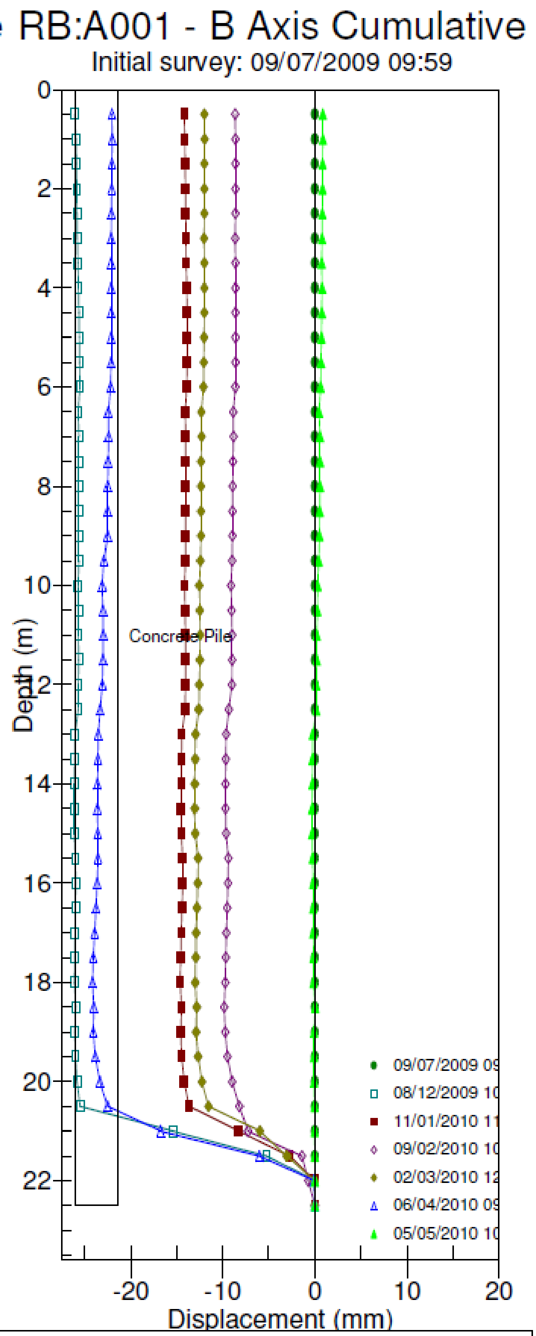
Drawing No. 1 Location Plan of Runswick Bay



Drawing No. 2 Location Plan of Knipe Point

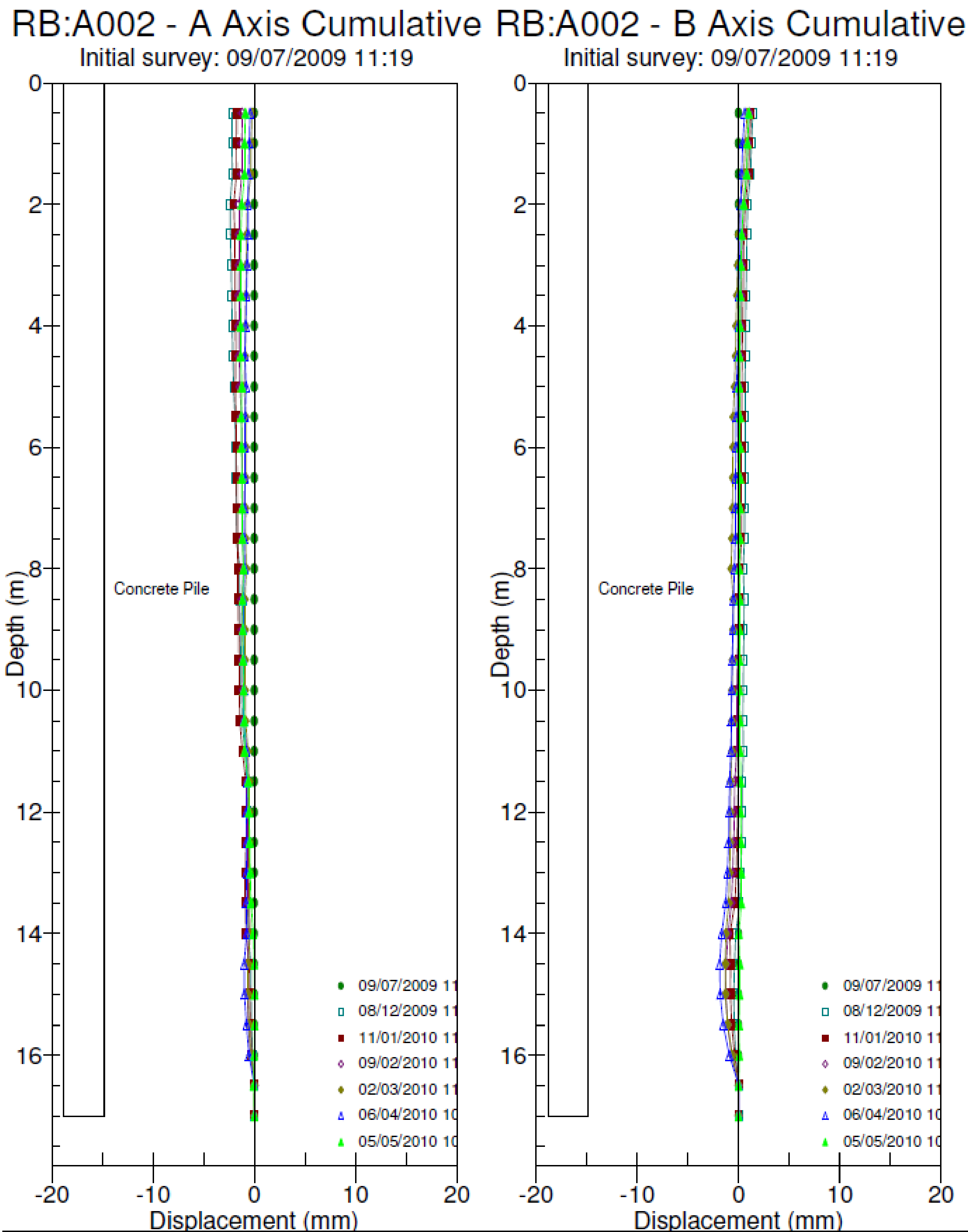
Appendix B Inclinometer Data Graphs





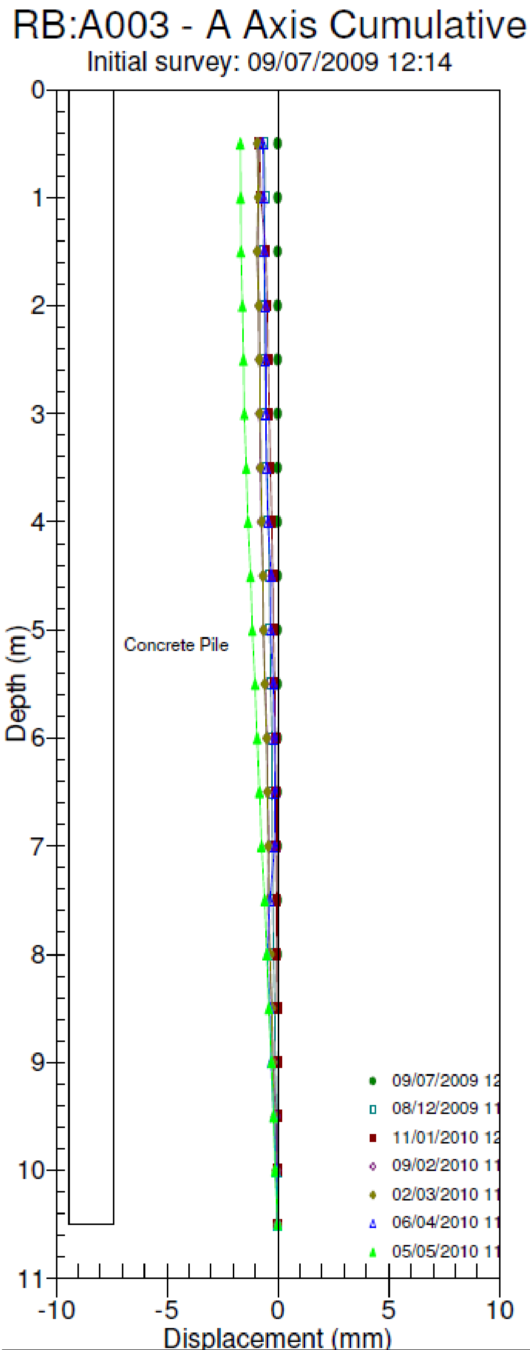
PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A001
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

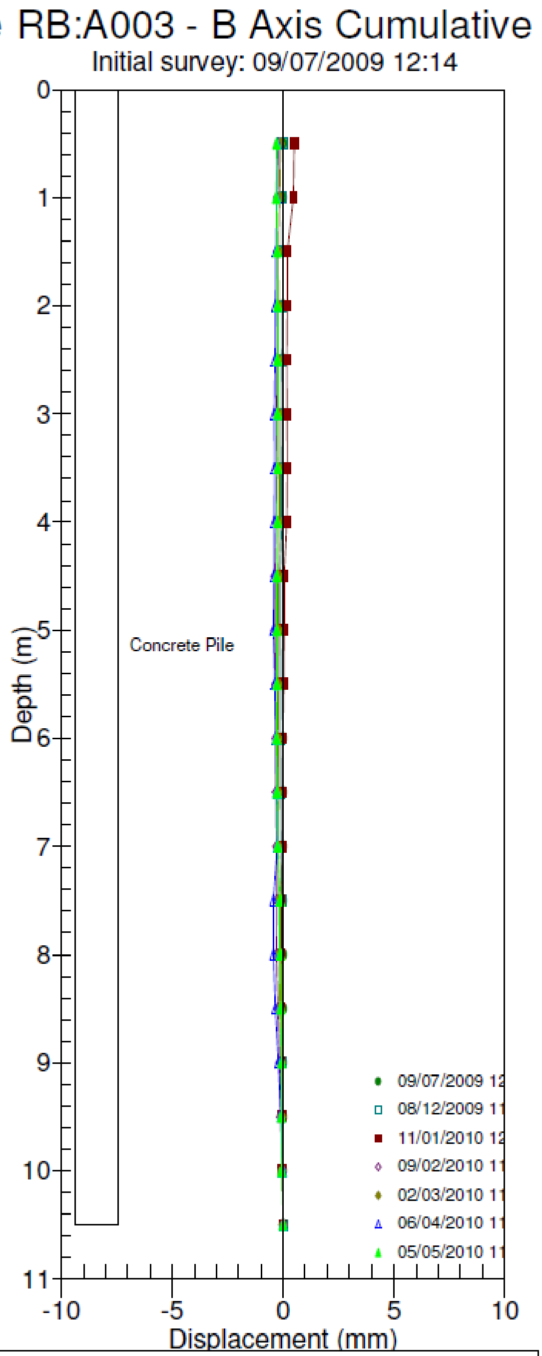
NOTE: A0 direction: East



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

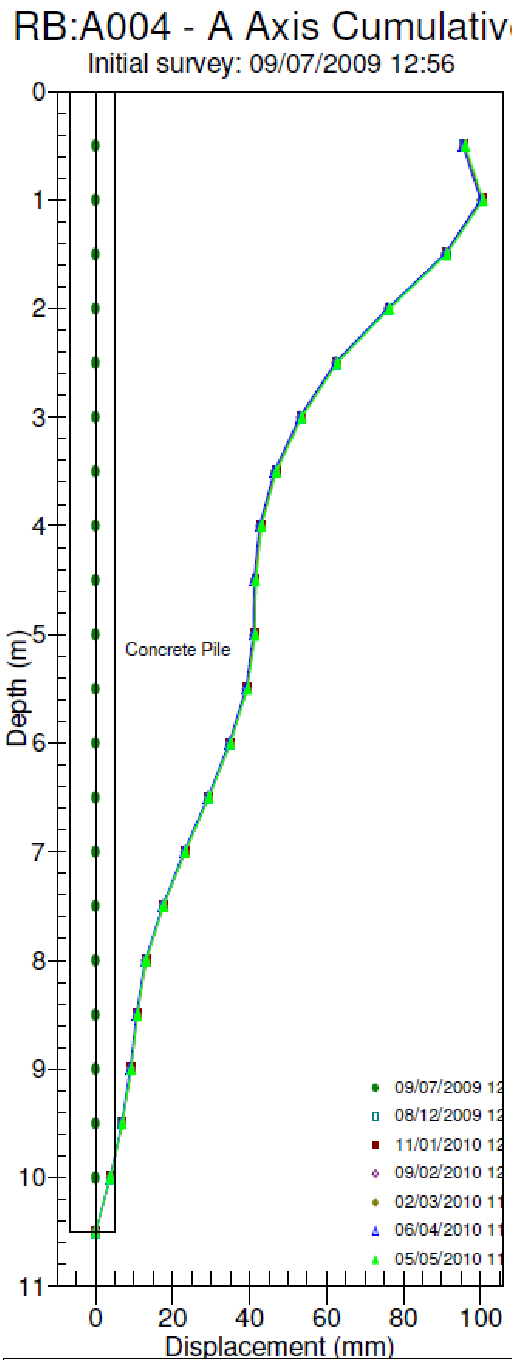
NOTE: A0 direction: East

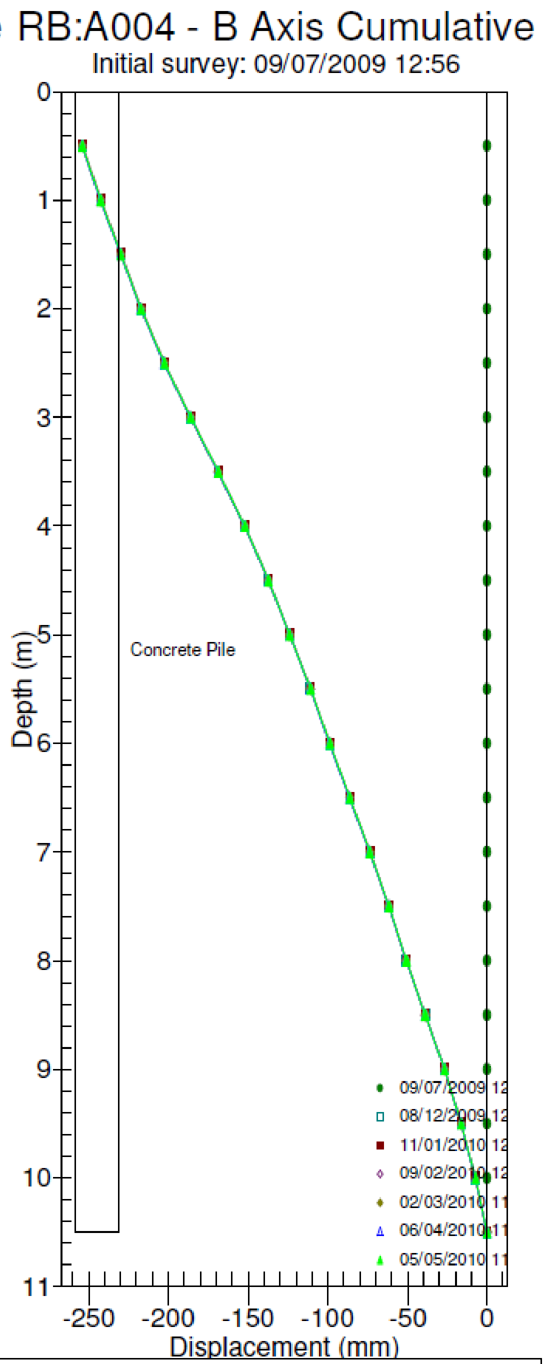




PROJECT: 721229 Ongoing Analysis of Coastal Monitoring Data
SITE: Runswick Bay
INSTALLATION: A003
COMPANY: Mouchel Ltd
CLIENT: Scarborough Borough Council

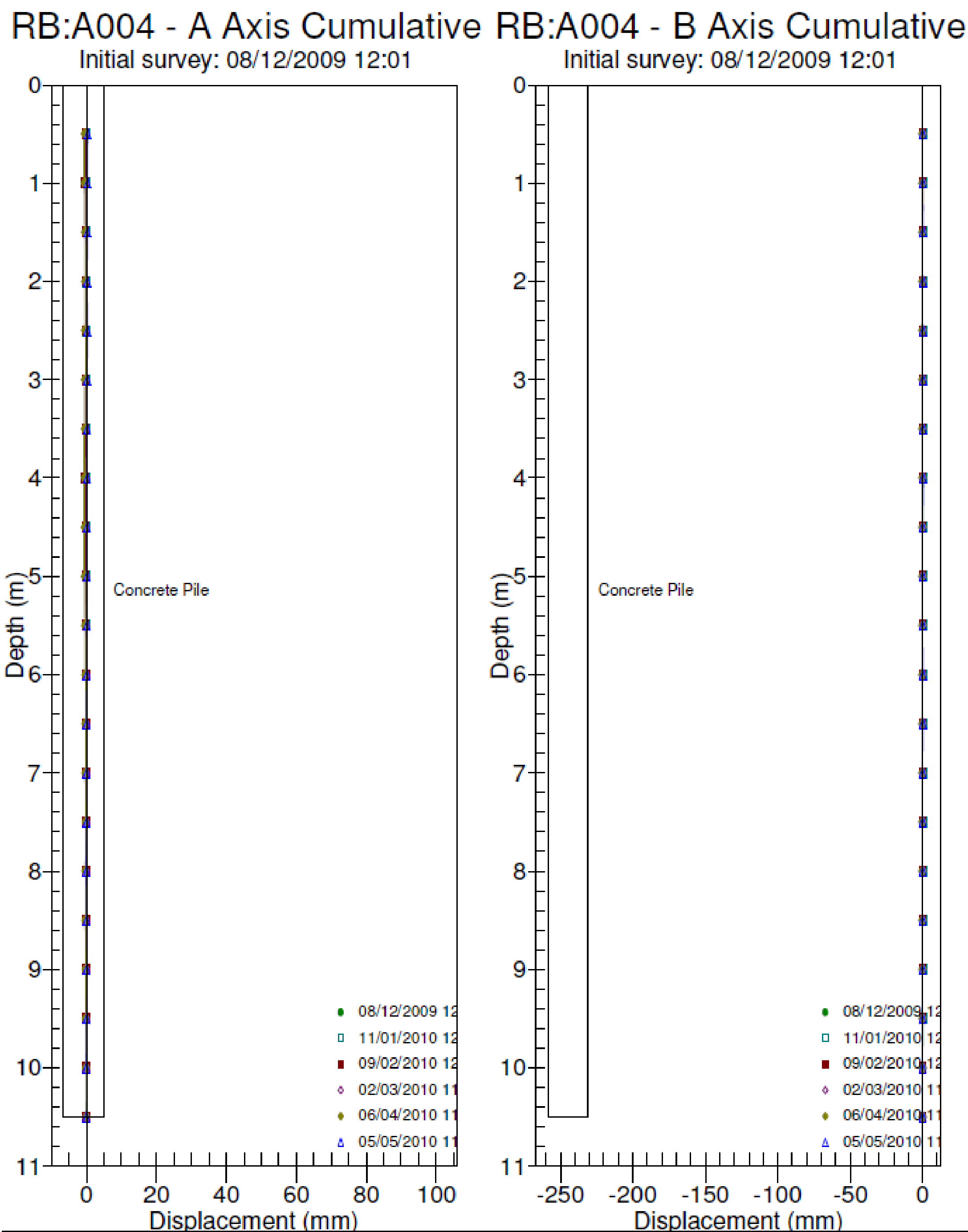
NOTE: A0 direction: South East





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

NOTE: A0 direction: East



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

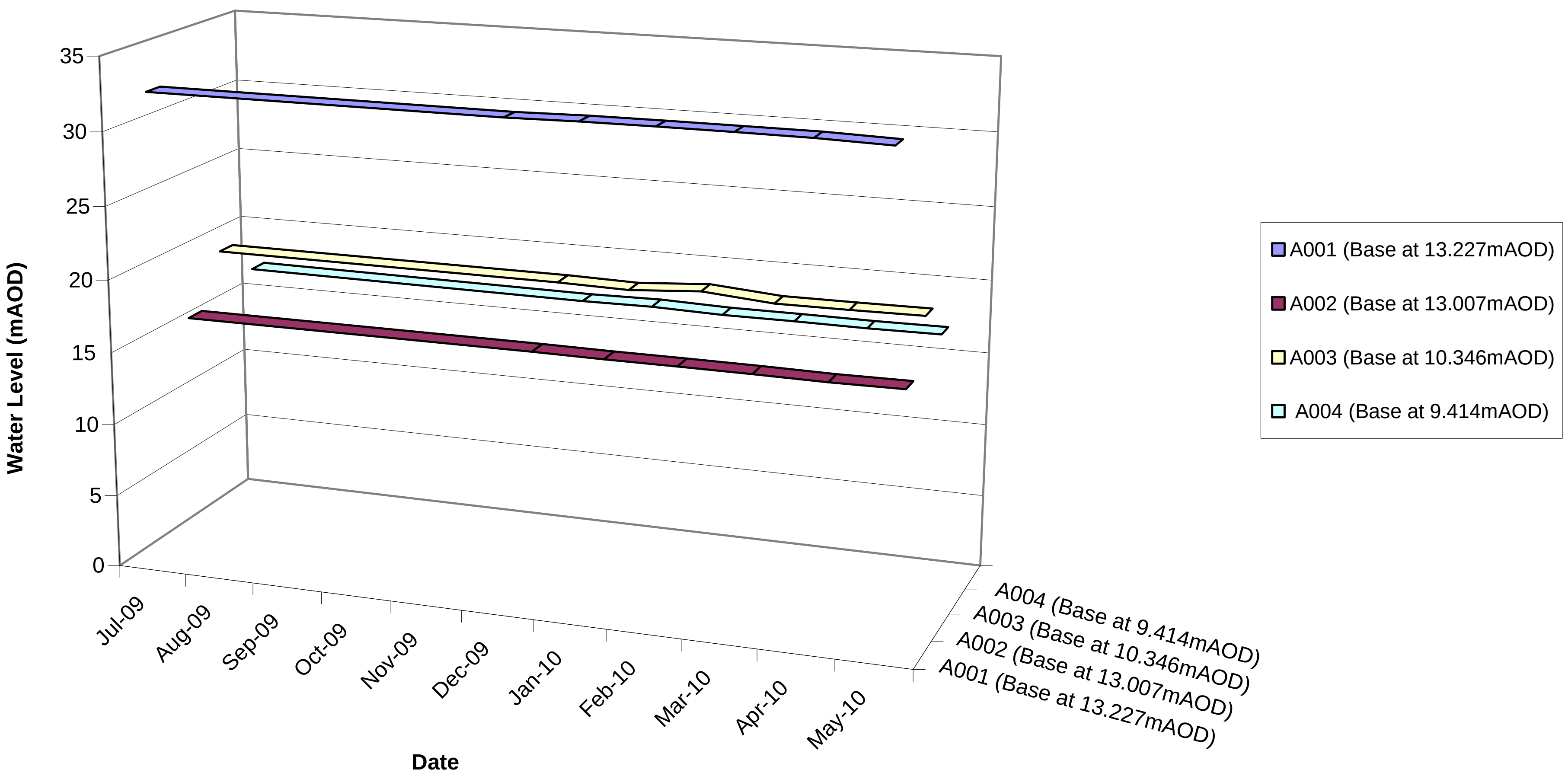
NOTE: A0 direction: East

mouchel

Adjusted RB-A004

Appendix C Runswick Bay Groundwater Graph

RUNSWICK BAY GROUNDWATER LEVELS



Appendix D Knipe Point Groundwater Readings

Groundwater Monitoring Readings – April 2010

SITE Exploratory hole No.	Date (2010)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
Knipe Point							
BH01	14th April	Piezo	86.10	39.63	-	45.00	S'st & Siltstone
BH02a	14th April	Piezo	86.60	-	3.38[1]	97.00	Glacial Till
BH02b	14th April	Piezo	86.60	-	3.38[1]	25.00	Mudst & Siltstone
BH03a	14th April	Piezo	79.10	-	63.80[2]	75.00	S'st & Siltstone
BH03b	14th April	Piezo	79.10	-	0.43	38.00	Glacial Till
BH04a	14th April	Piezo	70.00	-	0.50[3]	63.00	Mudstone and Siltstone
BH04b	14th April	Piezo	70.00	-	0.50[3]	90.00	Siltstone
BH05a	14th April	Piezo	30.10	10.12	19.89	75.00	Siltstone & S'st
BH05b	14th April	Piezo	30.10	14.53	20.04	32.00	Silty sandy CLAY
BH06	14th April	Piezo	34.40	0.34	28.42	30.00	Glacial Till

[1] - Borehole blocked at 3.38mBGL.

[2] - Dip meter jammed in borehole 'a' at 63.80mBGL, 'b' blocked at 0.43mBGL.

[3] - Borehole collapsed at ground level creating a depression 0.50m depth, 1.20m diameter (See Plates 8 & 9, Appendix F).

Groundwater Monitoring Readings – May 2010

SITE Exploratory hole No.	Date (2010)	Inst. Type	Ground Level (mOD)	Water Level (mBGL)	Dipped Depth (mBGL)	Instrument Depth (mBGL)	Response Stratum
Knipe Point							
BH01	5th May	Piezo	86.10	39.72	-	45.00	S'st & Siltstone
BH02a	5th May	Piezo	86.60	-	3.38[1]	97.00	Glacial Till
BH02b	5th May	Piezo	86.60	-	3.38[1]	25.00	Mudst & Siltstone
BH03a	5th May	Piezo	79.10	-	63.80[2]	75.00	S'st & Siltstone
BH03b	5th May	Piezo	79.10	-	0.43	38.00	Glacial Till
BH04a	5th May	Piezo	70.00	-	0.50[3]	63.00	Mudstone and Siltstone
BH04b	5th May	Piezo	70.00	-	0.50[3]	90.00	Siltstone
BH05a	5th May	Piezo	30.10	14.61	19.89	75.00	Siltstone & S'st
BH05b	5th May	Piezo	30.10	1.62	20.04	32.00	Silty sandy CLAY
BH06	5th May	Piezo	34.40	+0.18	28.42	30.00	Glacial Till

[1] - Borehole blocked at 3.38mBGL.

[2] - Dip meter jammed in borehole 'a' at 63.80mBGL, 'b' blocked at 0.43mBGL.

[3] - Borehole collapsed at ground level creating a depression 0.50m depth, 1.20m diameter (See Plates 8 & 9, Appendix F).

Appendix E Knipe Point Survey Data

Ongoing Coastal Monitoring of Survey Points - Monthly Comparison

Knipe Point						
Marker ID	Baseline Distance 12/02/10	Slope Distance 09/03/10	Slope Distance 14/04/10	Slope Distance 05/05/10	Slope Distance	Slope Distance
Knipe Point Headscarp						
H1I	12.25m	12.30m	12.28m	12.22m		
H2I	5.30m	5.35m	5.35m	5.40m		
H3I	4.40m	4.41m	4.44m	4.40m		
H4I	6.20m	6.20m	6.15m	6.15m		
H5I	19.80m	19.24m	19.22m	19.55m		
H6I	20.90m	20.72m	20.96m	20.85m		
H7I	19.10m	18.88m	18.73m	18.73m		
H8I	3.60m	3.65m	3.62m	3.64m		
H9I	7.40m	7.35m	7.30m	7.41m		
H10Ia	10.70m	10.64m	10.59m	10.59m		
H10Ib	14.00m	14.00m	14.01m	14.00m		
H11I	7.40m	7.05m	6.81m	6.78m		
H12I	15.90m	15.88m	15.90m	15.80m		
H13I	4.90m	5.10m	4.85m	4.74m		
H14I	4.07m	4.08m	4.04m	4.04m		
H14I	8.80m	8.80m	8.80m	8.81m		
H14I	11.18m	11.20m	11.19m	11.23m		
A165 Old Filey Road Headscarp						
R0	8.21m	8.21m	8.21m	8.21m		
R0	17.25m	17.25m	17.25m	17.25m		
R0	11.21m	11.21m	11.21m	11.21m		
R0	3.10m	3.10m	3.10m	3.10m		
R1	20.10m	19.96m	19.96m	19.96m		
R2	11.10m	11.14m	11.14m	11.14m		
R3	9.20m	9.39m	9.39m	9.39m		
R4	6.20m	6.35m	6.35m	6.35m		
R5	7.60m	7.99m	7.99m	7.99m		
R6	*	*	*			
Cornelian Bay Headscarp						
C1	3.70m	3.70m	3.70m	3.66		
C4	3.90m	3.90m	3.88m	3.89		
C8	New	N2.20,E3.01m	N2.01,E2.98m	N1.93,E3.00		

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

Appendix F Installation Photographs

Plate 1 Runswick Bay A001

Plate 2 Runswick Bay A002

Plate 3 Runswick Bay A003

Plate 4 Runswick Bay A004

Plate 5 Knipe Point BH01

Plate 6 Knipe Point BH02

Plate 7 Knipe Point BH03

Plate 8 Knipe Point BH04 (4th March 2010)

Plate 9 Knipe Point BH04 (5th May 2010)

Plate 10 Knipe Point BH05

Plate 11 Knipe Point BH06

Appendix G Knipe Point Site Photographs

Plate 1 Tension cracks trending northeast / southwest landward of BH05

Plate 2 Tension cracks trending northeast / southwest landward of BH05

Plate 3 Slope failures on Cornelian Bay side of Knipe Point looking northwest

(14^{th} April 2010)

Plate 4 Slope failures on Cornelian Bay side of Knipe Point looking northwest

(5th May 2010)

Note groundwater seepage from slope above horizontal timbers

Plate 5 Slope failures on Cornelian Bay side looking east (14th April 2010)

Plate 6 Slope failures on Cornelian Bay side looking east (5th May 2010)

Note groundwater seepage from slope immediately above timbers and below headscarp

Plate 7 View of ‘fresh’ mudslide on Knipe Point Headscarp, below Property No. 18 (14th April 2010) Note groundwater issues from slope

Plate 8 View of mudslide on Knipe Point Headscarp, below Property No. 18 (5th May 2010) Note continued groundwater issues from slope

Plate 9 Cliff recession at Knipe Point Headscarp (8th March 2010)

Plate 10 Cliff recession at Knipe Point Headscarp (5th May 2010)

Plate 11 Cliff recession at Knipe Point Headscarp (14th April 2010)

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

Plate 13 Cliff recession at Knipe Point Headscarp looking east (8th March 2010)

Plate 14 Cliff recession at Knipe Point Headscarp looking east (14th April 2010)

Plate 15 Cliff recession at Knipe Point Headscarp looking east (5th May 2010)

Plate 16 Cliff recession at Knipe Point Headscarp looking east (14th April 2010)

Plate 16 Cliff recession at Knipe Point Headscarp looking east (5th May 2010)

Plate 17 Knipe Point Weather Station with Chalet No. 50 in the background

Plate 18 Knipe Point Residential Plan