Robin Hood's Bay Coastal Strategy Study

Ground Investigation Report

Document Ref No.: 1022894/GEO/R/01/02/FINAL

August 2010

Produced for
Mouchel
York House
Thornfield Business Park
Standard Way
Northallerton
North Yorkshire
DL6 2XQ

☎ 01609 766628
🖷 01609 766624
✉ info@mouchel.com
🌍 www.mouchel.com

Document Control Sheet

Project Title	Robin Hood's Bay Coastal Strategy Study
Report Title	Ground Investigation Report
Revision	02
Status	Final
Control Date	August 2010

Record of Issue

Issue	Status	Author	Date	Checked	Date	Authorised	Date
01	Draft	L Frances	22.07.10	ABSW	23/07/10	ABSW	23/07/10
02	Final	L Frances	01.09.10	ABSW	06/09/10	ABSW	06/09/10

Distribution

Organisation	Contact	Copies
Mouchel, Northallerton	Angus Wheeler	Master
Mouchel, Haywards Heath	Zoe Hutchison	Pdf + word

Disclaimer

This report is a review of all the available geotechnical information for the proposed scheme. This report presents an interpretation of the results of the desk study and ground investigation in accordance with the guidelines that were issued by the Highways Agency (HA) in HD22/08 "Managing Geotechnical Risk". The objective of this report is provide recommendations as to the geotechnical design parameters, bearing capacity for foundation design and to review the slope stability of the proposed works.

Mouchel has prepared this report on the basis of the available information received during the study period. Although every realistic effort has been made to obtain all relevant information, all potential contamination, environmental and / or geotechnical constraints or liabilities associated with the site may not necessarily have been revealed. To a degree the completeness of the investigation was restricted by the access constraints of the client's site ownership and constraints imposed by third party landowners where the required works extended beyond the land owned by the client.

The risk assessment modelling undertaken for assessment of contamination is based on specific end uses, and predefined source – pathway - receptor conditions, should those end uses or exposure scenarios change, then the contamination sections of this report may need to be reviewed and amended accordingly.

Mouchel has also used reasonable skill, care and diligence in the design of the ground investigation of the site. However, the inherent infinite variation of ground conditions allows only definition of the actual conditions at the location and depths of exploratory holes, while at intermediate locations conditions can only be inferred.

This report has been prepared and written for the exclusive benefit of Scarborough Borough Council (SBC) for the purpose of providing geotechnical and geoenvironmental information relevant to the proposed scheme. The report contents should be only used in that context. Moreover, new information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

Note on BSEN14688

Soils and rocks in this document have been described in accordance with BSEN1468 and BSEN14689, in accordance with the implementation of Eurocode 7 in the UK.

Contents

Appendices

List of Figures

1 Executive Summary

On behalf of Scarborough Borough Council Mouchel were asked to carry out a ground investigation and to collect other information necessary to assess the ground conditions at Robin Hood's Bay in order to propose possible remedial measures to the ongoing problem of coastal erosion and slope failures in this area. This is part of an overall Coastal Strategy for Robin Hood's Bay (Management Areas 24 and 25)

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

Recent deep seated movement affected the cliffs south of the Victoria Hotel with a programme of remedial works to stabilise the cliffs carried out in 2000.

Published geological data indicates that the study site consists of cohesive glacial deposits with underlying rock being mudstone and siltstone. The findings of the recent ground investigation, February 2010, indicate the potential for deep seated movement.

The main geotechnical risks identified at this site are considered to be:

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

It is noted that some movement at depth has been recorded and it is recommended that inclinometers installed as part of the investigation continue to be monitored.

Constraints to the remedial works strategy have been identified, principally the fact that a large proportion of the cliff and coastal slope is a Site of Special Scientific Importance (SSSI). Potential stabilisation methods are discussed, together with a preliminary estimate of cost. Hard engineering solutions are estimated to provide the greatest improvement to stability. The coastal slope is inaccessible to conventional plant and civil engineering solutions.

2 Introduction

2.1 Scope and Objective of Report

This report relates to a ground investigation carried out at Robin Hood's Bay, North Yorkshire.

Parties to the investigation are as follows:

Client: Scarborough Borough Council

Designer: Mouchel

GI Contractor: Geotechnics

This report presents a discussion of the results from the ground investigation undertaken in February 2010 to provide geotechnical data and detailed knowledge of the behaviour and acceptability of the soils in the area of the proposed scheme. This investigation was designed to authenticate and augment the findings of the Preliminary Sources Study. The findings of the PSSR are not reported separately.

This document complements the Geotechnical Factual Report prepared by Geotechnics (ref.PC093976, April 2010) and is intended to act as a statement of the geotechnical aspects of the scheme, in accordance with the guidelines that were issued by the Highways Agency (HA) in HD22/08 "Managing Geotechnical Risk.

2.2 Description of Project

Robin Hood's Bay is a village situated within the North Yorkshire Moors National Park on the North Yorkshire coast, approximately 16 miles north of Scarborough and 35 miles south of Middlesbrough. Originally a fishing village Robin Hood's Bay is now an important tourist attraction. See **Figure 1** for a plan showing the location of Robin Hood's Bay.

Background & reason for the scheme.

The Shoreline Management Plan 2, produced in 2007, assessed that 9 properties in Robin Hood's Bay were at risk along the unprotected coastal frontage. The specific properties were not identified. A more detailed study in 2006 (Halcrow) had identified the Mount Pleasant area as a potential 'hot spot'. SMP2 concluded that there is increasing pressure on defences being outflanked with continual erosion of the coastal cliffs. The SMP2 considers that the need to sustain the village overrides the fundamental objective to allow natural regression of the coast to continue.

The area to the north and east of the Victoria Hotel in Mount Pleasant, Robin Hood's Bay, is undefended and nine properties are therefore at risk of damage due to coastal erosion.

Predicted sea level rise, increased winter rainfall and storminess as a result of climate change, are expected to accelerate cliff instability and the effects of erosion.

Aims & Objectives of the Study.

To undertake a detailed study and ground investigation to the north of the recent coastal stabilisation works.

- Carry out assessment of existing information (desk study).
- Carry out a walk over survey.
- Design and implement a site investigation for the area to the north of Mount Pleasant.
- Produce a report presenting a ground model and preliminary engineering discussion plus options for remedial measures

Aims & Objectives of the Scheme.

- Reduce landslide activity
- Arrest marine erosion
- Extend the life of properties/infrastructure
- Minimise impact on the SSSI and Heritage Coast
- Minimise disruption to coastal processes

2.3 Geotechnical Category of the Scheme

The geotechnical category, in accordance with HD22/08, is considered to be Category 2, i.e. projects which include conventional types of geotechnical structures, earthworks and activities.

2.4 Other Relevant Information

Robin Hood's Bay has a long history of coastal erosion: in 1780 much of the original road into the village, King Street, was lost together with two rows of cottages. Since 1780 over 200 properties have been lost as a result of cliff top recession.

Press cuttings from January and February 1956 describe recent cliff movement/landslides at the top of the Bank, in front of the Victoria Hotel, following wet weather and snow in the preceding months. The movement had started in 1954 and halted during the dry summer of 1955. Early in 1956 the drive and garden of the hotel were seriously affected and it was noted that only the boundary wall separated the road from the cliff. It was stated that the cliff face below the road had moved back 30 feet in the last 12 months. Rivulets of water were pouring from the land down the crumbling cliff. The movement was attributed to landslide rather than erosion by the sea. All services for the lower part of the village are within the road. Plans for moving the road several yards inland were noted; also provision of a 15 inch pipe to collect surface water to the rear of the Bank Top car park. The road providing access to the lower town was subsequently realigned. **Figure 2** shows the 1958 and 1975 alignment of the road.

To protect the lower part of the village vertical concrete walls, 14m high and anchored into the cliff, were built in 1975. The purpose of this wall was to prevent erosion along 'The Landing' and a section of the cliff located between the village slipway and Ground Wyke Hole. A sheet piled wall was also installed below the Esplanade but the date is not known. This part of the village is south of the study area.

In 1996, with an unstable slope and eroding cliffs only 2m from the only access to the lower part of the village, a study was commissioned to evaluate the problem and identify suitable coastal protection measures. The study area extended from the Victoria Hotel south to the Quarterdeck. The most significant findings were the relatively high rate of on-going erosion and the outflanking of existing coastal defences. It was also noted that there was movement behind the sheet piled wall. Coastal protection works based on this study were carried out in 2000/2001. The treated area is immediately south of the current study area.

A further study (Cliff Condition Analysis, Halcrow) in 2006 has identified Mount Pleasant as a potential cliff failure zone.

3 Existing Information

3.1 Topographical Maps (old and recent)

Historic maps and information on Sensitive Land Use have been obtained from the Envirocheck report from Landmark. This data has been used to provide a general assessment of the site. Selected historic maps are reproduced as **Appendix A**. The full Envirocheck report, on CD, is included as **Appendix B**.

Maps consulted include:
- Yorkshire, County Series (1:2,500)
- Yorkshire, County Series (1:10,560)
- Ordnance Survey Plan (1:2,500)
- Ordnance Survey Plan (1: 10,560)
- Ordnance Survey Plan (1: 10,000)
- Additional SIMs (1:2,500)
- Large-Scale National Grid Data (1:2,500)
- 10K Raster Mapping (1:10,000)

From **1853** the lower village was present, with Station Road leading in from the north. At Ground Wyke Hole a small, steep rock cliff is present, with up to 80m of gentler coastal slopes. From **1893** these show evidence of multiple slippages. A waterfall flows to the beach from the east of the modern-day Victoria Hotel. A track (Old Lane Cliff) runs from Station Road along the cliff top. Kings Beck flows from the west into the town and is culverted beneath the buildings. No outflow is yet evident. A ridge runs down to Ground Wyke Hole.

North of the town the railway is present and crosses the road into town on a bridge. An unnamed stream flowing from the north has been culverted north of the railway but is present at the surface to the south and can be traced to a waterfall outfall on the cliffs (**Figure 5**). Two springs and a reservoir are present north of the railway, immediately north of the railway in the vicinity of Graystone barn.

Trees were growing on the coastal slopes by **1912**. The Victoria Hotel had been built and Mount Pleasant was so-named. A rocket post was present to the northeast of the town, close to the footpath (this was intended for firing a roped rocket onto a sinking ship and pulling the passengers to safety using a breeches buoy). Urbanisation has started to occur at Mount Pleasant. No stream is now marked to feed the waterfall close to the Victoria Hotel. An outfall from the King's Beck led from the lower village, across the Landing and out to sea. A drain is present along the northern boundary of the railway.

By **1928**, the coastal slopes roughly 75m to the northeast of the Victoria Hotel show a recession of about 10m, to the edge of the footpath. A house is now present at the northeast corner of the village, close to the footpath, and the coastal slopes 60m to the northeast of this house have receded a small distance. The upper village has also undergone much more urbanisation at Mount Pleasant by this time.

The outfall from Kings Beck was no longer present by **1975**, but a small stream with various distributaries flowed from the same point. Station Road had been moved away from the cliff at the Victoria Hotel (see **Figure 2**), creating a new car park on either side of its new route. Much urbanisation had occurred in the upper village and the railway had been dismantled. A drain is shown to the rear of properties Finisterre and Class-Tae at the extreme north east of the study area with an outfall onto the coastal slope. The top of the coastal slope had receded by about 10-20m since **1928** along the length of the coastline adjacent to the village. The footpath was moved inland away from the edge.

By **1975,** New Road in the lower village had been widened.

The **1994** survey shows that the coastal slopes at Victoria Terrace have receded by 10-15m, and those just to the northeast of Class-Tae on the edge of the village had receded by about 2m. The cliff tops had receded by about 1m at Ground Wyke Hole further to the south.

The coastal slopes at Dungeon Hole and the Victoria Hotel had receded by 10m between **1980** and **2000** and those to the southwest of the north eastern-most house (Class-Tae) by 5m. The present owner of Two Gates indicated that a landslip had occurred adjacent to her property about 5 years ago, rendering the cliff path unsafe.

The base of the cliff at Ground Wyke Hole has receded by about 1m between **1994** and the present day (**2009**). The Station Road system has also changed at the Victoria Hotel, having had a roundabout installed and the road moved away from the edge of the slope. Stabilisation works were undertaken in 2000/2001 on the coastal slope south of Mount Pleasant as described in **Section 3.12**.

3.2 Aerial photographs

Aerial photographs, which were taken in 1999 on behalf of SBC, have been inspected. These precede the recent cliff stabilisation works (2000/2001). Specific details of the cliffs and slopes are difficult to determine due to dense vegetation and shadow.

Historic and current aerial photographs dated 1940, 1962 and 2008 were also examined and used to measure the rates of recession between these dates. Recession results have been quoted below but these should be treated with caution as accurate comparable measurements were hard to undertake.

3.3 Geological Maps and Memoirs

3.3.1 Published Information

The 1:50,000 British Geological Survey Sheet 35/44 (Whitby & Scalby), 1998, was consulted to determine the geology of the region. A 1:10,000 scale map is not available for this area.

The geology of the area reflects its recent glaciation and the subsequent rise in sea level. Quaternary drift deposits of glacial till cap the Lower Jurassic Lias rock cliffs, with exposed mudstones forming the wave cut platform.

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

Table 3-1: Geological Stratigraphy

Age	Stratum
Quaternary (Recent)	Till Clay with pebbles and lenses of gravel
Lower Jurassic	Cleveland Ironstone Formation Mudstone with ironstone bands Present immediately north east of the study area
Lower Jurassic	Staithes Sandstone Formation Sandstone
Lower Jurassic	Redcar Mudstone Formation Grey mudstone with thin limestone and sandstone beds

3.3.2 1st layer of Drift

The Quaternary glacial till comprises clay with pebbles, laminated clay and lenses of sand and/or gravel. It may be present to variable depths depending on local conditions of glaciation and subsequent erosion.

3.3.3 1st layer of Rock

The Lower Jurassic Staithes Sandstone Formation comprises fine to medium micaceous sandstone; commonly well-bedded and weathering to flaggy slabs and is present at the northern edge of the village.

3.3.4 *2nd layer of Rock*

The Lower Jurassic Redcar Mudstone Formation comprises soft grey shale/mudstone containing thin limestone and sandstone beds. Nodules of iron pyrite and mudstone and calcareous concretions are frequent. The formation is reported to be 250m thick at Robin Hood's Bay and forms the rock outcrop in the cliffs and on the foreshore area.

3.4 Records of Mines and Mineral Deposits

No mining activity is evident in this area according to the website of the British Geological Survey.

3.5 Land Use and Soil Survey Information

The upper part of the village sits on the till slopes above a near vertical rock cliff which reduces in height to the south. The road to the lower village runs close to the crest of this regressing coastal slope.

The arrival of the railways in 1885 led to the expansion of the village and the development of the Mount Pleasant area where there are large brick houses and hotels with views across the bay. The railway closed in 1965 but the village has continued to thrive and is now an important tourist attraction.

The area is recognised by its environmental designations, which include Heritage Coast, and several Sites of Importance for Nature Conservation. The foreshore and sea cliffs are designated as SSSIs on the basis of their geological values and the Beast Cliff Special Area of Conservation (which lies to the south of the village). This is protected under the Habitats Directive (vegetated sea cliffs of the Atlantic and Baltic coast).

The cliffs to the north end of Robin Hood's Bay are steep and extend to a rock platform. At the abrupt north corner of the bay the cliffs are near vertical, reducing in height to the south where they are overlain by glacial till. The till slopes have regressed to form a series of vegetated terraces with the road to the lower part of the village close to the crest and a rock revetment at the toe of the cliffs

3.6 Archaeological and Historical Investigations

A separate environmental study is being undertaken as part of the Robin Hood's Bay Coastal Strategy Study.

3.7 Existing Studies/Ground Investigations

Previous Studies and Site Investigation Reports that have been interrogated include the following:

Shoreline Management Plan 2, Report ref: 9P0184/R/nl/PBor, February 2007, Haskoning UK Ltd.

Draft SMP2 Appropriate Assessment Report, Report Ref, December 2007, Haskoning UK Ltd.

Condition Analysis of Coastal Protection Assets: Cliffs and Beaches Staithes to Speeton, Halcrow Group Ltd Nov. 2006

Strategic Coastal Monitoring Staithes to Scarborough: Cliff Condition Survey; High Point Rendel 2002

Robin Hood's Bay Coast Protection and Cliff Stabilisation Scheme, Report Ref 000646/C/1, March 2000, High Point Rendel.

Robin Hood's Bay – The Quarterdeck Coast Protection and Cliff Stabilisation, Report Ref NR/DP/F107780, August 1997, High Point Rendel.

Robin Hood's Bay Coast Protection and Cliff Stabilisation: Environmental Statement, Report Ref R/H443/1, July 1999, High Point Rendel.

Ground Investigation Report, Report Ref 3443N, December 1995, Geotechnical Engineering Ltd.

Report on Inspection of Sea Wall, Report Ref, December 1993, High Peak Access Services.

Robin Hood's Bay Coast protection and Slope Stabilisation Emergency Works: Health and Safety Report, Volume 2 As Built Drawings

The above reports do not include specific ground investigation data (borehole logs and laboratory test results).

Limited information from the ground investigation, referred to in the High Point Rendel Coastal Protection and Cliff Stabilisation Report is included as **Appendix D**. The factual report has not been made available. A cross section from the Victoria Hotel across the coastal slope towards the south east shows up to 31m of glacial deposits (BH5) overlying mudstone. A layer of Made Ground up to 2.5m thick is identified, possibly reflecting previous regrading/remedial works on the slope. The glacial deposits comprise gravely clay, sandy clay, silt, sand and gravel. A layer of sand with some gravel was noted overlying the mudstone (Redcar Mudstone). Laminated clay of high plasticity was noted with evidence of landslide shear zones. Groundwater strikes were noted in the superficial deposits in TPs 4 and 5 and BHs 2, 3 and 4 at depths of 0.58 to 4.5m bgl. It was stated that the laminated clay present was of high plasticity (LL=53%), with a residual strength, ϕ' of 9 degrees. The sandy till was stated to have a residual strength ϕ' of 22 degrees.

The GI carried out by Geotechnical Engineering in 1995 refers to the southern end of the site remediated in 2000 and covered in more detail by High Point Rendel in 1997.

3.8 Consultations with Statutory Bodies and Agencies

Those statutory bodies consulted are listed below

Envirocheck Report from Landmark

Natural England

Environment Agency

Scarborough Borough Council

British Geological Survey

North York Moors National Park

3.9 Flood Records

The Environment Agency's "what's in my backyard" map (**Figure 3**) shows that the rock cut platform at the base of the cliff is at risk of flooding by the sea, but that the village properties have little likelihood of flood damage. This is confirmed by the findings of the Envirocheck report. At high tide the sea reaches the base of the sea cliffs.

3.10 Contaminated Land

No current or historic waste sites or mining of any variety is evident from the British Geological Survey or the Environment Agency websites.

3.11 Sensitive Land Uses

The MAGIC website and the Sensitive Land Uses plan of the Envirocheck report reveals that the entire coastline around Robin Hood's Bay from Maw Wyke to Beast Cliff is classed as a Site of Special Scientific Interest. The coastline to the south of the village is also classified as a Special Area of Conservation. A description of the SSSI listing and a plan showing sensitive land use is given in **Appendix E**.

3.12 Other Relevant Information

The Cleveland Way, a National Trail, enters Robin Hood's Bay at the north east corner of the study area, near to the houses Class-Tae and Finisterre, and continues along Mount Pleasant North in to the town. Information from the National Trails Officer, North York Moors National Park, indicates that the Cleveland Way which opened in 1969 has always followed this route. In 1954 a portion of the cliff top path south and west of the Rocket House was washed away. This confirms information gained from historic press cuttings as discussed in section 2.4. The public footpath north of the Rocket House, along the coast north and east to Class-Tae, was subject to an extinguishment order in 2007 and is now no longer accessible.

The Coastal Protection and Cliff Stabilisation Scheme documents and public information board on the slope below the Victoria Hotel provide facts concerning the scheme, which was designed by High-Point Rendel and carried out by Amec Capital Projects in April 2000-2001.

The overall philosophy of the design for the coastal protection and cliff stabilisation at Robin Hood's Bay was to create a sustainable coastal protection scheme with at least a 50 years design life that would: eliminate the effects of marine erosion along the site foreshore; prevent outflanking of the Quarterdeck at the southern end of the village; provide a new sea wall with a low wave reflection, rock armour revetment that would also act as a toe load buttress to the more active area of the landslide; control ground surface movements over the site of active landsliding within the confines of the main site boundary and prevent further cliff top recession.

The design comprised four main parts: a reinforced rockfill buttress with associated rock armour revetment; earthworks to redistribute loading, forming a reinforced buttress to support the cliff and reduce the likelihood of landslides; piling (200No. 10m long, reinforced concrete piles) to support the reinforced earth buttress; and drainage works to lower the groundwater level at the site. The drainage works comprised counterforts, drilled horizontal drains and dewatering wells.

Extracts from the High Point Rendel Report (1999) and Contract documents (2000) showing the proposed stabilisation and coastal protection measures are given in **Appendix D**.

4 Field and Laboratory Studies

4.1 Walkover Survey

A walkover survey of the accessible parts of the site was carried out by two members of the Mouchel geotechnical team from Northallerton on 21st January 2009 on a cold sunny day. Site walkover notes and a plan showing the locations being described are included as **Appendix F**. Dr. Mark Lee, an independent geomorphologist, provided valuable input having been involved with the ground investigation and design for the cliff stabilisation and coastal protection works completed in 2001. Photographs taken during the walkover are included as **Appendix G**. Further photographs were taken at a later date when low tide afforded access to the foreshore. Access to the top of the cliff slope was extremely limited due to dense undergrowth.

Features identified during the walkover surveys are described in **Section 5** of this report.

4.2 Geomorphological/Geological Mapping

A detailed geomorphological map was prepared by High-Point Rendel in 1997, extending to the headland between Ground Wyke and Dungeon Hole (**Appendix D**). Further inspection and updating was carried out in January 2009. The cliff recession rates quoted are based on information from the 1970s. Sea level rise due to climate change will affect the rate of recession of the sea cliffs in the future.

Examination of the aerial photographs (**Appendix H**) and maps indicates that the rate of recession of the top of the rock cliff line beneath Mount Pleasant varied from 0.1 to 0.7 m/year between 1940 and 1962 and from 0.1 to 0.2 m/year between 1962 and 2008. The tops of the coastal slopes along this stretch of coastline are indicated to have receded at a rate of 0.2 to 0.6 m/year from 1940 to 1962 and at 0.1 to 0.3 m/year from 1962 to 2008. It is noted that the cliffs in the immediate vicinity of the small waterfall near to the Rocket House have a higher recession rate than elsewhere.

Average recession rates quoted in the 2002 Strategic Coastal Monitoring Report (High Point Rendel) are:

- Waterfall below Victoria Hotel: Cliff top 0.244 m/yr Cliff Base 0.21 m/yr
- East of Waterfall (east Unit 16/2); Cliff top 0.183 m/yr Cliff Base 0.146 m/yr
- Dungeon Hole(Mt Pleasant Unit 16/1); Cliff top 0.135 m/yr Cliff Base 0.11 m/yr

Cliff top is the top of the Coastal Slope. These figures also show that the waterfall is significantly contributing to the erosion of the cliff in the vicinity and that the figures are comparable to those measured from the aerial photographs..

4.3 Ground Investigation

The aim of the ground investigation was to provide information for geotechnical design of the earthworks and structures.

4.3.1 Rationale

The following aspects were investigated in order to assess the future potential for failure:

1. Confirmation of the nature and sequence of strata present.
2. The strength of the drift deposits to allow assessment of slope stability.
3. The bearing properties and settlement characteristics of the deposits and their ability to support foundations.
4. The depth of groundwater and its effect on bearing capacity, slope stability and drainage. Long term monitoring of groundwater levels.
5. Installation of inclinometers to monitor slope movement.

4.3.2 Description of Fieldwork

A ground investigation was carried out in February 2010. The investigation was designed and specified by Mouchel but was subject to variation, prior to commencement on site, due to limits on available funding. Initially 6 boreholes were planned but this was subsequently reduced to 4. In addition four shallow holes were put down using hand held window sampling equipment at the base of the coastal slope.

The ground investigation works were undertaken by Geotechnics during February 2010. Mouchel monitored the works part-time on site. The locations of the exploratory holes are shown on **Figure 4**.

Table 4-1 Location of Boreholes

Boreholes	Depth to base of cable percussion boring	Depth of base of rotary coring	Location
BH1	31m	50.50m	Victoria Hotel car park
BH2	32.50m	50.50m	Rocket House
BH3	20.38m	Not cored	Grass field to seaward side of Mount Pleasant East
BH4	12.10m	40.50m	Between disused railway and rear of Class Tae
WS1-4	2.3-3.0m		Clay slope below Rocket House

All the boreholes were bored to rock head using conventional cable percussion techniques. BHs 1, 2 and 4 were continued using rotary coring techniques with 92mm cores obtained. A core-liner was utilised and the flush medium used was air-mist. The cores were extruded horizontally and placed in core boxes on site.

Representative small and bulk disturbed samples were taken of the various strata and stored in airtight containers and bulk bags respectively for identification, description and testing purposes.

Piezometers were installed in boreholes BH1 and BH3. Inclinometers were installed in BHs 2 and 4.

4.3.3 *Ground Investigation Factual Report*

A copy of the geotechnical factual report issued by Geotechnics in April 2010 is submitted separately. This contains the logs, field tests and results of laboratory testing. An AGS data file and pdf. version of the report were also provided. The report was issued in April 2010.

4.3.4 *In-situ tests*

The subsurface strata were examined in the arisings from the exploratory holes. The consistencies of the cohesive subsoil and the relative densities of the granular deposits were assessed by inspection. In granular soils, and gravelly cohesive glacial deposits, Standard Penetration Tests (SPTs) were carried out at intervals. The results of test are included in the Factual Report and plotted as **Figure 17** of this report. The N values obtained measured within the upper 5m, across the site, are very low with values of 2-6 recorded in BHs 1, 2 and 4 at depths of 2m and 4m. In BH3 a value of 5 was recorded at 4m depth. With depth the N values increase, with all the results below 10m being in excess of 50.

4.4 Drainage Studies

Drainage in the Mount Pleasant area was observed during the site walkover. The stream that eventually outfalls as a waterfall on the cliffs to the south of Mount Pleasant was seen in the garden of Cliff Cote and in culvert (9 inch pipe) beneath the access to the Rocket House. The stream passes beneath a garden before flowing onto the cliff face. The exact location could not be determined due to steep and overgrown ground. The line of the stream, from the north, has been traced from the historic maps and is shown on **Figure 5**.

A very minor flow was also noted, in a shallow stone lined open channel, flowing from the east along the land behind the Rocket House and joining this stream.

Inspection of the bench above the sea cliff showed that the water from the stream did not keep to a channel but dispersed along the surface. The route of the stream down the slope is marked by willow trees. There is also an extensive soft wet area to the east of the stream supporting reeds and bulrushes. The underlying Lias rock is of low permeability. Photographs taken after a period of heavy rain show water flowing over the sea cliffs at several locations.

A drain is shown on the 1975 map to the rear of properties Finisterre and Class-Tae at the extreme north east of the study area with an outfall onto the coastal slope. This is not now evident. Construction of the railway in the 1880s included a drain along the north boundary. The early maps show springs and a reservoir to be present north of the railway.

Anecdotal evidence indicates that water flows west along the footpath at the front of Kenmore and the adjacent properties. The garden of Two Gates, further to the south, was also noted to have standing water present. Attempts to drain it by the owner were reported to be unsuccessful.

The Envirocheck report indicates that there are two consents to discharge sewage effluent and storm water in to the sea in the Mount Pleasant area. The information obtained from Yorkshire Water shows an overflow passing beneath gardens from the end of The Close towards the sea.

4.5 Geophysical Survey

Not Used.

4.6 Pile Tests

Not Used.

4.7 Other Field Work

Topographic and ecological surveys have been separately carried out by Mouchel and are reported separately. Evidence of badgers was noted in the field and cliff top margins in the vicinity of BH3.

4.8 Laboratory Investigation

4.8.1 Description of tests

Laboratory testing (geotechnical) was performed on selected samples by Geotechnics to provide data for classification purposes and measurement of geotechnical parameters for the design of the earthworks and structure foundations. The chemical testing (WAC) was subcontracted to ALcontrol, the effective stress testing to Structural Soils and the rock testing (UCS) to MATtest Ltd.

A summary of the laboratory tests undertaken is presented in Table 4-2 below

Table 4-2 Summary of Laboratory Testing

Type of test	Test method
Classification	
Moisture Content	BS1377: Part 2: 1990; Clause 3
Liquid / plastic limits	BS1377: Part 2: 1990; Clauses 4 and 5
Particle size distribution (sieving and sedimentation)	BS1377: Part 2: 1990; Clause 9
Strength	
Quick undrained triaxial (total) strength	BS1377: Part 4: 1990; Clause 9
Consolidated undrained triaxial (effective) strength	BS1377: Part 8: 1990; Clause 7
Point Load (rock)	ISRM
Unconfined Compressive Strength (rock)	ISRM
Chemical (tests on soil and groundwater)	
Water soluble sulphate (soil and groundwater), pH, organic content	BS1377: Part 3
Contamination (for waste disposal purposes)	
Metal suite (As, Cd, Cr, Hg, Pb, Se, Cu, Ni, Zn)	Environment Agency WAC testing
Speciated Petroleum Hydrocarbons	Environment Agency WAC testing

4.8.2 Copies of Test Results

A copy of the geotechnical factual report by Geotechnics is submitted separately. This contains the logs, field tests and results of laboratory testing. An AGS data file was also provided.

5 Ground Summary

5.1 Geography/Geomorphology

The scheme is located in the upper part of the village of Robin Hood's Bay, focusing on the coastline to the north and east of the Victoria Hotel at Mount Pleasant. Here, the land forms a steep till slope down towards the sea, with an almost vertical rock sea cliff below. No coastal defences exist in this area and regression of the sea cliffs and till terraces due to coastal erosion and landslide will eventually result in the loss of a few properties, but regression is expected to be slow.

Measured regression rates (High Point Rendel) of the base of the sea cliffs were 0.21m/year adjacent to the waterfall and 0.183m/yr on the area to the east. A slightly lower rate (0.11m/yr) was measured on the east facing cliff further north. The top of the cliff is assessed as regressing at a slightly faster rate (0.135 to 0.244m/yr). Boulders are noted on the foreshore, evidence of this erosion.

Movement within the clay slopes above the sea cliffs is interdependent on recession of the sea cliffs. As the cliffs retreat landslides on the mid-slope bench lose toe support and reactivation of landslips may occur with the till slopes trying to degrade to a more stable slope. Attempts have been made to assess the rate of regression of the top of the clay slope using the historic OS maps and aerial photographs but these are inconclusive. The movement affects localised areas of the slope with obvious loss of land at the top of the slope as witnessed by realignment of the coastal cliff path. This movement tends to occur as a 'one-off' slip rather than being a continuous but gradual process. During winter and spring of 2010, after prolonged wet weather, movement of the clay slope below the Rocket House was noted. This appeared to comprise shallow spalling and slumping of the clay face. The latter is exacerbated by the proximity of the stream down the slope (above the waterfall), perched water within the till and seepage erosion at exposed granular layers in the till. It is likely that the water table is recharged from springs and pipe work to the north.

The clay slope above the sea cliff is well vegetated immediately east of the regraded, stabilized slope, in the vicinity of the stream and top of the waterfall. The slope height east of the Victoria Hotel is estimated to be 25m high and the angle to be approximately 35 degrees. Further to the east the height of the cliffs increases and they appear to be steeper (circa 40 degrees). There has been much localized spalling of the slope surface, exposing brown gravelly clay. Erosion/slippage has produced a series of ridges with exposed clay in between. There is a level area, mid-slope bench, above the sea cliff and at the toe of the clay slope. This has been distorted by slumping/slippage of clay from above. Towards the east the bench reduces in width and is inaccessible.

It is estimated that there has been less than 10m cumulative loss over an 80 year period east of the treated slope, with projected loss of roughly 5m within the next 20-50 years (High Point Rendel, 1999).

The slope stabilization works carried out in 2000/2001 treated a deep seated rotational failure as well as more localized superficial movement. The backscarp to the deep movement was located below The Esplanade and arched around to the south of the Victoria Hotel. In general shallow landslips are much more common on this coast than deep rotational failures. Small scale movement can occur as shallow transitional slumps/slides or rotational slumps or debris flows/mudslides. The former are more common with movement usually within 3-4m of the surface. There is evidence of shallow movement on the clay slope east of the stabilized area. Movement is usually triggered by heavy or prolonged rainfall which increases pore pressures and also leads to localized surface run-off. Water seepage is common in the more granular layers and lens within the glacial till and above the rock.

5.2 Historical Development

This is discussed in **Sections 2.4** and **3.1**. Robin Hood's Bay was originally a fishing village, reaching its peak in the early 19th century. With the arrival of the railway in 1885 it became established as a tourist attraction and has continued to thrive despite closure of the railway in 1965. There is a long history of coastal erosion, first documented in 1780 and continuing to the present day. Significant coastal defences have been built with the most recent in 2000 to stabilise the cliffs in front of the Victoria Hotel and safeguard the road access to the lower village. As the village has developed streams and issues from north of the railway have been culverted.

5.3 Topography

The Victoria Hotel is at a height of 52m AOD. The land to the south falls in a series of wide steps towards the low sea cliffs and the rocky foreshore. This area was regraded in 2000/2001. East of the hotel the cliffs are about 50m high, comprising an upper cliff of glacial till at an angle of approximately 45 degrees and a lower, near vertical cliff of mudstone rock. Further up the coast, at the east end of the village the ground level rises to 70m AOD and the overall cliff height increases; the coastal slope formed in the till becomes less significant. Ground levels immediately north of the study area are 70m AOD with the ground rising gently to the north. The main access road into Robin Hood's Bay, from the A 171 Scarborough to Whitby road, falls steeply towards the village.

5.4 Geology and Ground Conditions

The underlying geology along the route corridor of interest has been discussed in **Section 3.3** of this report; an extract of the geological map is included as **Appendix C**. The findings of the intrusive site investigation proved the geology of the site to be generally in agreement with the published geology, comprising a succession of glacial deposits (cohesive and granular) overlying extremely weak to weak siltstone and mudstone with occasional thin bands of limestone.

The bedrock is present at 31-33 metres below ground level at the south edge of the site (BHs1 and 2), rising to 20m bgl in BH3, and 12m in BH4 at the north-east corner of the village. A summary of the strata encountered in the Ground Investigation is presented below.

5.4.1 *Topsoil*

Topsoil was not described in the exploratory holes; the upper surface of boreholes 3 and 4, both in grassland was described as brown sandy gravelly clay in BH3 and brown slightly gravelly clayey sand in BH4. Both contained frequent rootlets.

5.4.2 *Made Ground*

There were thin layers of Made Ground recorded at the surface in BHs 1 and 2. In BH1 the upper 0.25m comprised tarmac on to gravelly sand (car park construction); in BH2 the upper 1.1m was described as sandy gravel of brick, concrete, and sandstone with pockets of sandy clay. In BHs 3 and 4 the upper 0.2-0.3m was described as Made Ground but both areas are grassland possibly with some surface debris incorporated into the topsoil by historic activities.

The Made Ground in both instances is for access purposes with BH1 located in the car park to the Victoria Hotel and BH2 on the stoned access track to the Rocket House. It is possible that the Made Ground is not 1.1m thick at BH2 but that gravel has been pushed in to the soft clay beneath.

5.4.3 *Glacial Till*

The Drift comprises glacial till, as exposed in the coastal slope above the rock cliffs. This varies in thickness from 11.7m, in BH4 at the northern edge of the site, to 31m in BHs 1 and 2. In BH3 the glacial till is 19.8m thick.

The material is predominantly low plasticity slightly sandy, slightly gravelly CLAY but intermediate to high plasticity laminated CLAY and granular lenses are also present; the consistency is soft within the upper 5-6m, becoming stiff to hard with depth. The proportions of sand and gravel vary significantly across the site, and with depth, hence this deposit is also described as slightly gravelly sandy CLAY or slightly sandy gravelly CLAY. Very few cobbles were reported. BHs 1 and 2 required chiselling through the glacial till, with little or no chiselling reported for the other holes.

Borehole 1 was notably more varied with very dense clayey very gravelly SAND present at 11-14m depth and 16-17.3m depth. Thin lenses or small pockets of clayey sand/sandy clay were identified in BH2 at various levels and in BH3 just above rock head. In BH4 silty gravelly SAND was present between 1.7 and 2m depth.

High plasticity thinly laminated clay, described as firm, was identified in BH1 at 0.25-1.7m. Stiff thinly laminated clay was also recorded in BH1 from 17.3 to 21.8m and 25-26.6m, with the deeper layer being of intermediate plasticity and the shallower one low plasticity. Laminated clay was not reported from the other exploratory holes on the cliff top.

Window sample holes at the base of the clay slope, below boreholes 1 and 2, revealed similar material ie. slightly sandy slightly gravelly CLAY. These holes were put down using hand held equipment; the depth was restricted by either hitting firm material or by collapse of the soft surface clay (WS1 and WS2). Pockets of organic clay, including wood fragments, were present in WS1 and 2. Both were located near to the stream that flows down the slope. Lenses of gravelly sand were noted in the slope face, exposed by recent slumping, and cobbles and small boulders were present on the surface.

5.4.4 *Staithes Sandstone*

In BH4 the upper surface of the rock, at 11.7m depth (62.37mOD) was recovered as grey sandy siltstone and the upper 4m is described as very weak to weak, grey micaceous siltstone with shell fragments. It is likely that the upper part of the core for BH4 is the lower part of the overlying Staithes Sandstone Formation. Recovery was better than for the top of the rock in BHs 1 and 2 and the rock was less fractured. It was also noticeably more iron stained.

In BH4, between 15.8 and 22.5m depth (58.27-51.57mOD), the siltstone becomes darker in colour and also weaker. Below 22.5m depth the rock is medium strong, this description continues to the base of the core at 40.5m (33.57mOD). It is possible that the lower part of this core hole is within the Redcar Mudstone Formation as there is a gradation between the strata.

5.4.5 *Redcar Mudstone*

The Redcar Mudstone Formation forms the broad rocky scars on the foreshore at Robin Hood's Bay and is present in the cliffs below the high part of the village. This was proved in BHs 1 and 2 by coring. Full details of the strata are given on the borehole logs in the factual report. In boreholes 1 and 2 the weathered upper surface of the rock is present at 31-31.5m depth (20.5-23.5mOD), and is described as very stiff gravelly clay/very stiff grey mudstone; this was proved by boring but the penetration was minimal despite chiselling.

BH3 was not cored but the upper surface of the rock was determined by boring. Mudstone, recovered as grey gravelly clay was present at 19.8m and proved to 20.38m.

The rock is described as extremely weak to weak dark grey SILTSTONE in the logs for BH1 and BH2. Recovery was poor (less than 90%) within the upper 4-5m with much of the material described as non-intact. Fracture planes are noted to be iron stained. With depth the material becomes stronger, slightly micaceous and less fractured. Fracture planes have clay smear. The total core recovery (TCR) exceeds 90% and the solid core recovery (SCR) also increases. In BH1 two thin beds of medium strong limestone are present (47.4-47.67m and 50.4-50.5m bgl) separated by medium strong mudstone; BH2 continues to 50.5m depth in siltstone.

5.5 Hydrogeology

The Groundwater Vulnerability Map (Sheet 9) of north east Yorkshire has classified the area partly as a minor aquifer and partly as a non-aquifer. A region of non-aquifer stretches from the southern part of the village, south to Old Peak. This is ringed by an arc of minor aquifer and an outer ring of non-aquifer.

Minor aquifers are classed as variably permeable due to their low primary and variable secondary permeability. However, groundwater flow through such rocks, although imperceptible, does take place and needs to be considered in assessing the risk to stability. They seldom produce large quantities of water for abstraction but are important for local supplies and for base flow. Major aquifers may underlie minor aquifers.

The overlying soils of the region are classed as having a low leaching potential. These are therefore soils in which pollutants are unlikely to penetrate the soil layer because either water movement is largely horizontal or they have the ability to attenuate diffuse pollutants. Lateral flow from these soils may contribute to groundwater recharge elsewhere in the catchment. They generally have high clay and silt content but observations and borehole logs indicate that significant granular layers are present, though these are known to be inconsistent.

Build up of pore pressures, after heavy or prolonged rainfall, within the clay forming the slopes will contribute to failure. Seepages are evident on exposed clay slopes, particularly within the more granular horizons, with water issuing from the top of the mid-slope bench at various locations after heavy rain.

Groundwater was met in all the boreholes. In BH1 the strike at 25.5m depth rose to 16.2m in 20 minutes and in BH3 water met at 20m depth, at the base of the till, rose to 15m in 20 minutes. Neither of these strikes was sealed. The site at BH3 was waterlogged due to snow melt and heavy rain and surface water entered the hole. The area around WS1 and WS2, on the coastal slope, was also waterlogged due to the presence of the stream. Details of water strikes during boring are given in Table 5-1.

Table 5-1 Groundwater strikes in the Boreholes

Hole ID	Geology	Water Strike Depth (m bgl)	Water Depth after 20 minutes(m bgl)	Depth cased	Depth sealed
BH1	Slightly sandy gravely clay	10.4	Seepage	10.00	10.50
BH1	Slightly sandy slightly gravely clay	24.2	23.1	24.00	25.00
BH1	Laminated clay	25.5	16.2	25.00	Not sealed
BH2	Slightly sandy slightly gravely clay	4.2	3.0	4.00	6.00
BH3	Sandy slightly gravely clay	0.5	Seepage from surface	None	1.50
BH3	Sandy slightly gravely clay with very sandy clay pockets	4.0	3.0	4.00	6.00
BH3	Gravely sandy clay	9.0	8.5	9.00	10.50
BH3	Mudstone recovered as gravely clay	20.0	15.0	12.00	Not sealed
BH4	Gravely sandy clay	9.0	8.7	7.50	10.00

Piezometers were installed in boreholes 1 and 3. These were read on completion of the site work, 1st March, and at two week intervals. The readings received to date are given on Table 5-2.

Table 5-2 Groundwater Monitoring

Hole No	Filter zone (mbgl)	Tip Depth (mBGL)	Readings			
			Date	Water depth (mBGL)	Piezometric Elevation * calculated	Comments
BH1(a)	24-26	26	01/03/2010	22.26	29.37	
			16/03/2010	22.31	29.32	
			30/03/2010	22.65	28.98	
			12/05/2010	23.02	28.61	
			03/06/2010	22.36	29.27	
			09/07/10	22.37	29.26	
BH1(b)	12-14	14	01/03/2010	DRY		
			16/03/2010	DRY		
			30/03/2010	DRY		
			12/05/2010	DRY		
			03/06/2010	DRY		
			09/07/10	DRY		
BH3(a)	18.3-20.3	20.3	01/03/2010	15.79	44.56	
			16/03/2010	15.56	44.79	
			30/03/2010	15.56	44.79	
			12/05/2010	15.85	44.50	
			03/06/2010	15.88	44.47	
			09/07/10	15.98	44.37	
BH3(b)	3.5-5.5	5.5	01/03/2010	3.67	56.68	
			16/03/2010	3.63	56.72	
			30/03/2010	3.51	56.84	
			12/05/2010	5.10	55.25	
			03/06/2010	5.04	55.31	
			09/07/10	4.07	56.28	

5.6 Hydrology

A waterfall was observed flowing down the cliff about 100m to the east of the Victoria Hotel. The historic maps show this stream to have been present in 1893 (see **Figure 5** for alignment). The walkover survey revealed that the stream was culverted across the access track to the Rocket House, after running between the Cliff Cote and Raven Hill properties. Adjacent owners report over-topping of the culvert in times of high flow. As this section of route is also shown on the early maps it is inferred that the stream route has changed little since 1893. Inspection of the coastal slope shows that the stream flows in a fairly narrow channel down the steeper parts of the slope but the water spreads out above the top of the rock cliffs. There is a large area of waterlogged ground populated by bullrushes and other water-loving vegetation. Due to the topography this area is predominantly to the east of the stream bed and below a steep clay slope. Photographs taken during the topographical survey show water flowing over the sea cliffs after prolonged rainfall.

The historic maps indicate the presence of springs and drains in the slopes to the north of the study area. There was a drain constructed along the north side of the railway, presumably to pick up surface flows. Standing water within gardens is noted and water is reported flowing along footpaths, particularly the footpath leading to Finisterre, the most north-easterly house in Robin Hood’s Bay.

5.7 Slope Stability

Monitoring of the inclinometers in boreholes 2 and 4 was undertaken at intervals from March 2010 with the base readings taken on 1st March. This was done by the GI contractor, Geotechnics. The readings at the end of March from the instrument in BH2 were noted by Geotechnics to be ‘slightly odd’, this was eventually attributed to likely deviation of the reading torpedo from the tracks due to pipe distortion between 26m and 29m bGL. Subsequent readings were terminated at 25m bgl. Following a site meeting with Mouchel readings to the full depth of the inclinometer were completed. It was noted that difficulty was experienced with lowering the torpedo past the depth where the original distortion was recorded. The latest set of readings, taken on 4th August, indicates 35mm movement down slope (towards the sea) at the location of BH2 (Rocket House).

There are no indications in the borehole why there would be any movement at this depth as no laminated clay or high ground water pressure was noted at this location. Further monitoring is recommended as discussed in Chapter 8.

No significant movement was recorded in BH4.

5.8 Man - Made Features

Stabilisation works immediately to the south of the study area are described in **Section 3.12**.

6 Ground Conditions and Material Properties

6.1 Introduction

The objective of this section is to provide an interpretation of the ground conditions for the scheme and to describe the various material properties, together with justification for the geotechnical design parameters adopted. This section discusses the results of laboratory tests together with the field-derived data and relevant published data to evaluate the behaviour of soils in relation to the proposed works.

Geotechnical parameters used for the design works have been derived from:

The results of geotechnical laboratory testing.

Atterberg Limit results and their published correlations of Plasticity Index and effective angle of shearing resistance (BS 8002).

SPT 'N' values and published correlations for undrained shear strength (c_u), Co-efficient of volume compressibility (m_v) and drained and undrained angle of shearing resistance (for non-cohesive soils)

Where no field or laboratory data is available geotechnical parameters are estimated from published reference data.

The materials encountered during the recent ground investigation suggest the presence of different material types. The results of in-situ tests and laboratory tests conducted on samples of the materials encountered together with suggested design parameters are all summarised in separate headings below.

6.2 Made Ground

There are thin layers of Made Ground recorded at the surface in BHs 1 and 2. In BH1 the upper 0.25m comprised tarmac on to gravelly sand (car park construction); no testing was carried out. The upper 1.1m of soil in BH2 was described as sandy gravel of brick, concrete, and sandstone with pockets of sandy clay underlain by thin layers of slightly sandy slightly gravelly clay and clayey sand.

Classification testing on a sample from BH2, at 0.3m depth, shows the clay to be of high plasticity (Liquid limit=55%, Plasticity index=31%) and high moisture content (30%). It is likely that the gravel has been placed on a soft clay surface to facilitate access as the upper surface of the underlying natural clay (1.2m) has similar characteristics (LL=60, PI=36 and mc=30).

6.3 Topsoil

Topsoil was not described in the exploratory holes; although boreholes 3 and 4 were both in grassland the upper surface was described as brown sandy gravelly clay (BH3) and brown slightly gravelly clayey sand (BH4). Both contained frequent rootlets.

6.4 Glacial Till

The Drift comprises predominantly soft to stiff sandy gravelly CLAY (glacial till) with varying proportions of sand and gravel and occasional layers of clayey sand and laminated clay in BH1.

The parameters discussed below are shown on **Figures 6-26**.

6.4.1 Sandy gravelly Clay

The clay encountered in all the boreholes is predominantly slightly sandy, or sandy, and slightly gravelly, or gravelly, and of low plasticity. Classification testing, comprising liquid and plastic limits (LL, PL), moisture content (mc) and grading was carried out on a large number of samples. The moisture content is in the range 11-23% for all the boreholes but the material within 7-8m of the surface generally has higher mc than the deeper material and that in BH1 appears to be slightly wetter than elsewhere (**Figure 6**). The moisture contents and Atterberg limit values for each BH are plotted as **Figures 7-10**. Almost all the clay in this category has Plasticity Index (PI) in the range 10-20% and PL typically 14-16%, **Figures 18-21** refer.

Samples from the window sample holes, located on the coastal slope, also exhibited high mc (17-38%) with mc generally greater than the PL indicating normally consolidated conditions. The material was classified as clay of low to intermediate plasticity with one sample, WS4 at 1.7m, being of high plasticity (LL=52, PI=24). The test results for the window sample holes are summarised as **Figures11, 16 and 22**.

The moisture content is greater than the PL for all samples in BH1 and BH4. By contrast the samples tested from BH2 generally have moisture contents below the PL indicating over consolidated conditions. This is reflected in the Liquidity Index (LI), a measure of the moisture content with respect to its plasticity characteristics. Where the mc=LL the LI is 1.0 and the strength very low; for mc=PL the LI is 0 and the soil is stiff. The LI is plotted as **Figures 12-16**.

Gradings were carried out on several samples from each borehole. The clay content varied from 6-25%, the silt 17-48%, sand 26-63% and gravel 2-46%. In all instances the silt content was greater than the clay content with the combined total being in the range 30-66%, typically 40-60%. One sample (BH1, 29.5m) consisted of clay and silt only with no coarser material present; the log describes this as having silty laminations.

Material described as clayey, very gravelly sand is present at 11-14m and 16.0-17.3m depth in BH1. Gradings show the clay content to be 6-10%, silt 17-21%, sand 33-41% and gravel 34-38%. It is likely that this layer commences at c.10m depth as the material present has a similar grading with slightly more gravel (46%) but less sand (27%).

The grading curves are given in the factual report.

Standard penetration test results show the upper 6m across the site to be soft and loose with N values in the range 2 to 6. The one exception being at 2m in BH3 (N=12). With depth the N values increase, see **Figure 17**, with all results below 10m exceeding 50 in all holes.

Figures 23 to 26 show the undrained shear strength calculated from the SPT results, measured by triaxial testing and calculated from liquidity index (CuLi). The plots of shear strength, measured and calculated, show that the material from BH1 and BH4 is softer than that in boreholes 2 and 3.

Assuming a plasticity index of 15% the N values in the upper 6m of the boreholes equate to an undrained shear strength of 11-33kPa (Factor f1=5.5 after Stroud). The material in BH3 at 2m is described as having sandy pockets; the N value indicates shear strength of 66kPa.

The triaxial tests give very variable results and are considered to be fairly unreliable due to the nature of the soil and the disturbance caused by driving the tubes. For the upper 5.5m the triaxial shear strength results are in the range 5-101kPa and between 7 and 9m 20-437kPa, for all holes. The results for BH4 are more consistent, in the range15-85kPa, to 9m depth. Some of the material collapsed on extrusion from the sample tubes and was too soft to test (BH1 at 1.2m; BH3 at 3m; BH4 at 11.5m).

The shear strength can be related to LI [(mc-PL)/PI], with values in excess of 0.4 indicating Cu<20kPa (very soft), and between 0.4 and 0.18 Cu 20-40kPa (soft), after Trenter (Earthworks, a guide). This relationship is intended for remoulded clays and should be used with caution for undisturbed soils. It should be noted that the plastic limit is difficult to measure accurately.

One consolidated undrained triaxial test was carried out (BH3 at 14.5m). This gave an effective cohesion (c') of 25kpa and angle of shear resistance (ϕ') of 26 degrees.

The material present in the window sample holes on the clay slope was predominantly sandy and gravelly with some cobbles evident; sand lenses were exposed in the unstable slope. The material was described as soft and very soft at the surface, becoming firmer with depth. Wood and organic pockets were present in WS1, WS2 and WS4. The classification test results (**Figures 11 and 22**) indicate that the clay is of low plasticity (LL=28-34, PI=14-18, mc=17-20) with some intermediate and high plasticity material (LL=36-52, PI=19-24, mc=24-38) also present. Moisture content is generally higher than that in the boreholes. The liquidity index (**Figure 16**) was determined for 7 samples, with 5 values indicating soft or very soft clay.

The values given below are moderately conservative 'worst case' derived parameters.

Table 6-1: Summary Geotechnical Parameters (Sandy gravelly Clay)

Parameter	Min	Max	Average	No. of Tests	Derived values
SPT (0-6m)	2	12	5	8	5
SPT (6-11m)	18	> 50	35	12	20
SPT (11m – base)	> 50	> 50	> 50	18	50+
Natural Moisture Content (%)	10	38	18	>100	18
Plastic Limit (%)	12	20	15	76	15
Liquid Limit (%)	23	38	30	76	30
Plasticity Index (%)	9	21	17	76	17
Liquidity Index (%)	1.25	-0.45	0.3	76	0.3
Bulk density (Mg/m^3)	2.0	2.35	2.16	18	2.16
Clay & silt	23	66		29	
Sand	26	63		29	
Gravel	31	46		29	
Clay	6	25		28	
Silt	17	48		28	
C_u (kPa) from QUT tests	5	437		18	
C_u (kPa) from SPT N values to 6m	11	66	25	8	0-6m 20
C_u (kPa) from SPT N values to 11m	99	>275	190	12	6-11m 60
C_u (kPa) from SPT N values below 11m	>275	>275	>275	18	11m-base 120
C_u (kPa) from LI	10	380	50	76	
$\Phi'_{p\ \&\ crit}$ (from I_P)	28	30	28	76	28°

6.4.2 *Laminated Clay*

In BH1 firm thinly laminated CLAY, with silt dusting on the laminae, was present immediately below the car park construction, and also at depth (17.3 to 21.8m and 25-26.6m) and immediately above the weathered mudstone. This is characterised by high moisture content and LL>50. The upper clay, in BH1, is classified as clay of high plasticity (LL=50-55, PI=27-30, mc=23-32). This layer is limited in depth and extends to 1.7m in BH1.

High plasticity cohesive material was intermixed with the track construction in BH2 as described in paragraph 6.2 (LL=55-60, PI=31-36, mc=30). Intermediate plasticity clay (LL=38-46, PI=20-25, mc=22-33) is also present within 2m of the surface in BHs 3 and 4 but is not described as laminated.

For the intermediate/high plasticity clay within 2m of the surface the moisture content is significantly higher than the PL and the liquidity index is in the range 0.2-0.6, typically 0.3.

The laminated clay at 17.3-21m depth, in BH1, is described as stiff and very stiff thinly laminated slightly sandy slightly gravelly CLAY and is classified as low plasticity and cannot be differentiated from the surrounding gravelly clay on the basis of LL and PL parameters; the liquidity index is 0.21 to 0.53.

Stiff to very stiff thinly laminated CLAY with lenses of silty sand, present at 24-26.6m in BH1, is classified as clay of intermediate plasticity, with the results from samples at 24m, 25m and 26m recording the following values: LL=37-45, PI=19-28 and mc=21-34. The sample at 25m has a mc of 34%, a plastic limit of 17% and a liquidity index of 0.61 suggesting that it is very soft.

The presence of laminated clay at depth in BHs 2 and 3 is suggested by classification test results. The samples at 30m and 31m depth, in BH2, are classed as being of intermediate plasticity with LL=41-42 and PI=24-25; both have a mc of 19%, just above the PL. One sample in BH3, at 18m depth, is also of higher plasticity than the surrounding clay but is not differentiated in the log (LL=45, PI=25, mc=19). Liquidity indices are in the range -0.04 to 0.08.

Shear strength was determined by triaxial testing on 3 samples, all at 1.2m depth; the sample from BH1 at 1.2m collapsed when extruded and was too soft to test. The results from the other boreholes were 65, 25 and 36kPa. SPTs were not taken in the laminated clay at shallow depth. All values in the deep laminated clay exceed 50 blows/300mm.

The plots of shear strength, from triaxial tests and calculated from the Liquidity Index, **Figures 23-26**, suggests that both the shallow and deep laminated clay in BH1 is a material with a shear strength below 40kPa. Lower strength material is (Cu=60-75kPa) also identified at 30m and 31m, in BH2, just above rock head; this is not identified as laminated clay but is classified as clay of intermediate plasticity and is distinct from the overlying sandy gravelly clay.

The values given below are moderately conservative ‘worst case’ derived parameters.

Table 6-2: Summary Geotechnical Parameters (Laminated Clay)

Parameter	Min	Max	Average	No. of Tests	Derived values
Natural Moisture Content (%)	19	34	25	14	28
Plastic Limit (%)	17	28	21	14	22
Liquid Limit (%)	38	60	46	14	46
Plasticity Index (%) to 2m	20	36	25	9	28
Plasticity Index (%) deep	24	28	25	5	25
Liquidity Index (%)	0.75	-0.17	0.2	14	0.25
Bulk density (Mg/m^3)	2.0	2.11	2.06	3	2.06
C_u (kPa) from QUT tests to 2m	25	65	35	3	
C_u (kPa) from SPT N values				0	0-2m 25
C_u (kPa) from Liquidity Index to 2m	10	75	35	9	deep 30
C_u (kPa) from Li Index (deep)	20	130	50	5	
$\Phi'_{p\ \&\ crit}$ (from I_P) to 2m	23	28	25	5	23°
$\Phi'_{p\ \&\ crit}$ (from I_P)	25	27	26	5	25°

6.5 Rock

The site is underlain by siltstone with mudstone and occasional thin limestone bands also present. The rock was cored using rotary drilling techniques in boreholes 1, 2 and 4 to produce cores 92mm in diameter. Rock was encountered at a depth of 31-31.5m in boreholes 1 and 2, at 19.8m in BH3 and at 11.7m in BH4.

6.5.1 Highly weathered rock (all boreholes)

Although penetration into the rock, by boring techniques, was limited to between 0.48 and 1m the upper surface of the rock was noted to be highly weathered. This was described as very stiff gravelly clay in BH1 and as mudstone recovered as gravelly clay in boreholes 2 and 3; in BH4 the upper surface of the rock was described as siltstone, recovered as sandy angular gravel. The undisturbed sample at 11.5m in BH4 was described as too soft to test being a clay matrix with siltstone fragments. A pocket penetrometer gave a reading of 0.

Classification tests indicate a moisture content of 13-20%, LL27-41, PL 14-19 and PI 13-23, **Figures 7-10 and 18-21** refer. The liquidity index, **Figures 12-15**, is in the range -0.22 to 0.38 with the soft material (LI 0.38) being in BH3; water under pressure was encountered at rock head (20m bgl) in BH3.

6.5.2 Staithes Sandstone

In borehole 4 rock head was encountered at a much shallower depth than in boreholes 1, 2 and 3. Siltstone, recovered as sandy angular gravel was met at 11.70mbgl (62.37mOD) and proved to 12.18m in the borehole before commencement of coring. The cored siltstone was described as very weak to weak, becoming extremely weak to weak from 15.8m depth. Below 25.50m the rock became medium strong to completion at 40.50mbgl. Total core recovery (TCR %) values are in the range 80-98% to 16m depth and > 98% to the base of the hole. These are higher than in boreholes 1 and 2. In general the upper 6m of the core (12-18m depth) is more fractured than the deeper rock with solid core recovery (SCR) in the range 2-70% and rock quality designation (RQD) in the range 0-22%. Variation in total core recovery, solid core recovery (SCR) and rock quality designation (RQD) can be seen in **Figure 29**.

Unconfined compressive tests were carried out on core samples (siltstone) from BH4 at four depths between 20m and 30m. The results indicate moisture content of 4.8-5.7%, dry density 2.35-2.40 Mg/m3 and UCS 10.4-22.7 MPa, typically 10.4-12.6 MPa. Point load tests on 11 further samples of siltstone rock gave mc in the range 4-8.6%, typically 4-6.2%, and Is50 values of 0.08-1.732 MN/m2 (typically >0.5 MN/m2) measured in the axial plane.

It is possible that the lower part of BH4 is within the underlying Redcar Mudstone as there is a gradation between the strata of the two formations.

6.5.3 Redcar Mudstone

In borehole 1 the upper surface of the rock, from 31.10mbgl (20.53mOD) to 33mbgl is described as very stiff to hard Clay. Extremely weak to weak siltstone was present from 33m to 35.35mbgl becoming very weak to weak with depth. Beneath this siltstone, at 47.40m (4.23mOD) a thin layer of medium strong dark grey limestone was present underlain by medium strong, occasionally weak, mudstone. The core was completed at a depth of 50.50mbgl (1.13mOD). In BH1 total core recovery (%) was 43% at 31-32.50mbgl increasing to 87-100% below 34.0mbgl. The SCR also increased with depth, being in the range 0-23% to 35.5m then gradually increasing to 60-80%. RQD was below 10% to 37m depth and in the range 27-50% for the remainder of the core. Variations in total core recovery, solid core recovery and rock quality designation are shown in **Figure 27**.

In borehole 2 very stiff grey gravelly clay (weathered mudstone) was present from 31.5mbgl (23.52mOD) and proved to 32.42m by boring. The siltstone was cored from 32.50 to 50.50mbgl (4.52mOD). From 32.50 to 37mbgl this material is described as extremely weak; becoming very weak to weak to 39.22m. Below this depth the siltstone is described as weak to medium strong to the base of the hole. Total core recovery (TCR %) generally increases with depth ranging from 27-67 % between 32.5 and 37m and 76 to 100% to completion. SCR was also low (0-32%) to 37m, increasing to 46-88% with depth. These results are reflected in the RQD vales of 0-29% to 41.5m depth and 58-68% to the base of the hole. Variation in total core recovery, solid core recovery and rock quality designation are shown in **Figure 28**.

Unconfined compressive tests were carried out on core samples (siltstone) from boreholes 1 (5 No.) and 2 (6 No.) at depths between 39m and 50m. The results indicate moisture content of 2.9 to 6.5%, dry density 2.34-2.44 Mg/m3 and UCS 7.0-9.3 MPa, average 8.3 MPa. Point load tests on 15 further samples of rock from each hole gave mc in the range 1.7-5.7%, typically 4-5%, and Is50 values of 0.105-4.42 mN/m2 (typically 0.4-0.8 mN/m2) measured in the axial plane. The test results are detailed in the factual report.

The parameters given above (RQD and UCS) together with information on groundwater and fracture spacing/condition from the core logs have been used to determine the rock classification (after Bieniawski) as discussed by Farmer. The rock is generally rated as Class V 'very poor' with the rock below 41m depth in BH2 being of slightly better quality (Class IV, poor). The parameters suggested for design of slopes are cohesion <100kN/m2 and friction angle <30 degrees.

6.6 Groundwater

Groundwater was met in all the boreholes as detailed on Table 5-1 in section 5.5. Slow inflows were noted in all the boreholes at depths between 4m and 24m. Water under significant pressure was recorded in BH1 at 25.5m depth in a layer of laminated clay, rising to 16.2 mbgl in 20 minutes; in BH3 water was met at the top of the mudstone, 20m depth, and rose to 15 mbgl in 20 minutes.

Groundwater levels monitored in the piezometers in boreholes 1 and 3 are given as Table 5-2. Two piezometers were installed in each of the holes to monitor water strikes recorded in the boreholes at different levels. The high water pressure recorded in BH1 at 25.5m, during boring, is no longer present with the maximum water level monitored at 22.6m bgl. In May this water level dropped slightly but rose again by early June. The piezometer in the clayey gravelly sand in BH1 has remained dry. In BH3 the piezometer installed at rock head has recorded a maximum water level 4.74m above the tip with little variation in the level between March and June; the shallow piezometer showed a significant fall in water level between the end of March and mid May.

Water was not encountered in the window sample holes but the ground in the vicinity of WS1, 2 and 3 was waterlogged.

6.7 Soil Chemistry

Chemical testing to determine the pH and water soluble sulphate content was carried out on a number of samples from BHs 1, 2 and 3. Seven samples (4 of water and 3 of soil) were sent for chemical analysis. The corresponding pH values are in the range 6.4 – 8.4. Water soluble sulphate concentrations are low: 0.07-0.27g/l of SO_4 in soil and 0.05-0.12g/l in water. All are ACEC Class DS-1 from Table 2 in BRE Special Digest 1 (2001).

6.8 Ground Contamination

Three samples (BH1 at 2-2.5m, BH2 at 0.25m and BH3 at 8-8.5m) were sent for specialist chemical testing to determine their compliance with the Environment Agency Waste Acceptance requirements for disposal in landfills. These are classed as inert for disposal purposes.

7 Geotechnical Risk Register

7.1 Risk Register

In accordance with the guidance given in HD22/02 the geotechnical risks identified have been assessed following the findings of the ground investigation and the risk register is attached. Risk control measures will be considered during assessment of options for stabilisation.

KEY TO GEOTECHNICAL RISK REGISTER

RISK = LIKELIHOOD X CONSEQUENCE

LIKELIHOOD

Factor	Likelihood	Chance
5	Almost Certain	>70%
4	Probable	50-70%
3	Likely	30-50%
2	Unlikely	10-30%
1	Negligible	<10%

CONSEQUENCE

Factor	Effect	Impact			
		Cost	Activity Duration	Contract Duration	Safety
5	Very High	>20%		>10 weeks delay	Loss of life
4	High	10-20%		>1 week delay	Severe Permanent Disability
3	Medium	2-10%	>4 weeks delay	<1 week delay	Minor Permanent Disability
2	Low	0.5-2%	1-4 weeks delay	None	Temporary Disability
1	Very Low	<0.5%	<1 week delay	None	< 3 Days off Work

RISK LEVEL

Risk Score < 8…………………………………….....LOW RISK

8 < Risk Score < 15…………………………..MODERATE RISK

Risk Score > 15………………………..…………..HIGH RISK

Project:	**Robin Hood's Bay Strategy Study**	Assessor:	L Frances
Project Status	**Ground Investigation Report**		
Date Assessed:	15.07.2010	Revision	A (1st issue, Ground Investigation Report)

GEOTECHNICAL RISK REGISTER – Robin Hood's Bay: Mount Pleasant area of upper town

Risk Description		Date Identified	Effect (PCESQ)	Risk Prior to RCM							Consequence to Scheme	Risk Control Measure (RCM)	Residual Risk							Owner
					Severity			Risk						Severity			Risk			
				Probability	Cost	Program	Safety	Cost	Program	Safety			Probability	Cost	Program	Safety	Cost	Program	Safety	
1	Variable Geotechnical ground conditions																			
1.1	Variable ground conditions across the site	15/07/10	C,P, S,E	3	3	3	2	9	9	6	Need to identify higher risk areas and propose different options for stabilisation	Further GI may be required prior to detailed design of remedial measures	3	2	2	1	6	6	3	Designer
1.2	Soft glacial till (gravelly clay and laminated clay) within upper 6m across site	15/07/10	C,P, E,Q	4	3	3	1	12	12	4	Potential for shallow slips within upper 6m of coastal clay slope	Vigilance on site to establish any variations in ground conditions from the G.I. when implementing remedial measures	4	2	2	1	8	8	4	Designer
1.3	Presence of layers and lenses of clayey and/or gravelly sand (BH1)	15/07/10	C,P, E, Q, S	3	3	3	1	9	9	3	Potential for ingress of water from upland areas to the west of the village which will increase pore pressure; also increases risk of surface spalling within coastal slope	Further GI may be required prior to detailed design of remedial measures	3	2	2	1	6	6	3	Designer
1.4	Presence of laminated clay at depth	15/07/10	C,P, S	3	4	3	1	12	9	3	Potential for deep slip planes and hence need to consider cost of remedial options with respect to viability of residential properties close to existing cliff slope	Further GI may be required prior to detailed design of remedial measures. Ensure that remedial measures mitigate against deep failure	3	3	2	1	9	6	3	Designer

GEOTECHNICAL RISK REGISTER – Robin Hood's Bay: Mount Pleasant area of upper town																				
Risk Description		Date Identified	Effect (PCESQ)	Risk Prior to RCM							Consequence to Scheme	Risk Control Measure (RCM)	Residual Risk							Owner
				Probability	Severity			Risk					Probability	Severity			Risk			
					Cost	Program	Safety	Cost	Program	Safety				Cost	Program	Safety	Cost	Program	Safety	
1.5	Variation in thickness of clay overburden/depth to rock head	15/07/10	C, P, E, S	3	4	3	1	12	9	3	Will affect feasibility of options (cost and effect on stability)	Further GI may be required prior to detailed design of remedial measures	2	4	2	1	8	4	2	Designer
1.6	Instability due to high water pressure and/or highly fractured material at rock head	15/07/10	C, P, S	2	4	4	1	8	8	2	Considerable increase in cost to stabilise deep seated movement	Further GI may be required prior to detailed design of remedial measures. Ensure that remedial measures mitigate against deep failure	2	3	3	1	6	6	2	Designer
1.7	Stability of existing slopes	15/07/10	P,C, E, S	4	4	3	2	16	12	8	Increase in instability may accelerate with changes in climate (extreme conditions)	Design to parameters interpreted from GI. Vigilance required on site for variation to existing conditions from the GI	3	3	3	2	9	9	6	Designer
1.8	Sulphate bearing soils (sulphate attack on buried structures).	15/07/10	Q	2	2	1	1	4	2	2	Attack on buried concrete or steel work	GI conservatively indicates Class DS-1	1	1	1	1	1	1	1	Contractor
2	Variable groundwater conditions & drainage																			
2.1	Effect of high groundwater levels	15/07/10	C,P, S,Q	3	4	4	4	12	12	12	Increased instability	Design to high water level. Vigilance for change in ground water levels required on site.	2	3	3	2	6	6	4	Designer
2.2	Stream outfalling down slope	15/07/10	C,P, Q	3	3	3	2	9	9	6	Softening of bench at base of coastal slope	Divert if possible	2	2	2	1	4	4	2	Designer

mouchel

GEOTECHNICAL RISK REGISTER – Robin Hood's Bay: Mount Pleasant area of upper town																				
Risk Description		Date Identified	Effect (PCESQ)	Risk Prior to RCM							Consequence to Scheme	Risk Control Measure (RCM)	Residual Risk							Owner
					Severity			Risk						Severity			Risk			
				Probability	Cost	Program	Safety	Cost	Program	Safety			Probability	Cost	Program	Safety	Cost	Program	Safety	
2.3	High pore water pressure within laminated clay, granular layers, or at rock head	15/07/10	C,P, E,Q	3	4	4	4	12	12	12	Will lead to decrease in stability of slope and possibly result in deep seated movement	Indicated by GI, in BH1 and BH3. Remedial works to relieve high water pressures.	3	3	3	1	9	9	3	
2.4	Possible redundant storm outfalls and ditches	15/07/10	P, C, E	3	3	2	1	9	6	3	May lead water towards coastal slope	Trace with help of Yorkshire Water, SBC, landowners. Divert water away from slope.	2	2	2	1	4	4	2	
3	General Risk Items																			
3.1	Major landslip while Options are being scoped	15/07/10	C,P, E, S	2	4	4	2	8	8	4	Change to timescales	Continue monitoring of existing instrumentation at regular intervals. Install survey points along affected coast to facilitate monitoring of slope stability	1	4	4	2	4	4	2	
3.2	Restriction or freeze on Government spend	15/07/10	C,P, S	3		5			15		Need to quantify cost and benefit of lower cost Options	Make a strong case for stabilisation measures based on findings of GI.	3		5			15		

GEOTECHNICAL RISK REGISTER – Robin Hood's Bay: Mount Pleasant area of upper town																				
Risk Description		Date Identified	Effect (PCESQ)	Risk Prior to RCM							Consequence to Scheme	Risk Control Measure (RCM)	Residual Risk							Owner
					Severity			Risk						Severity			Risk			
				Probability	Cost	Program	Safety	Cost	Program	Safety			Probability	Cost	Program	Safety	Cost	Program	Safety	
4.	Land/Environmental Issues																			
4.1	Lack of cooperation from owners of land required to construct retaining walls or re-grade slope	15/07/10	C, P	3	4	5	2	12	15	6	Significant cost/programme implication if required	Early consultation with affected landowners	2	4	4	2	8	8	4	Employer
4.2	Resistance to granting wayleaves needed for installation of long soil nails to stabilise slope beneath existing proerties	15/07/10	P	3	1	4	1	3	12	3	Residents unlikely to object as proposals will safeguard property	Early consultation with affected landowners	2	1	3	1	2	6	2	Employer
4.3	Proposed works impact on SSSI status of coastal slope	15/07/10	P, C, E	4	4	4	1	16	16	4	Major restrictions may be applied to work on the slope eg. re-grading or soil nailing and installation of drains; also to protection of sea cliffs	Early discussions with Natural England and other statutory bodies prior to development of remedial works design	3	4	4	1	12	12	3	Employer

8 Preliminary Assessment of Options

8.1 Introduction

This section of the report discusses the possible options necessary to minimise the effects of the instability currently affecting the coastal slope, upper slope, surrounding the Mount Pleasant area of the upper town of Robin Hood's Bay. The potential for both deep seated and shallow failures within this clay slope are indicated by the findings of the ground investigation. In winter 2010 the slope below Victoria Terrace and the Rocket House were noted to be unstable with surface degradation on-going.

A small number of residential properties are now within 12-20m of the top of the coastal slope with the edge of this clay slope subject to localised and irregular landslip activity. The slope is 30m high from the Victoria Hotel east to the Rocket House, reducing in height to 20m behind Mount Pleasant East and to 12m at the north east edge of the houses. At this location the end house is only 5m from the edge of the slope.

It is impossible to determine the future rate of regression of the cliff top accurately as this is dependent on weather events. However study of aerial photographs and historic maps suggests 0.1-0.7m/year from 1940 to 1962 and 0.1-0.3m/year from 1962 to 2008. Photographs taken from the beach indicate that the slopes east of Prospect Field, The Close and Mount Pleasant South have also suffered recent instability; the cliff path has been realigned inland since 1995. This section of the slope is devoid of shrubs suggesting continuing instability. Further along the coast, towards the north eastern outskirts of the town, the slope is covered in dense vegetation (shrubs).

Previous loss of property in the lower town and realignment of the road have been discussed earlier in this report.

Erosion of the rock cliffs below the coastal slope has been estimated from previously issued data and the study of aerial photographs and is discussed in this report with an average annual rate of 0.11-0.21m/year for the base of the cliffs and 0.1-0.3 m/year for the top (including the upper slope). The cliff below the waterfall has the highest rate of erosion. Gradual regression of the rock cliffs will impact on the overall stability by removing support at the toe of the clay slope.

The ground investigation has identified the presence of several factors that will impact on stability:

- Soft cohesive soils to a depth of 5-6m across the site
- Highly plastic clay at the surface in boreholes 1 and 2

- Laminated clay of intermediate plasticity at depth in BH1 and also possibly in BHs 2 and 3
- Layers and lenses of clayey, gravelly sand
- Significant quantities of soft and very soft clay as identified by the classification tests (MC>>PL and LI>0.18)
- Upper surface of the rock is highly fractured
- Water seepage in all boreholes
- Water present under pressure in BH 1 (25.5m bgl) and BH 3 (20m bgl)
- No significant fall in standing water levels, in the piezometers, through April, May and June 2010 despite prolonged dry weather

8.2 Stabilisation Options

The various options are discussed below and summarised in Table 8-1.

8.2.1 Diversion of Surface water

The stream that flows from the north side of the town, which is partly in culvert, outfalls over the cliff to the west of the Rocket House. The stream flows down the coastal slope and over the cliff and is marked as a waterfall on the map. Accelerated erosion of the cliff is noted at this locality. The toe of the clay slope, east of the stream, has also degraded due to water spreading out from the stream channel. At the top of the slope this stream has caused flooding in adjacent gardens during periods of prolonged rainfall.

A plan from Yorkshire Water shows an underground overflow crossing land to the east of The Close; this outfalls on to the coastal slope behind No. 3 The Close. This has not been observed and it is not known whether it is still in use; however it is possible that water can still follow this channel onto the slope.

The Yorkshire Water plan also shows a drain flowing from the disused railway, towards the coastal slope, at the north east edge of the town. This area was inspected but there was no evidence of an open ditch. It is possible that the drain has been piped.

Additionally it would appear that there is no mains sewerage serving the properties beyond the eastern end of Mount Pleasant North (Kenmore to Class-Tae). It is possible that seepage from septic tanks could be contributing to the instability.

Removal and collection of surface water from all the above sources will have an impact on future coastal stability by reducing the amount of water flowing onto the coastal slope; is a relatively low cost option. It will not solve the stability issues but would slow down localised erosion/instability in the affected areas. It will also prevent flooding of the gardens. Diversion in to the road drainage is suggested, subject to sufficient capacity. There would be minimal impact on the SSSI but this option would require co-operation from Yorkshire Water and the affected landowners.

The boreholes encountered water at depths greater than 4m and it is not therefore considered appropriate to construct a deep drain to intercept groundwater to the rear of the town.

8.2.2 *Soil nailing*

Installation of a grid of soil nails on the coastal slope would increase the stability of the slope. Given the potential for deep seated failure it is anticipated that the nails would need to be long (in excess of 20m) and spaced typically at 2m horizontal spacing and 1m vertically, giving a minimum of 1500 nails/100m length of slope treated. The nails would need to be galvanised to resist the marine environment. This option will necessitate the use of A-frame rigs and roped access so there are health and safety implications. It is likely that significant vegetation clearance and some reprofiling will be required to facilitate access to the slope for this process. The nails are anchored at the surface by a pattress plate and the entire surface would be meshed/netted. This would have a major impact on the SSSI. The use of long nails, possibly extending beneath the houses, will require way-leaves to be signed by the landowners.

This solution can be provided on a Design and Build basis or through a traditional contract. A very approximate cost, for treating a 100m unit length of the coastal slope, is estimated to be of the order of £1-1.5million inclusive of design and drainage. This is based on a grid of galvanised nails on the coastal slope at 2m horizontal spacing, 1m vertical spacing and 12m in length.

8.2.3 *Installation of horizontal drainage wells*

The ground investigation has shown that high groundwater pressures exist in the vicinity of boreholes 1 and 3. This will have a major effect on stability. In BH1 water was met at 25.5m bgl, within a layer of laminated clay, and rose to 16.2m bgl in 20 minutes. Piezometers were installed in the boreholes during the ground investigation and have been monitored at interval between March and June 2010. Subsequent monitoring of the piezometer (tip depth 26m) has recorded a water level of 22.6-23.02m bgl.

In BH3 water was met at 20m bgl, at the upper surface of the weathered mudstone, and rose to 15m bgl in 20 minutes. A piezometer installed in BH3 (tip depth) has recorded a water level of 15.56-15.88m bgl.

The water pressures will impact on the stability of the clay slope; installation of horizontal drainage wells to relieve the water pressure within the laminated clay and at rock head would slow down the rate of regression and reduce the potential for large scale instability of the clay mass, but not eliminate the risk entirely. This would require specialist roped access. The water from the wells would need to be collected. Surface water drainage is present in the remediated slope south and west of BH1 but there is no existing drainage on the slope below BH3. Collector drains can be incorporated on the slope. This solution would affect the SSSI as the drains would be drilled in to the coastal slope.

It is unlikely that this would be a feasible stand-alone option but would increase the stability of a soil nailed solution and would be relatively cheap to instigate in conjunction with soil nailing.

8.2.4 Re-grading Coastal Slope

The existing coastal slope in the glacial deposits is up to 30m high and at an angle of 30-40 degrees to the horizontal. The slopes are generally unstable with on-going shallow landslips exacerbated by water seepage. Reducing the slope angle would increase stability but this would require significant land take and incur high disposal costs. A preliminary assessment, using the Slide analysis, indicates that re-grading of the top 10-12m of the slope, to 27 degrees, would not increase the stability of the slope to an acceptable level, with the Factor of Safety still below 1.3.

The psychological impact on the local residents would be difficult to overcome. In addition there would be significant damage to the SSSI. Due to the proximity of the houses and the difficult access this option is not recommended.

8.2.5 Contiguous bored pile wall

This option would prevent further recession of the upper slope on the landward side of the wall. The wall would be constructed on top of the slope and hence minimise impact on the SSSI. The land on the seaward side of the wall would continue to degrade and there would be a reduction in lateral support in the long term. It would therefore be necessary to drill the piles in to the rock and install anchors through the capping beam. A preliminary calculation, using Reward, indicates an embedment length of 44m for the piles where the clay slope is 31m high (depth to bedrock 31m) and 22m where the clay slope is 12m high (depth to bedrock 12m).

Indicative costs suggest that a 100m long unit length of wall would cost ~ £1m (based on industry enquiries). However due to the depth of piles needed (approximately 44m) and the requirement for embedment in to the rock it is likely that the number of companies able to undertake such work would be limited.

A long construction period is anticipated. Vibration and loading during the works may trigger further movement of the slope. Restricted access to the coastal slope, for the large plant needed to construct the wall, could be problematic. At the north east end of the village the area between the house and the top of the slope is only 4-5m wide which would prove difficult for the construction of a wall.

Eventually the soil in front of the wall may fail and expose the piles, thus the long term visual impact would need to be addressed.

8.2.6 Ground Improvement: lime piles

The upper 6m of the ground was found to be soft throughout. Ground improvement using lime mixing would improve shallow stability but not impact on potential deep seated failure. There are uncertainties in design. This is a relatively cheap solution, requiring smaller plant than a bored pile wall and with a shorter construction period. The visual impact and effect on the SSSI will be minimal as the piles would be constructed on top of the slope. However the use of lime in a residential area needs careful consideration for health and safety reasons.

8.2.7 Vegetation

Planting of vegetation on slopes has been widely utilised to stabilise shallow slips on railway and highway earthworks. There are no known case studies covering the use of vegetation alone to stabilise coastal slopes; the exposed conditions (wind and salt) are likely to impede growth. Planting on the unstable slope would require the use of specialist roped access and in the case of Robin Hood's Bay the movement is considered to be too deep for vegetation to be effective. As movement is on-going it is unlikely that the roots would establish. Although the surface at the top of the slope was noted to be waterlogged in places the shallowest ingress of water reported in the boreholes was at a depth of 4m bGL (boreholes 2 and 3). Planting at the top of the slope is therefore considered unlikely to contribute significantly to stabilisation of the slope.

8.2.8 Monitoring

The provision of survey stations at regular intervals along the affected length of coast would enable the rate of erosion to be measured accurately. This is not a solution but would be of use for long term planning and focussing available resources in those areas most affected. Consideration should also be given to the installation of additional inclinometers to supplement those installed during the ground investigation and currently being monitored.

8.2.9 Rock Armour at base of sea cliffs

This would slow the rate of erosion at the base of the cliff but not impact on the stability of the upper coastal slope. There is likely to be opposition to this proposal as it has a severe impact on the SSSI which is of geological importance. During the previous stabilisation, 2000/2001, the lateral extent of the rock armour was limited. Preliminary enquiries indicate a figure of £1-1.5m for a km of treatment.

Ideally rock armour would be used in conjunction with one of the options above. This approach would protect the rock cliffs from regression and hence contribute to overall stability of the coastal slope.

8.3 Future Works

It is advised that monitoring of the instruments, installed during the ground investigation (February 2010), is continued as part of the Scarborough Coastal Monitoring project currently being undertaken by Mouchel on behalf of Scarborough Borough Council. This is particularly the case with respect to the inclinometer in BH2 which currently indicates 35mm movement at a depth of between 26 and 29m bGL; this has occurred during the driest part of the year, between March and August.

Although in itself this movement is not considered to be "catastrophic" continued monitoring on a monthly basis, and after prolonged rainfall is strongly recommended to determine whether the movement is accelerating or reaching a critical point.

Table 8-1 Summary of Proposed Remedial Design Options 'from a Geotechnical Perspective'

Proposed Remedial Design Option	Anticipated Advantages	Anticipated Disadvantages	Geotechnical Recommendation	Approximate Cost
Option 1 – Diversion of surface water	• Fairly cheap solution • Minimal effect on SSSI • Land take from third parties is unlikely to be required • Does not solve deep stability issues but will slow down localised shallow slippages associated with water flow and seepage • Fairly minor works therefore minimal construction materials to be imported to or exported from site	• Not a complete solution • Needs buy-in from Yorkshire Water and affected landowners • Apparatus in ownership of Yorkshire Water	Needs further study and liaison with SBC and Yorkshire Water	Potentially funded by Yorkshire Water
Option 2 – Soil nailing	• Long-term solution, increases stability of clay slope particularly when combined with drainage	• Increasing cost, nails will need to be long to counteract the potential for deep slip planes • Health and safety issues as working on unstable slope • Will need roped access, specialist contractors • Way-leaves where nails extend below properties • Visual impact on SSSI as surface will be meshed	Likely to be Design and Build by specialist contractor	£1-1.5 million inclusive of design for a 100m unit length of slope

Proposed Remedial Design Option	Anticipated Advantages	Anticipated Disadvantages	Geotechnical Recommendation	Approximate Cost
		• Supplementary GI may be needed prior to detailed design		
Option 3 – Horizontal Drainage	• Will increase stability of clay slopes • Relatively cheap as an add-on to soil nailing	• Not a complete solution on its own, will slow down rate of slippage • Need to provide outfall for drainage • Health and safety issues: roped access needed, specialist contractors • Visual impact on SSSI as works are on coastal slope	Likely only to be used in conjunction with soil nailing as uses same plant and equipment	Approximately £100 per drain in addition to cost of soil nailing, £10,000/100m unit stretch of slope.
Options 4 – Re-grading coastal slope	• Increase in stability by reducing angle of clay slope	• Land take • To increase stability to a Factor of Safety above 1.3 it would be necessary to demolish properties closest to slope • Significant amount of equipment and plant • Will need to work from top of slope • Health and safety issues associated with working on, or close to, slope • Major psychological impact on residents if land in front of houses is removed • Visual impact on SSSI as surface of clay slope will be subject to massive disturbance • Large quantities of spoil to be disposed of (landfill tax and transport)	Not Recommended	

Proposed Remedial Design Option	Anticipated Advantages	Anticipated Disadvantages	Geotechnical Recommendation	Approximate Cost
Option 5 – Contiguous bored piled wall	• Long term solution • Minimal land take • Little short term impact on SSSI	• Access difficulties for large plant needed to form piles • Vibration may cause instability in the short term • High imposed loads due to plant used to form piles • Contractor capability for deep piles into rock could be limited • Very high cost and technical difficulties as piles need long embedment in to rock • Visual impact on SSSI in long term as clay will eventually fail and expose piles • Way-leave issues if piles are anchored • Supplementary GI needed prior to detailed design • Restricted access at north east end of village	Long term solution but cost likely to be high; access for large plant could be limited	Approximately £1 million for a 100m unit length of wall inclusive of the cost of spoil removal.
Option 6 – Ground Improvement: lime piles	• Improves stability of soft clay, to 6m depth • Fairly cheap • Minimal visual impact on SSSI • Small plant and equipment better suited to restricted access	• Not a long term solution, only treats soft clay within 6m of surface • Restricted access at north east end of village • Use of lime close to residential properties • Uncertainties in design	Not a tried and tested method	Unknown at this stage but likely to be significantly cheaper than a pile wall.

Proposed Remedial Design Option	Anticipated Advantages	Anticipated Disadvantages	Geotechnical Recommendation	Approximate Cost
Option 7 – Vegetation	• Low cost	• Unlikely to significantly reduce rate of erosion • Planting at top of slope would severely compromise residents' sea view	Not recommended	
Option 8 – Monitoring	• Gives a rate of erosion for the upper slope for use in long term planning • May provide an early warning of accelerated movement	• Not a solution	Installation of survey points and instrumentation is a fairly cheap option if funding is not forthcoming for an engineering solution	Installation of survey points at 25 locations~ £5,000 To be monitored as part of SBC coastal monitoring programme
Option 9 – Rock Armour to base of sea cliffs	• Slows erosion of rock cliffs and thus minimises undermining of toe of coastal slope	• Does not contribute greatly to stability of clay slope • Visual impact on SSSI • Placement restricted to work between tides • Likely to require import of large quantity of sound, high quality, igneous rock (Scotland or Norway)	Does not slow down instability of coastal (clay) slope	£1-1.5m/km length of cliff

9 References

BS 5930: 1999 Code of Practice for Site Investigations. British Standard Institution

BS 1377: 1990 Soils for Civil Engineering Purposes. British Standard Institution

BS 6031: 1981 Code of Practice for Earthworks. British Standard Institution

BS 8002: (1994) Code of Practice for Earth Retaining Structures, British Standard Institution

BS8004 (1986) Code of Practice for Foundations, British Standard Institution

DESIGN MANUAL FOR ROADS AND BRIDGES – Volume 4, Section 1, Part 2 HD 22/08: Managing Geotechnical Risk.

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

Farmer, I., Engineering Behaviour of Rocks, 2nd edition

E. M. Lee, Landslide Risk Assessment: QJ of Engineering Geology and Hyrdogeology, Vol 42, Part 4, Nov 2009

Strategic Coastal Monitoring: Staithes to Scarborough, Cliff Condition Survey, High Point Rendel 2002

Tomlinson, M. J., Foundation Design and Construction, 7th edition

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

Whitlow, R., Basic Soil Mechanics, 2nd edition.

Rayner and Hemingway, The Geology and Mineral Resources of Yorkshire

Envirocheck report from Landmark

1:50,000 British Geological Survey Sheet 35/44

MAGIC website

Shoreline Management Plan 2, Report ref: 9P0184/R/nl/PBor, February 2007, Haskoning UK Ltd.

Draft SMP2 Appropriate Assessment Report, Report Ref, December 2007, Haskoning UK Ltd.

Condition Analysis of Coastal Protection Assets: Cliffs and Beaches Staithes to Speeton, Halcrow Group Ltd Nov. 2006

Robin Hood's Bay Coast Protection and Cliff Stabilisation Scheme, Report Ref 000646/C/1, March 2000, High Point Rendel.

Robin Hood's Bay – The Quarterdeck Coast Protection and Cliff Stabilisation, Report Ref NR/DP/F107780, August 1997, High Point Rendel.

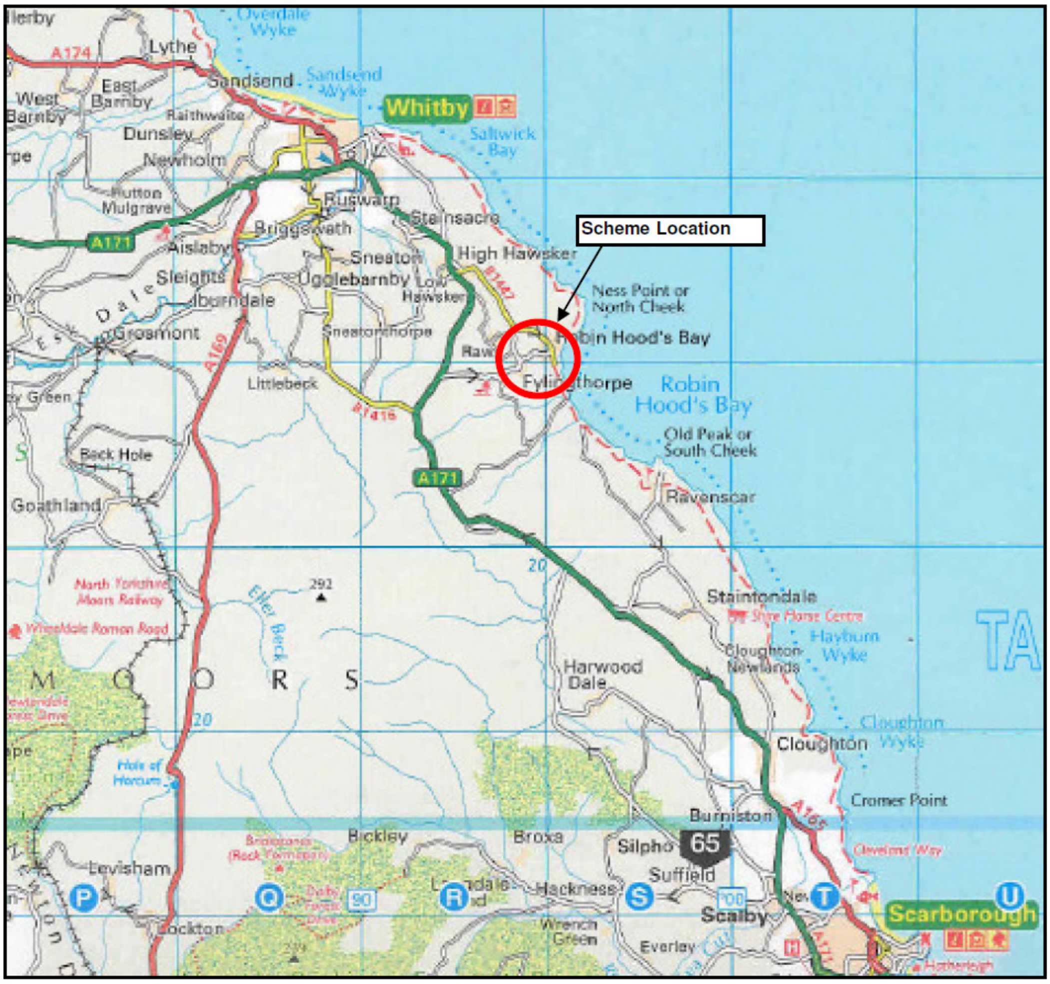
Robin Hood's Bay Coast Protection and Cliff Stabilisation: Environmental Statement, Report Ref R/H443/1, July 1999, High Point Rendel.

Ground Investigation Report, Report Ref 3443N, December 1995, Geotechnical Engineering Ltd.

Report on Inspection of Sea Wall, Report Ref, December 1993, High Peak Access Services.

Robin Hood's Bay Coast protection and Slope Stabilisation Emergency Works: Health and Safety Report, Volume 2 As Built Drawings

FIGURES



A great place to live, work & play

Original scale: 1:190,000

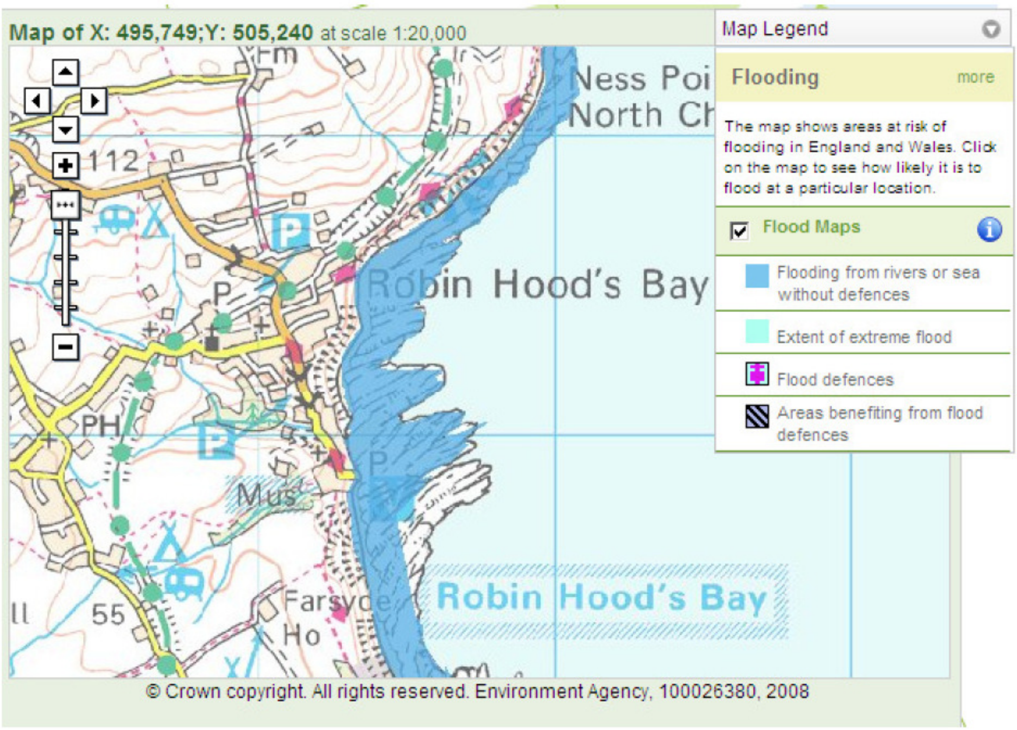
Location of Scheme	mouchel
Scarborough Borough Council **Robin Hood's Bay Strategy Study**	**Reference: 1022894/GEO/R/01/01** **Date: Jun 10** **Figure: 1**

Reproduced from OS maps by permission of Ordnance Survey ® on behalf of The Controller of Her Majesty's Stationery Office.

A great place to live, work & play

Not to scale

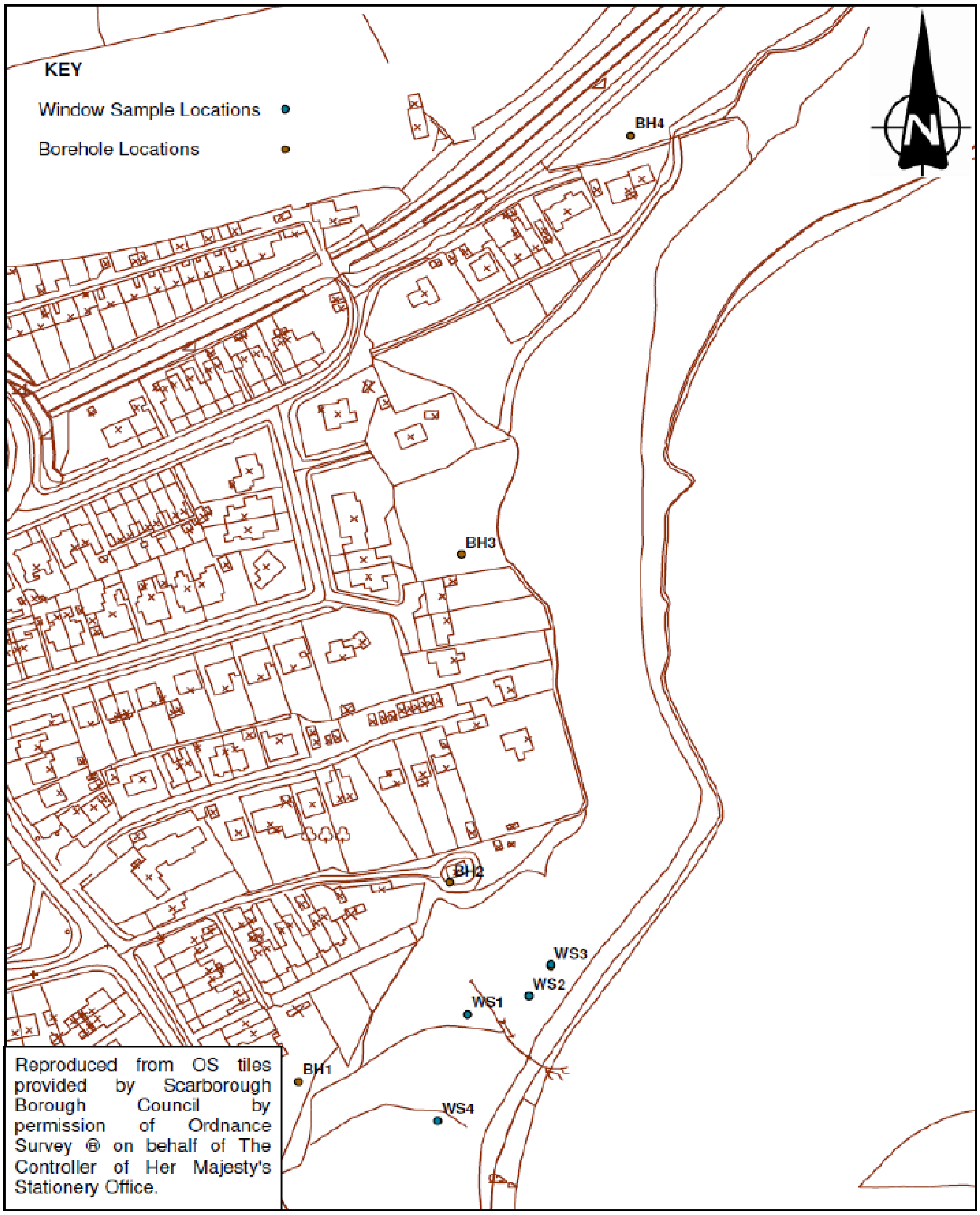
Plan of road route alteration between 1958 and 1975 (Envirocheck Analysis)	mouchel
Scarborough Borough Council **Robin Hood's Bay Strategy Study**	**Reference: 1022894/GEO/R/01/01**
	Date: Jun 10 / **Figure: 2**



A great place to live, work & play

Not to scale

Plan showing areas of potential flooding (Environment Agency)	mouchel
Scarborough Borough Council **Robin Hood's Bay Strategy Study**	**Reference: 1022894/GEO/R/01/01**
	Date: Jun 10 / **Figure: 3**



Scale: 1:2,000

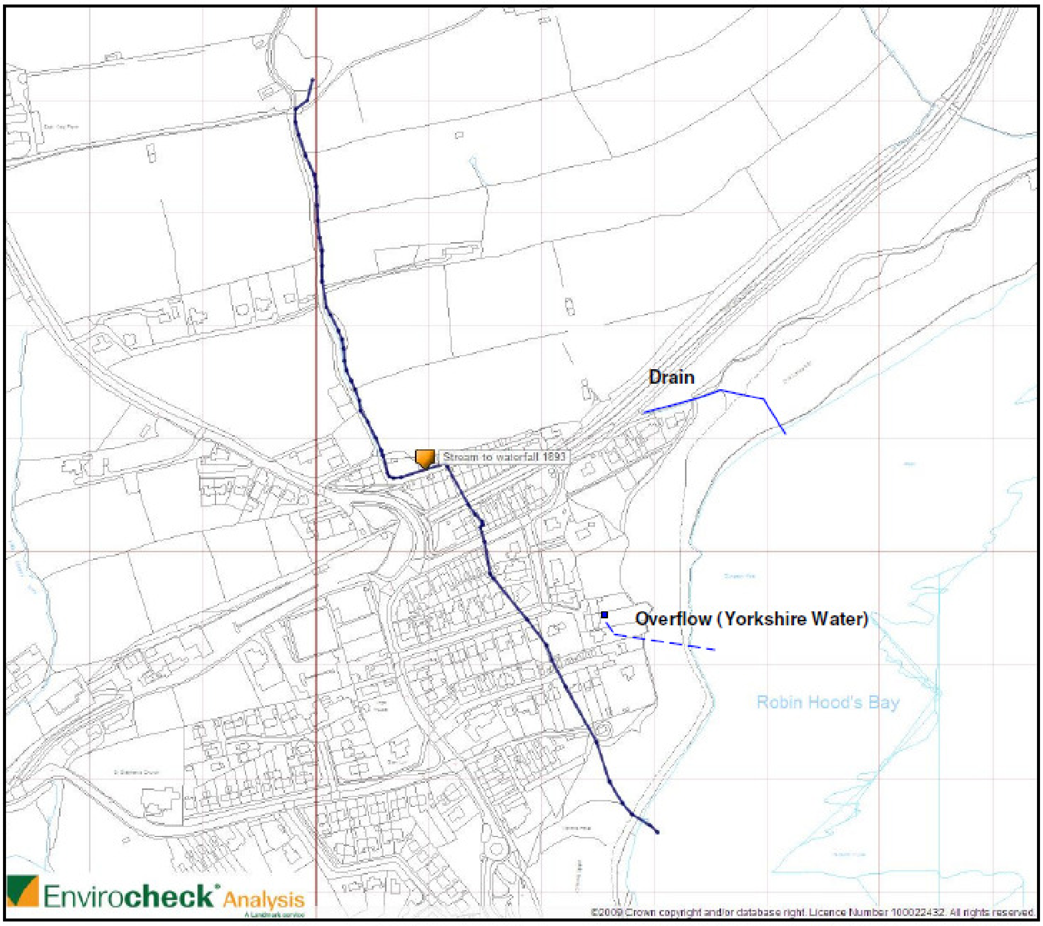
Exploratory Hole Location Plan

Scarborough Borough Council
Robin Hood's Bay Strategy Study

A great place to live, work & play

Reference: 1022894/GEO/R/01/01

Date: May 2010 **Figure: 4**



A great place to live, work & play

Not to scale

Route of stream from 1893 to present (Envirocheck Analysis)

mouchel

Scarborough Borough Council
Robin Hood's Bay Strategy Study

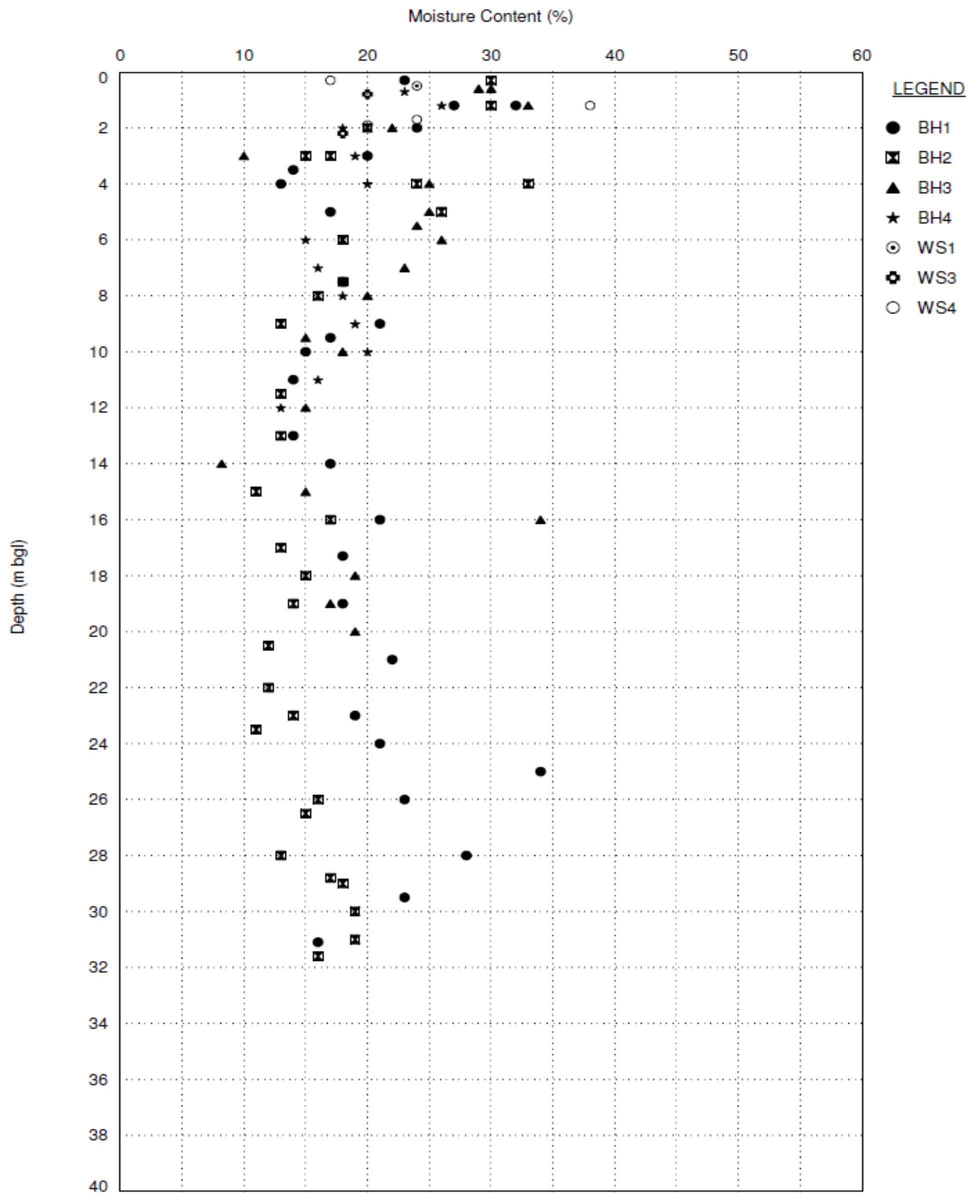
Reference: 1022894/GEO/R/01/01

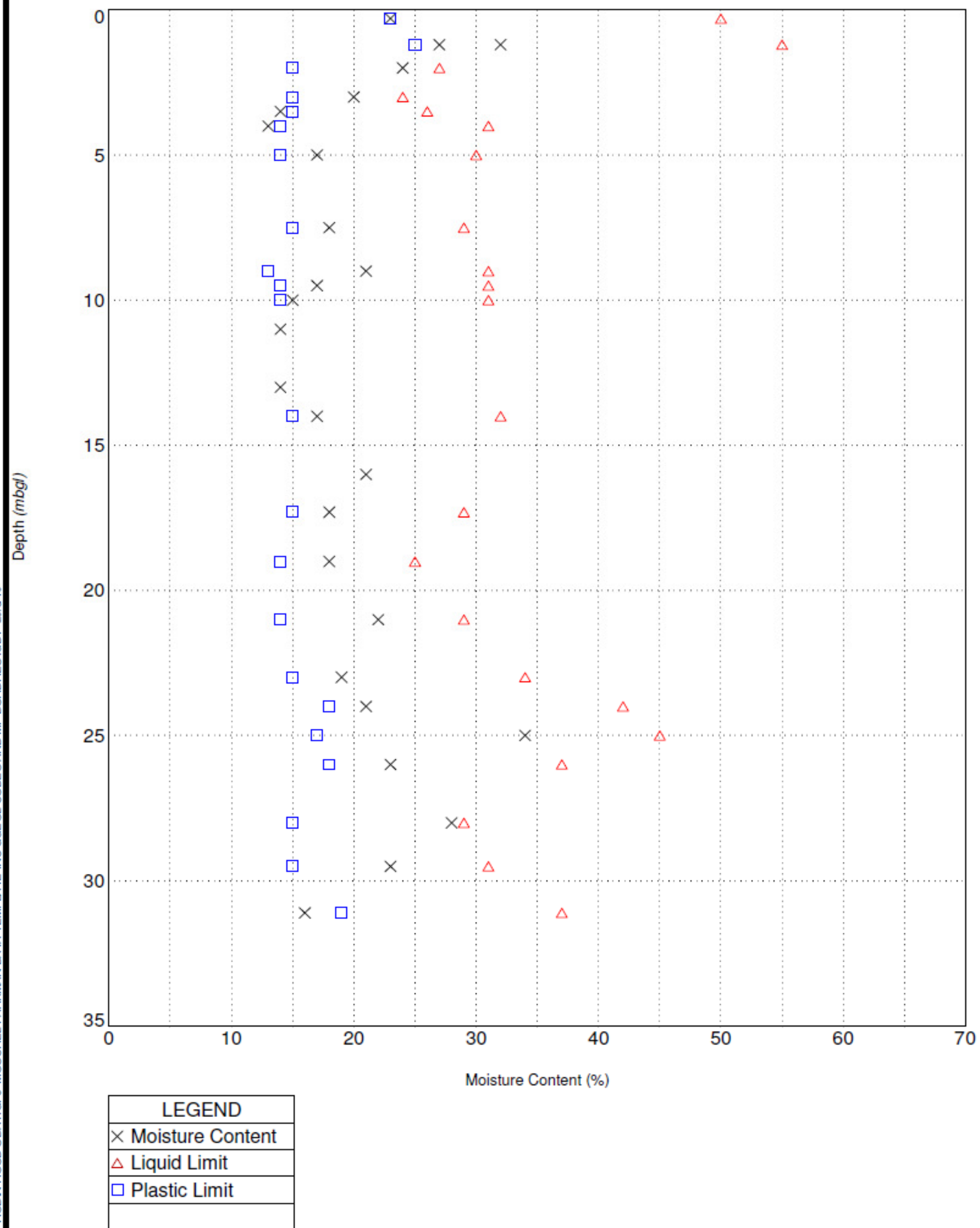
Date: Jun 10 | **Figure: 5**

	PROJECT **GROUND INVESTIGATION AT ROBIN HOOD'S BAY**	FIG No. **6**
mouchel		PROJ No. 1022894

TITLE:- **Moisture Content vs Depth**

All Strata





MP ATTERBERG V DEPTH ROBIN HOOD'S BAY.GPJ MOUCHEL PARKMAN DATA TEMPLATE INC GGEOL CODES AND MP BORDRES.GDT 20/5/10

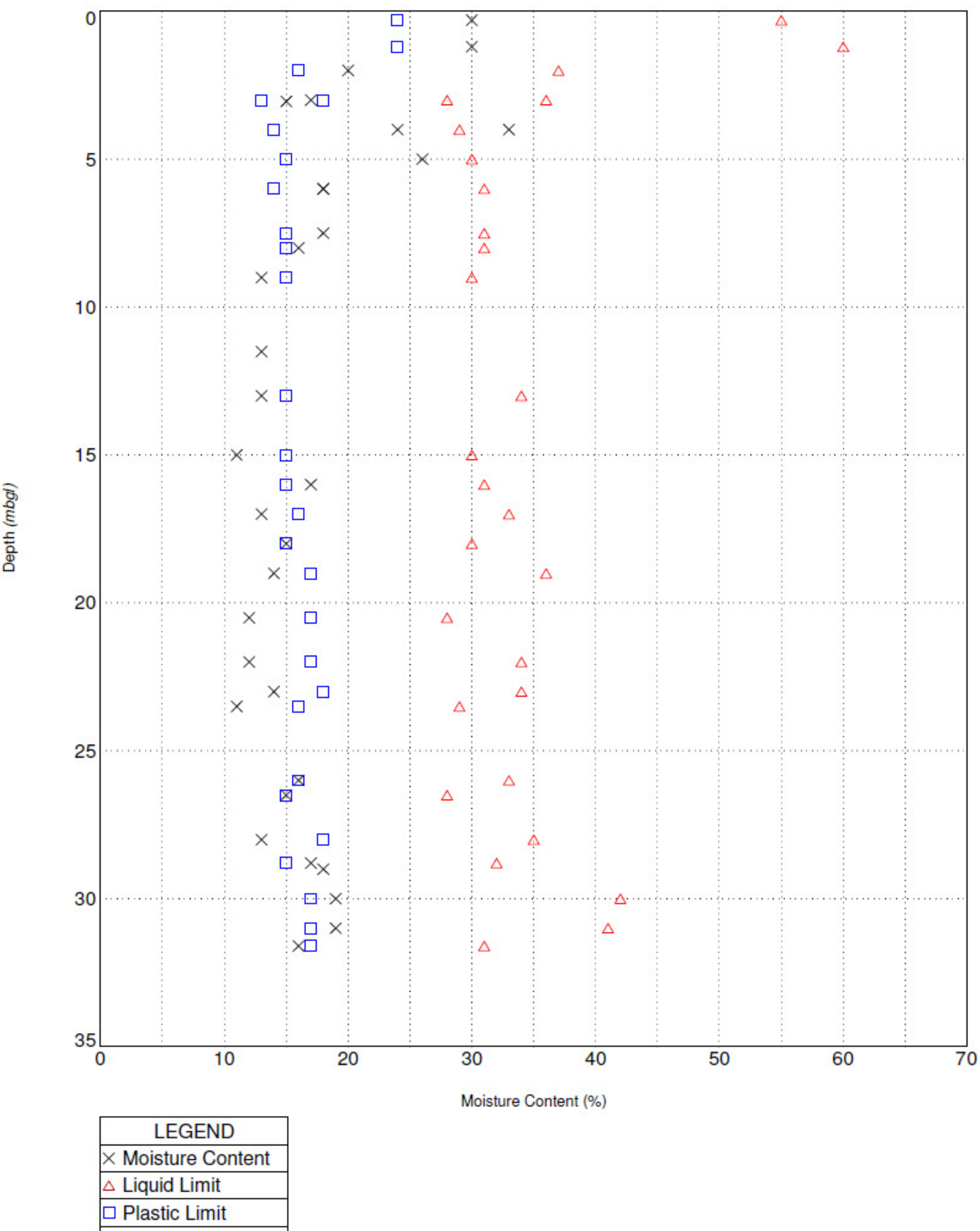
Figure 7 - ATTERBERG LIMITS vs Depth BH1

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

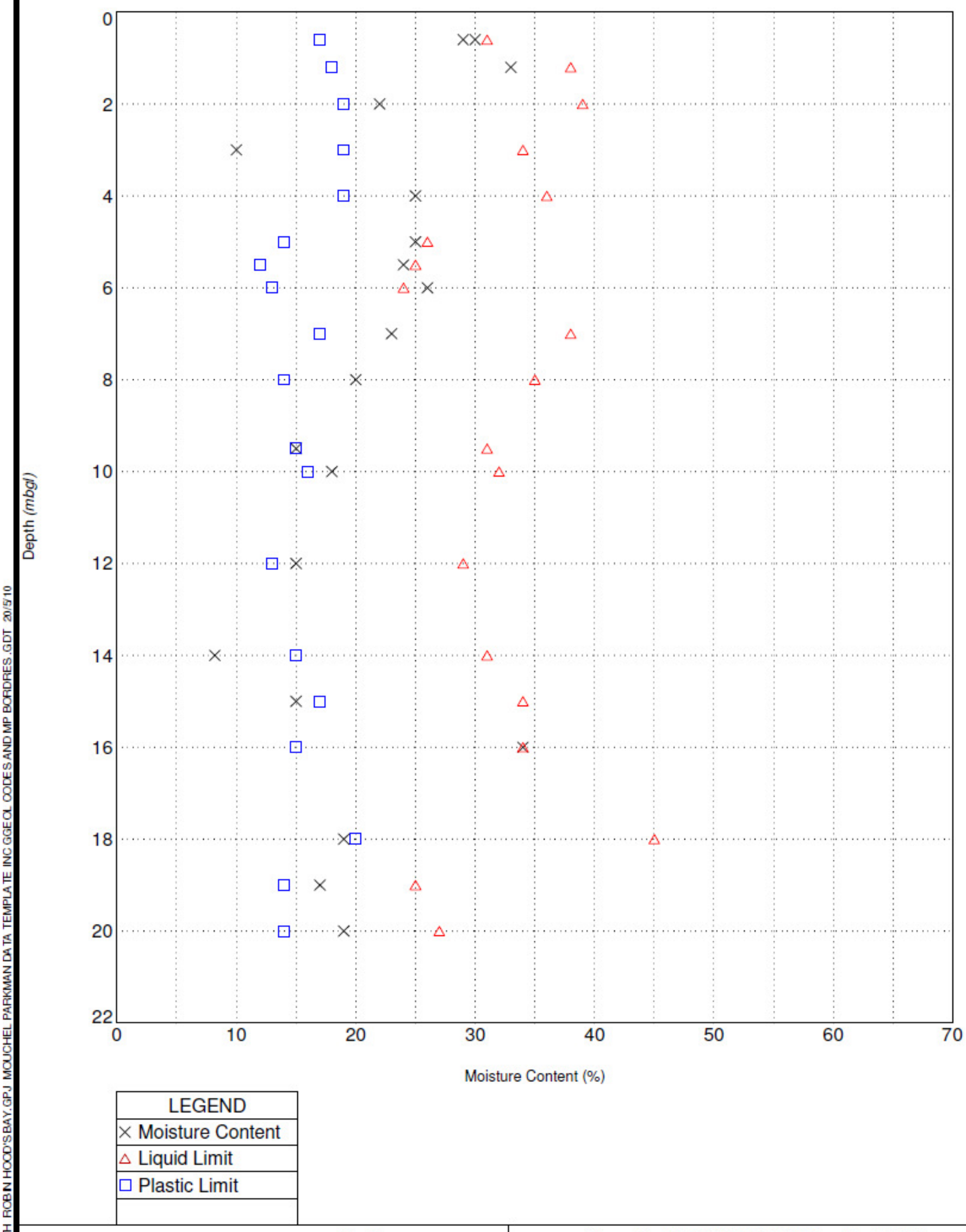
Ref: 1022894 | Date: May 2010

Telephone: 01609766667 Fax: 01609766624



Telephone: 01609766667 Fax: 01609766624

Figure 8 - ATTERBERG LIMITS vs Depth BH2	
Client: SCARBOROUGH BOROUGH COUNCIL	
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY	
Ref: 1022894	Date: May 2010



mouchel

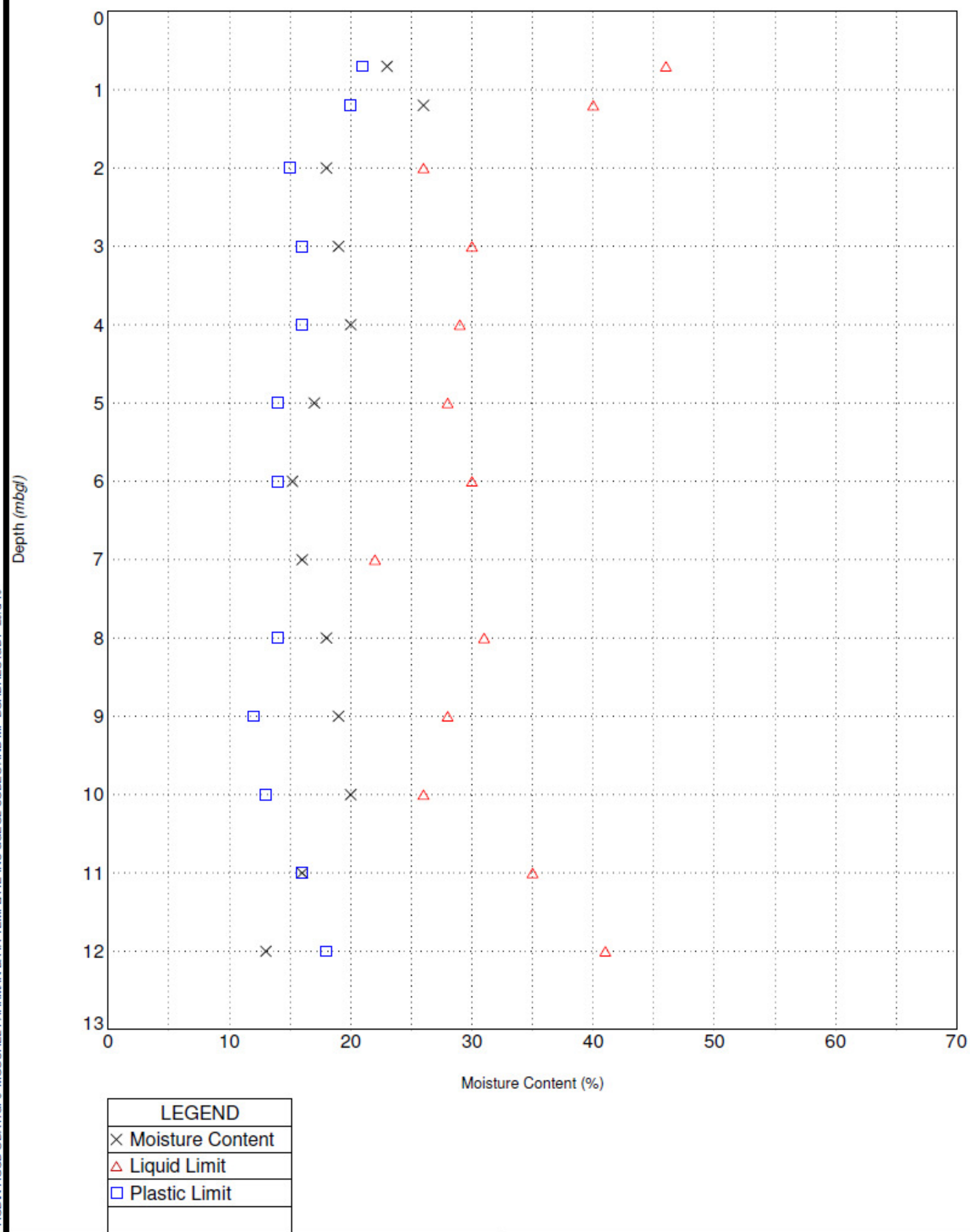
Telephone: 01609766667 Fax: 01609766624

Figure 9 - ATTERBERG LIMIT vs Depth BH3

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010



mouchel

Telephone: 01609766667 Fax: 01609766624

Figure 10 - ATTERBERG LIMIT vs Depth BH4	
Client: SCARBOROUGH BOROUGH COUNCIL	
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY	
Ref: 1022894	Date: May 2010

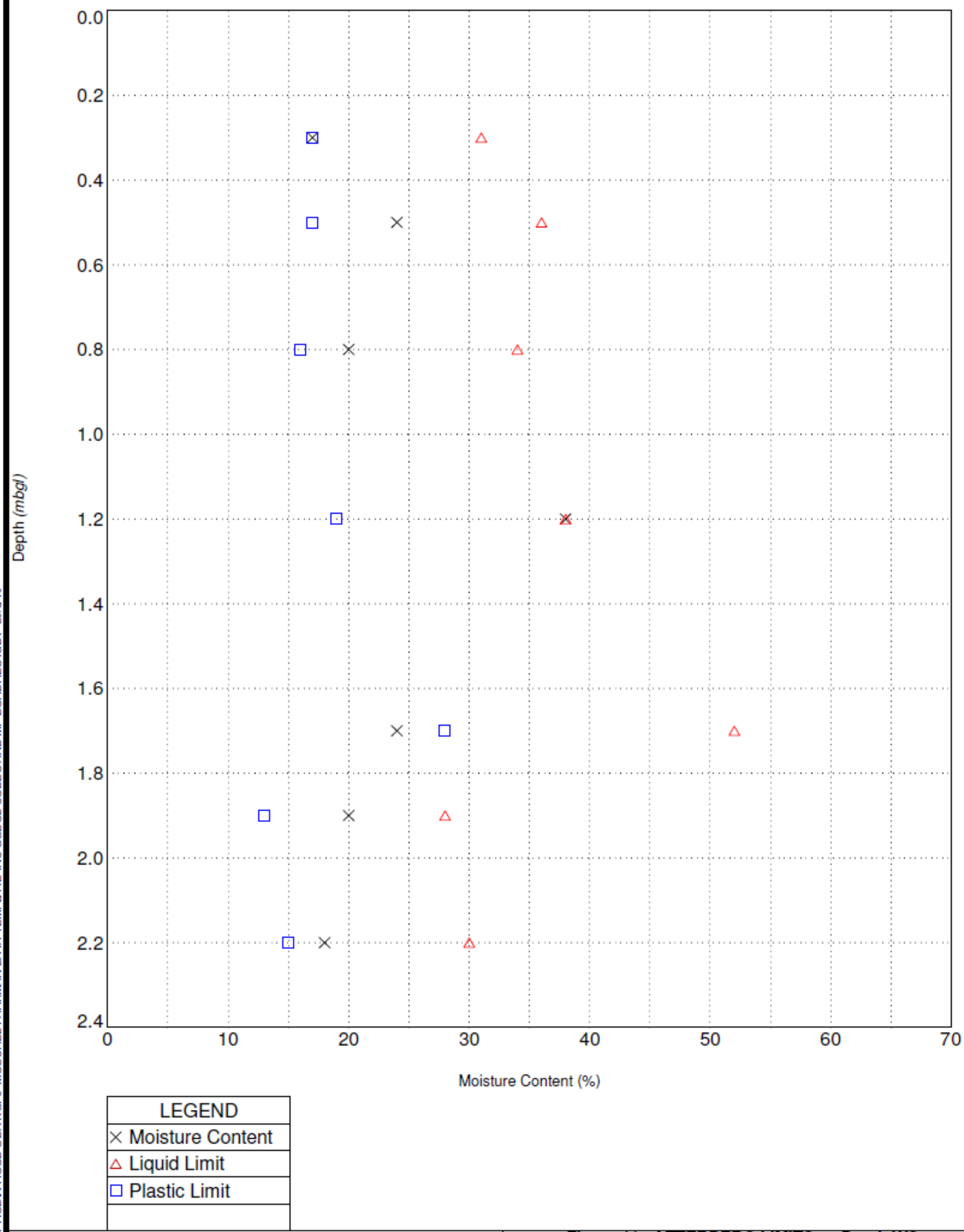


Figure 11 - ATTERBERG LIMITS vs Depth WSs

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010

Telephone: 01609766667 Fax: 01609766624

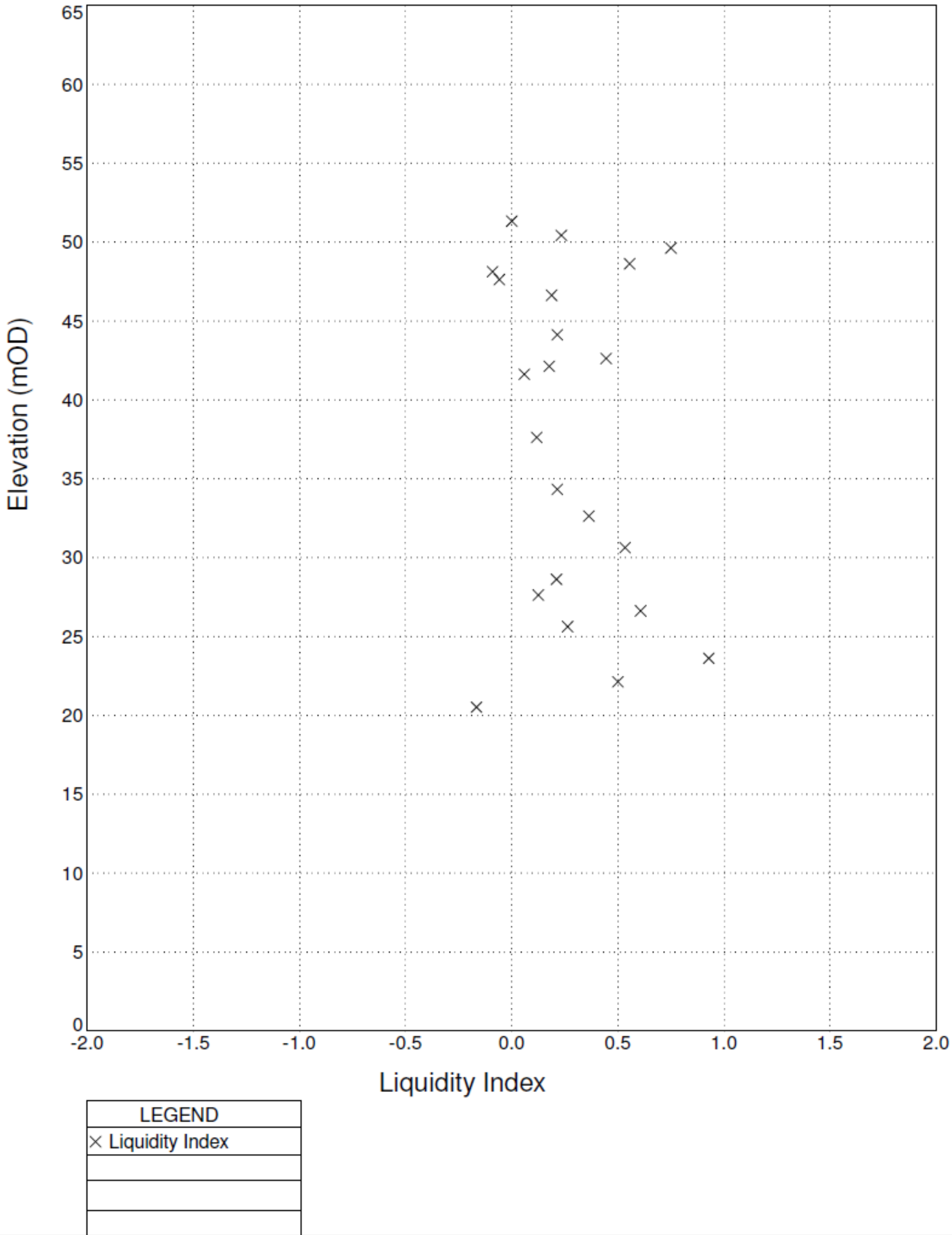


Figure 12 - Liquidity Index vs ELEVATION BH1
Client: SCARBOROUGH BOROUGH COUNCIL
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY
Ref: 1022894

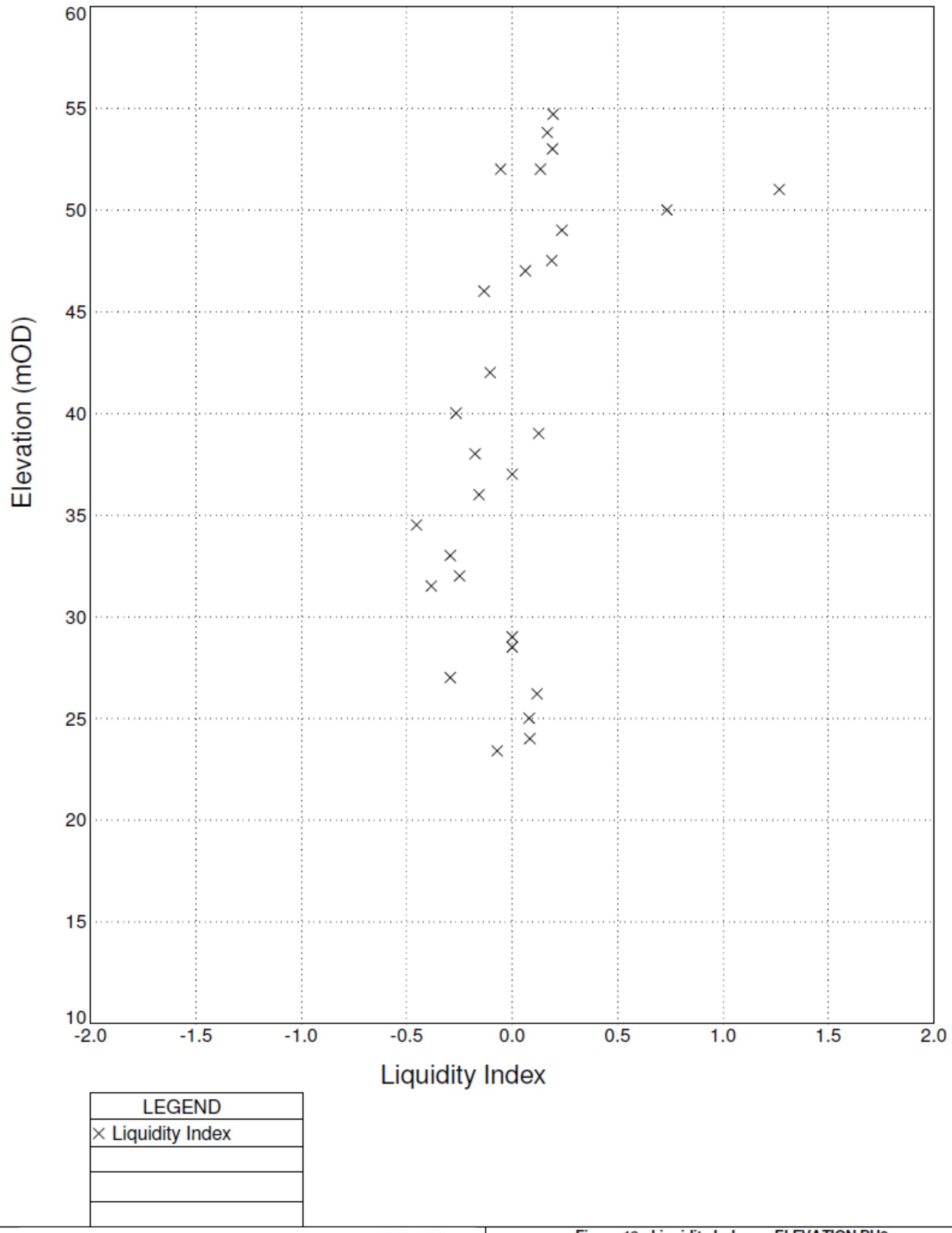
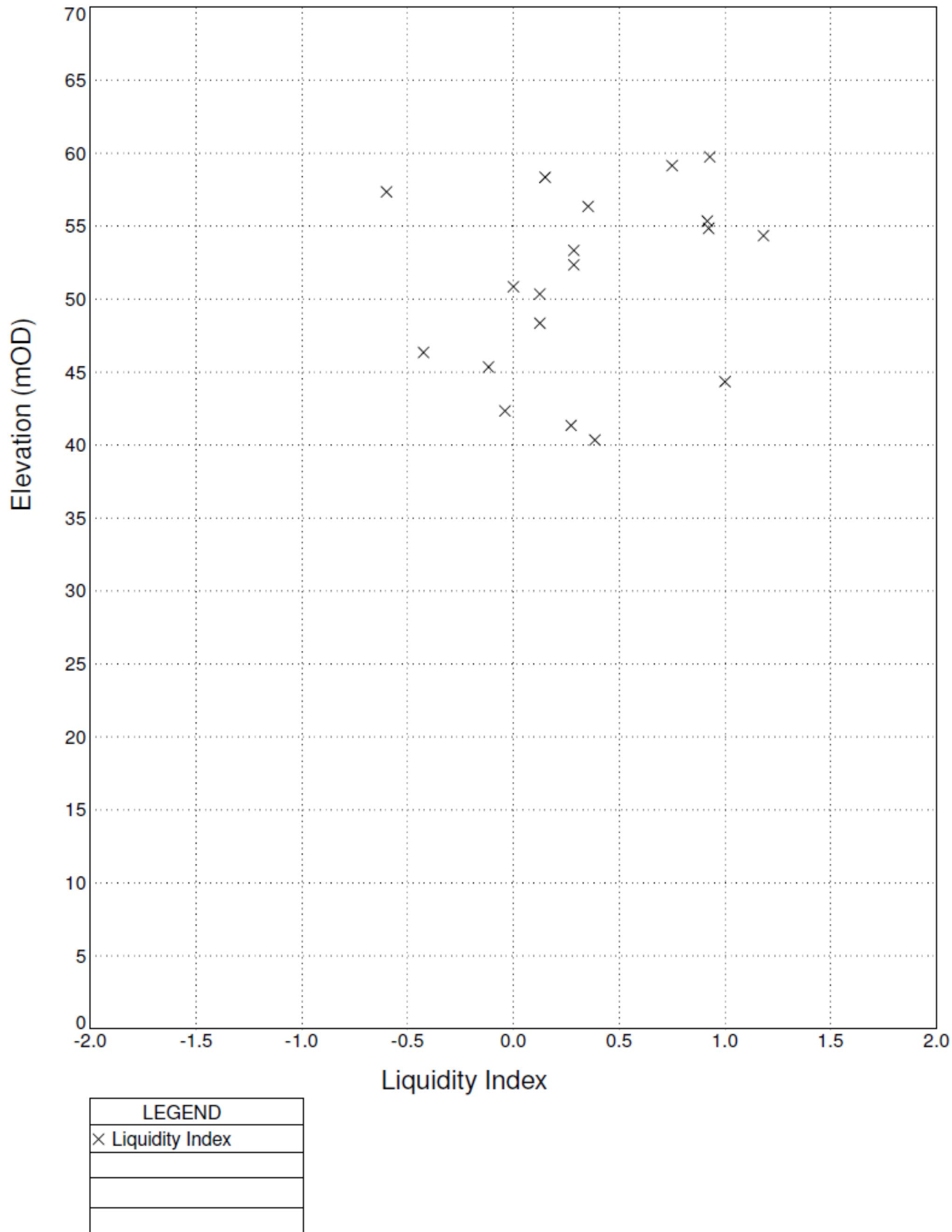


Figure 13 - Liquidity Index vs ELEVATION BH2

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894



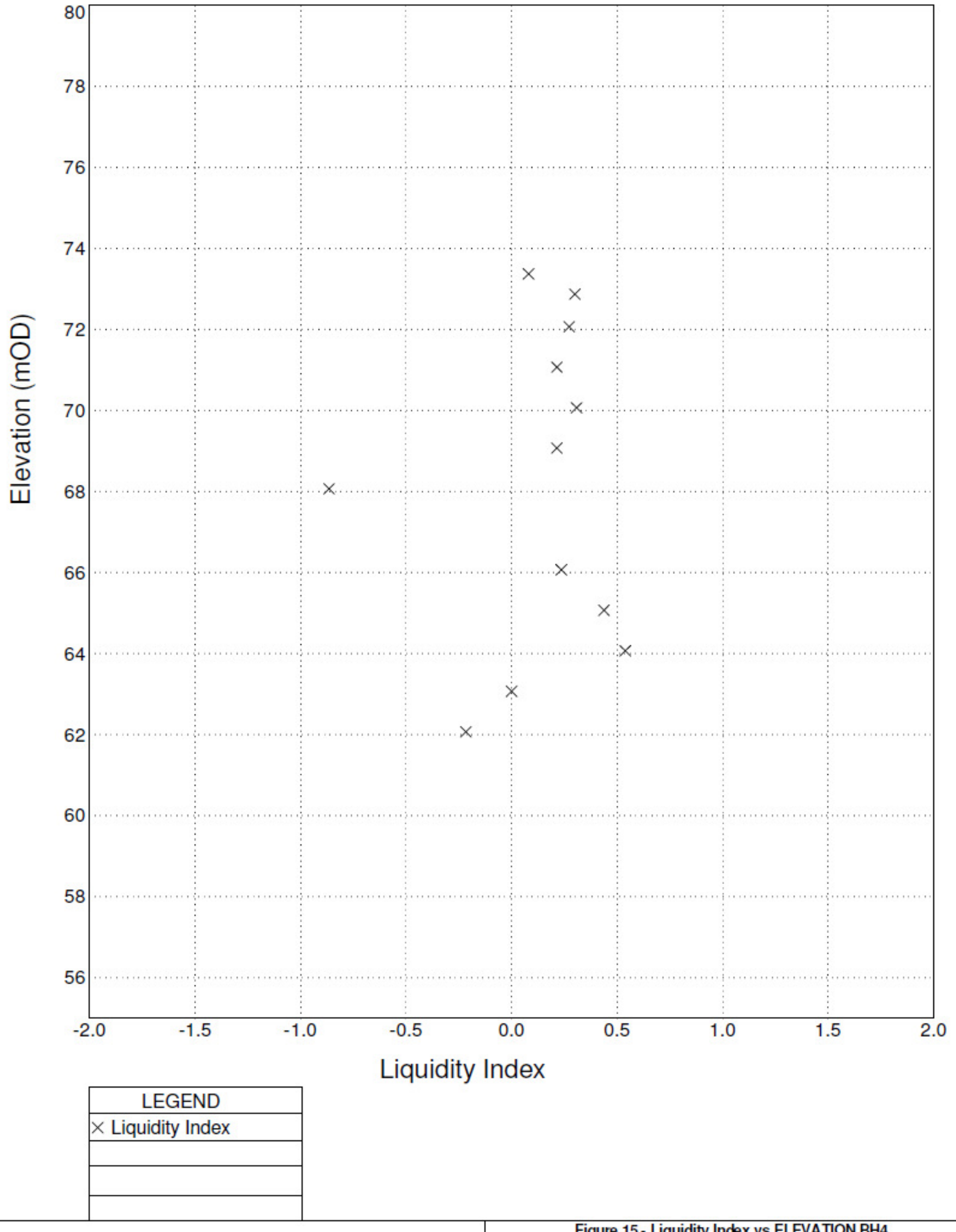
mouchel

Figure 14 - Liquidity Index vs ELEVATION BH3

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894



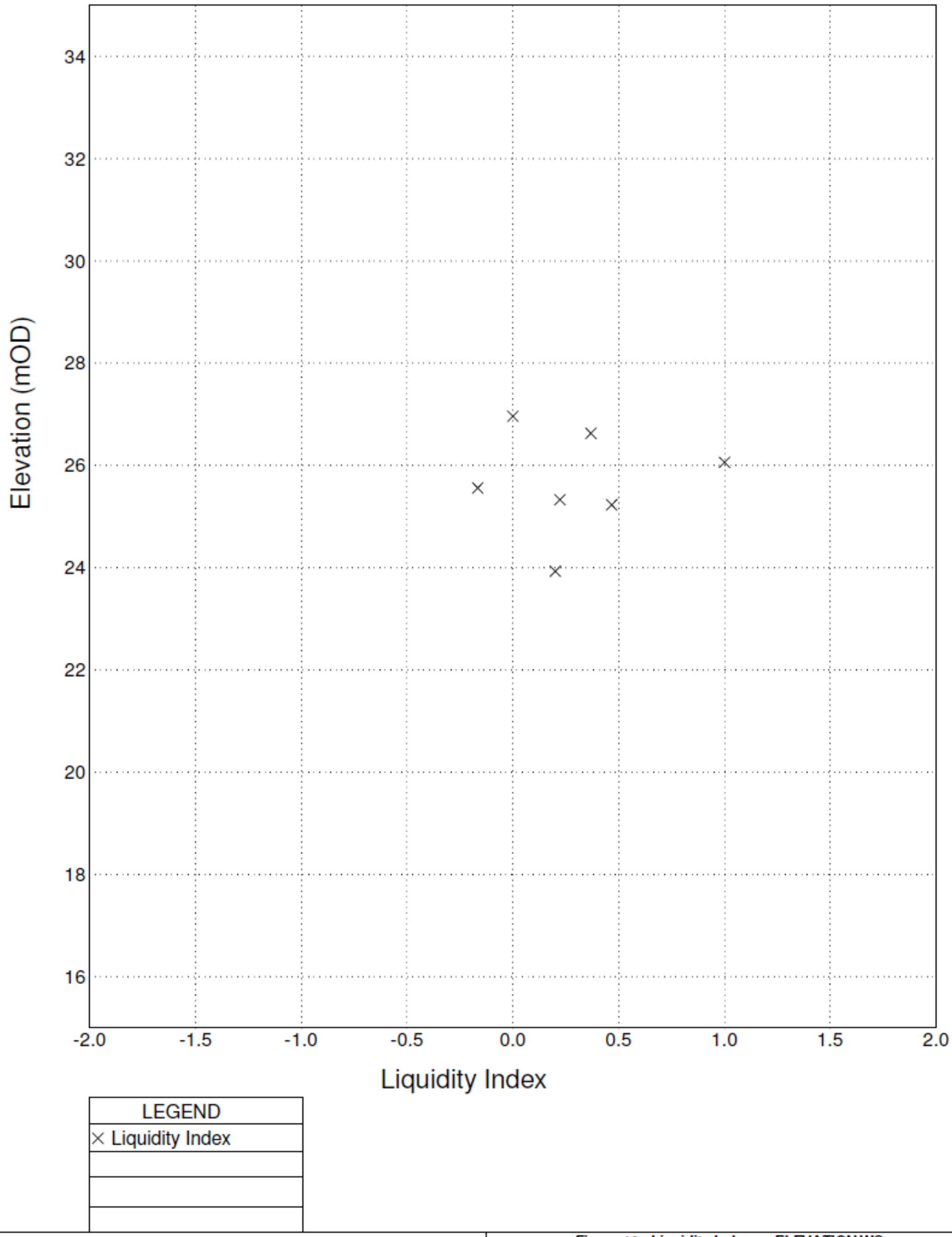
mouchel

Figure 15 - Liquidity Index vs ELEVATION BH4

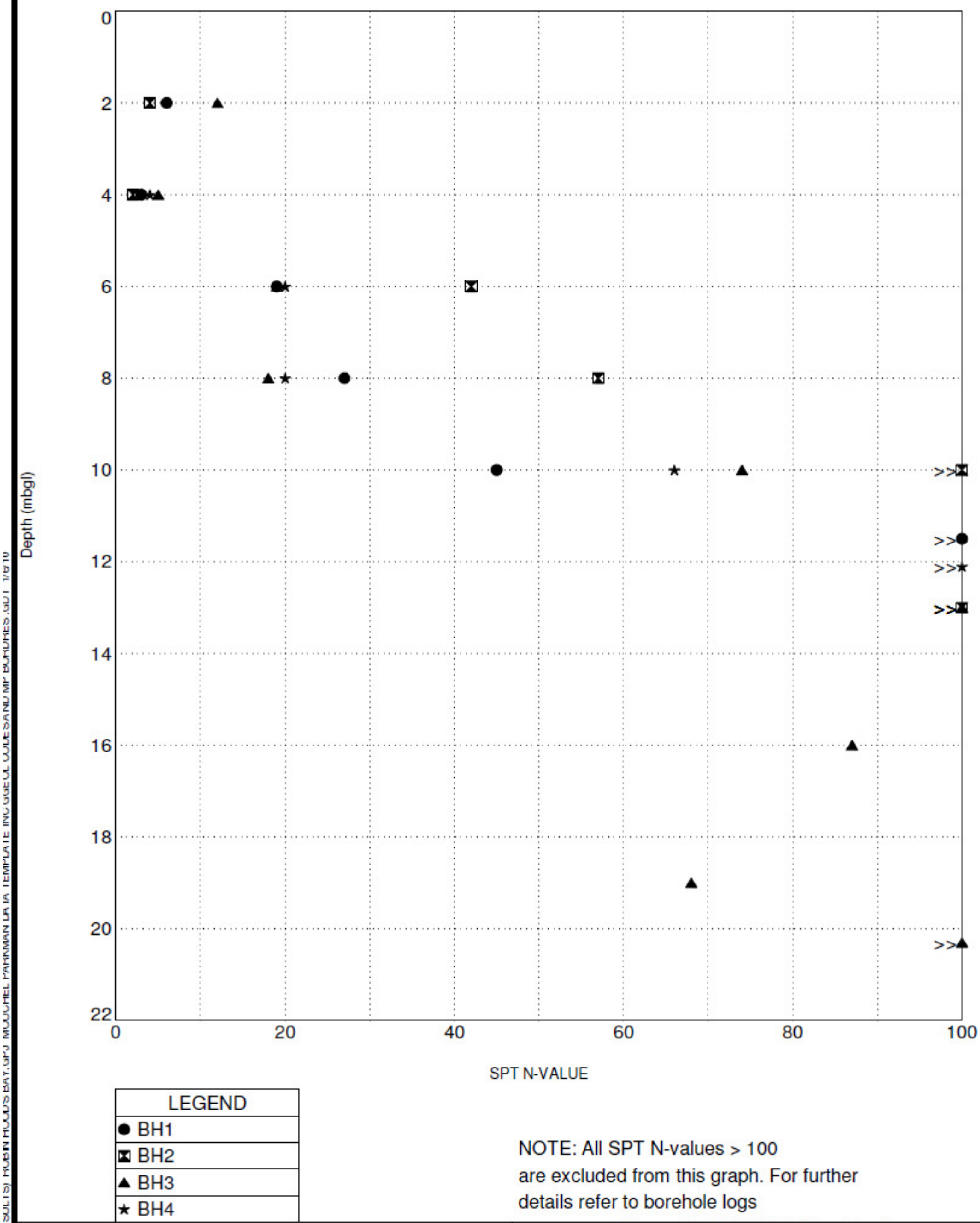
Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894



mouchel	**Figure 16 - Liquidity Index vs ELEVATION WSs**
	Client: SCARBOROUGH BOROUGH COUNCIL
	Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY
	Ref: 1022894



NOTE: All SPT N-values > 100
are excluded from this graph. For further
details refer to borehole logs

Figure 17 - SPT N-VALUE vs Depth

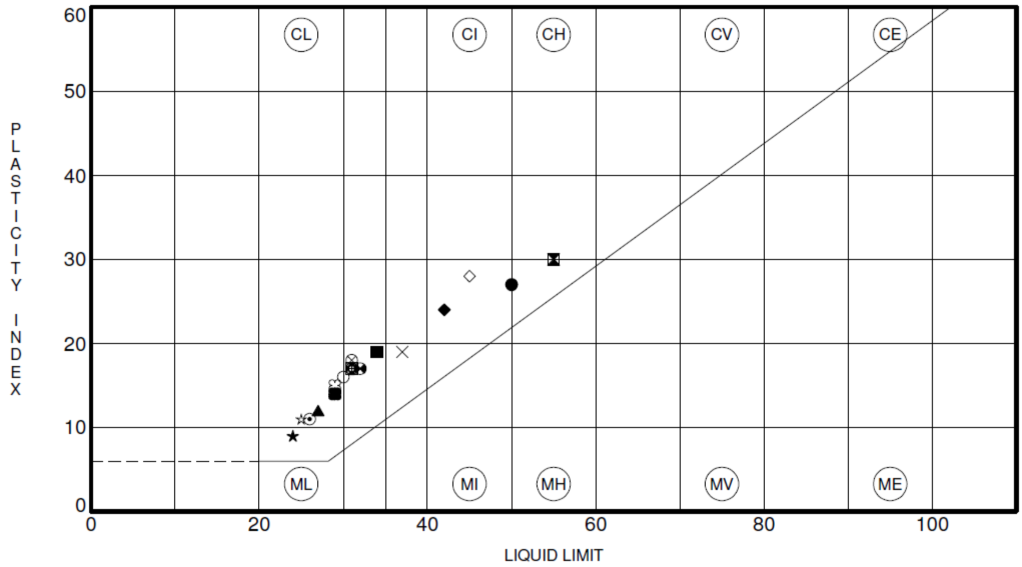
Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010

mouchel

Telephone: 01609766667 Fax: 01609766624



	Hole ID	Depth (m)	LL	PL	PI	Fines	Classification
●	BH1	0.30	50	23	27		
⧗	BH1	1.20	55	25	30		
▲	BH1	2.00	27	15	12		
★	BH1	3.00	24	15	9		
⊙	BH1	3.50	26	15	11		
✚	BH1	4.00	31	14	17		
○	BH1	5.00	30	14	16		
△	BH1	7.50	29	15	14		
⊗	BH1	9.00	31	13	18		
⊕	BH1	9.50	31	14	17		
□	BH1	10.00	31	14	17		
◉	BH1	14.00	32	15	17		
◕	BH1	17.30	29	15	14		
☆	BH1	19.00	25	14	11		
✧	BH1	21.00	29	14	15		
■	BH1	23.00	34	15	19		
◆	BH1	24.00	42	18	24		
◇	BH1	25.00	45	17	28		
×	BH1	26.00	37	18	19		
✖	BH1	28.00	29	15	14		

mouchel

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

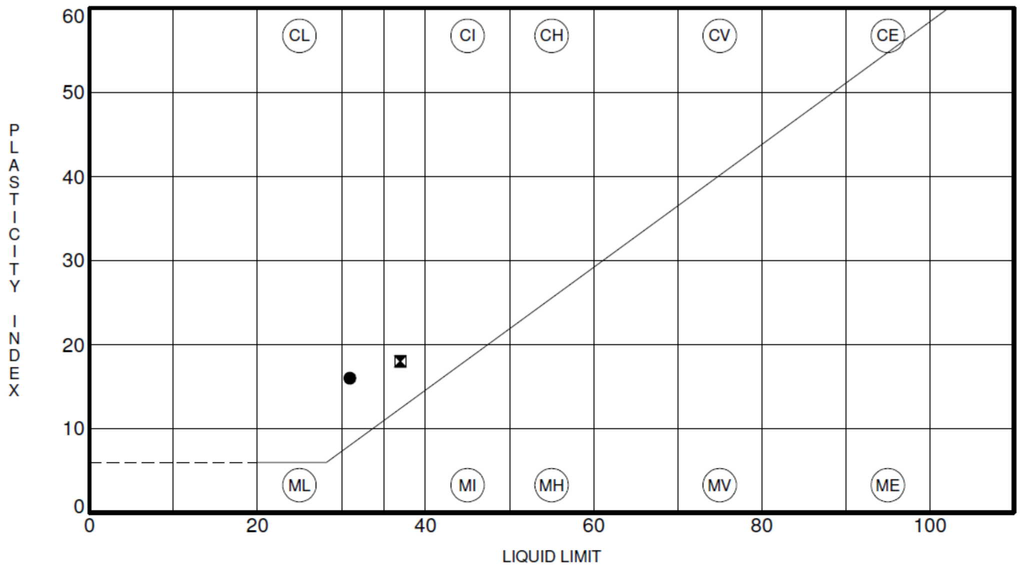
Telephone: 01609 766667
Fax: 01609 766624

Figure 18 - CASAGRANDE PLASTICITY CHART

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010



	Hole ID	Depth (m)	LL	PL	PI	Fines	Classification
●	**BH1**	**29.50**	**31**	**15**	**16**		
⧗	**BH1**	**31.10**	**37**	**19**	**18**		

mouchel

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

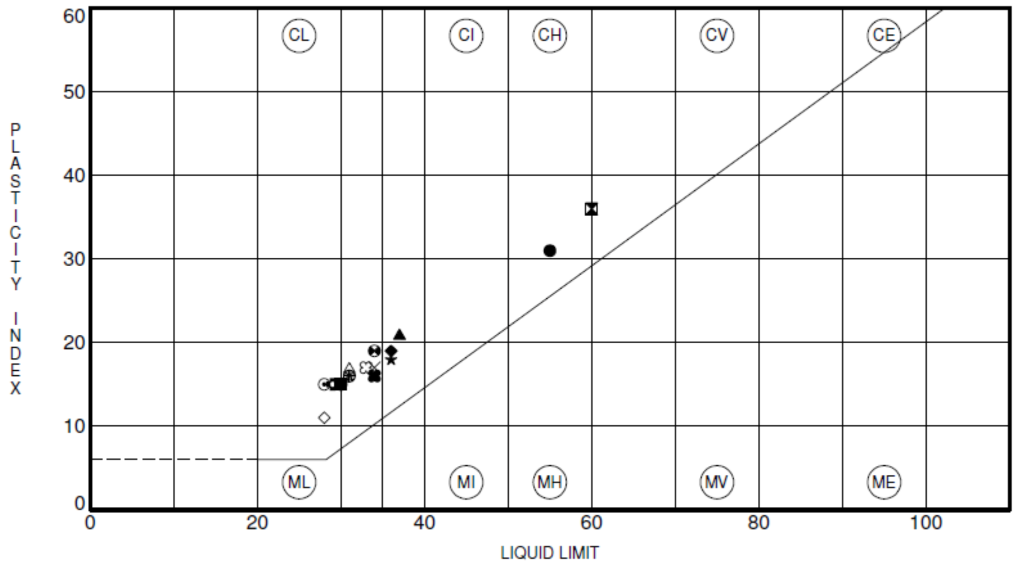
Telephone: 01609 766667
Fax: 01609 766624

Figure 18 - CASAGRANDE PLASTICITY CHART

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010



	Hole ID	Depth (m)	LL	PL	PI	Fines	Classification
●	BH2	0.30	55	24	31		
⊠	BH2	1.20	60	24	36		
▲	BH2	2.00	37	16	21		
★	BH2	3.00	36	18	18		
⊙	BH2	3.00	28	13	15		
✿	BH2	4.00	29	14	15		
○	BH2	5.00	30	15	15		
△	BH2	6.00	31	14	17		
⊗	BH2	7.50	31	15	16		
⊕	BH2	8.00	31	15	16		
□	BH2	9.00	30	15	15		
◉	BH2	13.00	34	15	19		
◕	BH2	15.00	30	15	15		
☆	BH2	16.00	31	15	16		
✤	BH2	17.00	33	16	17		
■	BH2	18.00	30	15	15		
◆	BH2	19.00	36	17	19		
◇	BH2	20.50	28	17	11		
×	BH2	22.00	34	17	17		
✖	BH2	23.00	34	18	16		

mouchel

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

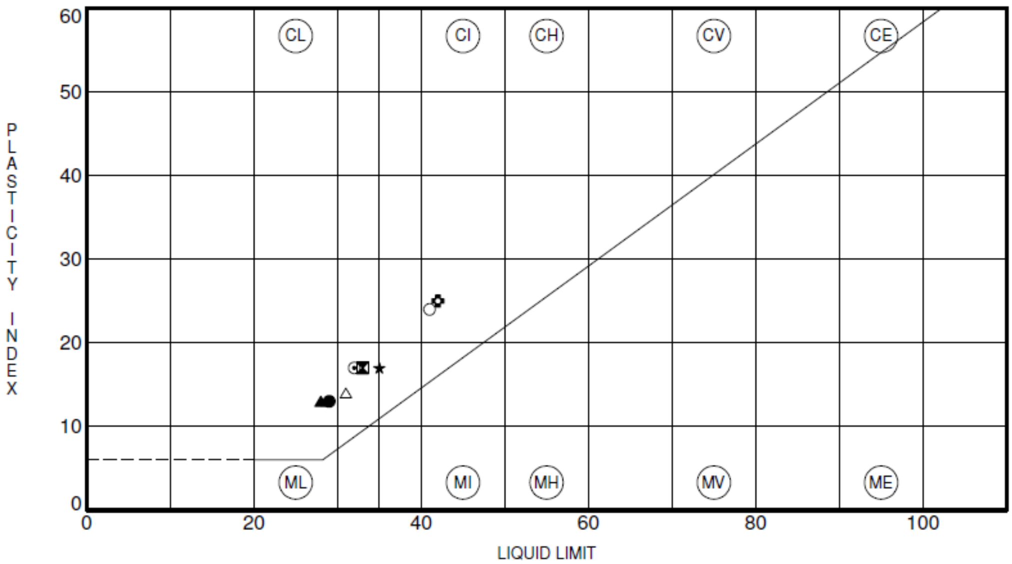
Telephone: 01609 766667
Fax: 01609 766624

Figure 19 - CASAGRANDE PLASTICITY CHART

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010



	Hole ID	Depth (m)	LL	PL	PI	Fines	Classification
●	BH2	23.50	29	16	13		
⊠	BH2	26.00	33	16	17		
▲	BH2	26.50	28	15	13		
★	BH2	28.00	35	18	17		
⊙	BH2	28.80	32	15	17		
✿	BH2	30.00	42	17	25		
○	BH2	31.00	41	17	24		
△	BH2	31.60	31	17	14		

mouchel

Telephone: 01609 766667
Fax: 01609 766624

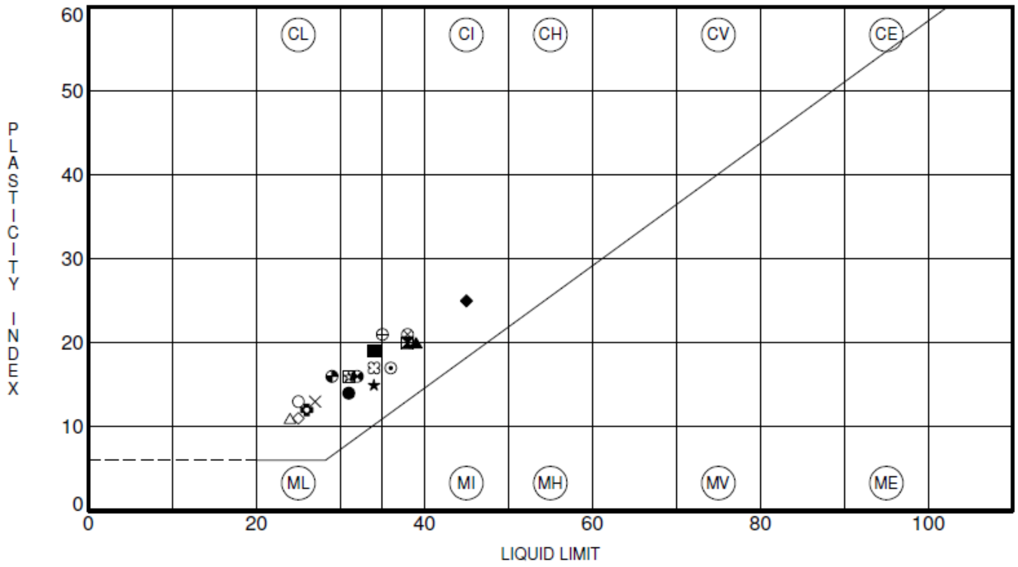
York House
Thornfield Business Park
Standard Way
Northallerton
N Yorkshire
DL6 2XQ

Figure 19 - CASAGRANDE PLASTICITY CHART

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 Date: May 2010



	Hole ID	Depth (m)	LL	PL	PI	Fines	Classification
●	BH3	0.60	31	17	14		
⊠	BH3	1.20	38	18	20		
▲	BH3	2.00	39	19	20		
★	BH3	3.00	34	19	15		
⊙	BH3	4.00	36	19	17		
✪	BH3	5.00	26	14	12		
○	BH3	5.50	25	12	13		
△	BH3	6.00	24	13	11		
⊗	BH3	7.00	38	17	21		
⊕	BH3	8.00	35	14	21		
□	BH3	9.50	31	15	16		
◉	BH3	10.00	32	16	16		
◕	BH3	12.00	29	13	16		
☆	BH3	14.00	31	15	16		
☒	BH3	15.00	34	17	17		
■	BH3	16.00	34	15	19		
◆	BH3	18.00	45	20	25		
◇	BH3	19.00	25	14	11		
×	BH3	20.00	27	14	13		

mouchel

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

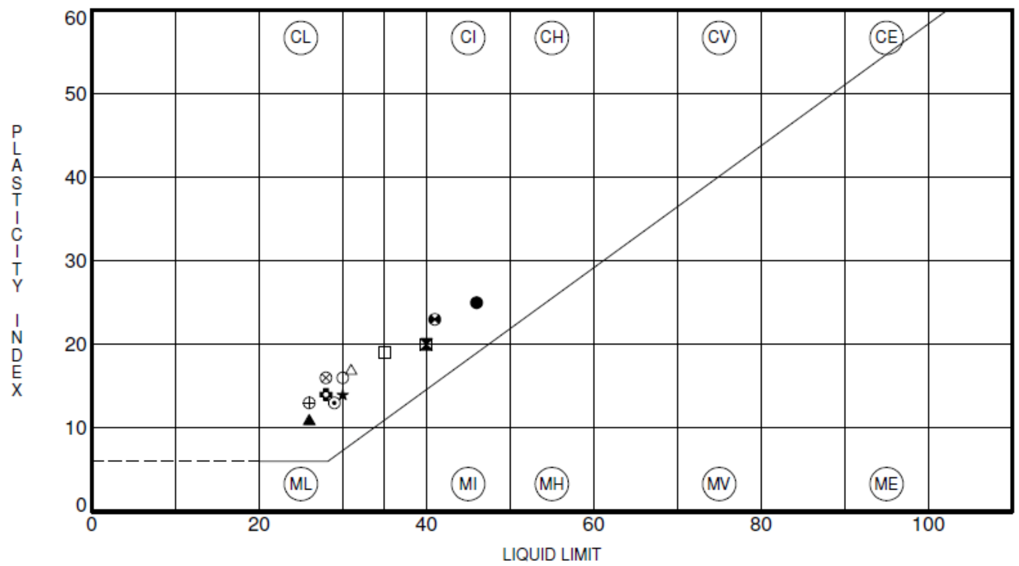
Telephone: 01609 766667
Fax: 01609 766624

Figure 20 - CASAGRANDE PLASTICITY CHART

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010



	Hole ID	Depth (m)	LL	PL	PI	Fines	Classification
●	BH4	0.70	46	21	25		
⧗	BH4	1.20	40	20	20		
▲	BH4	2.00	26	15	11		
★	BH4	3.00	30	16	14		
⊙	BH4	4.00	29	16	13		
✣	BH4	5.00	28	14	14		
○	BH4	6.00	30	14	16		
△	BH4	8.00	31	14	17		
⊗	BH4	9.00	28	12	16		
⊕	BH4	10.00	26	13	13		
□	BH4	11.00	35	16	19		
◉	BH4	12.00	41	18	23		

mouchel

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

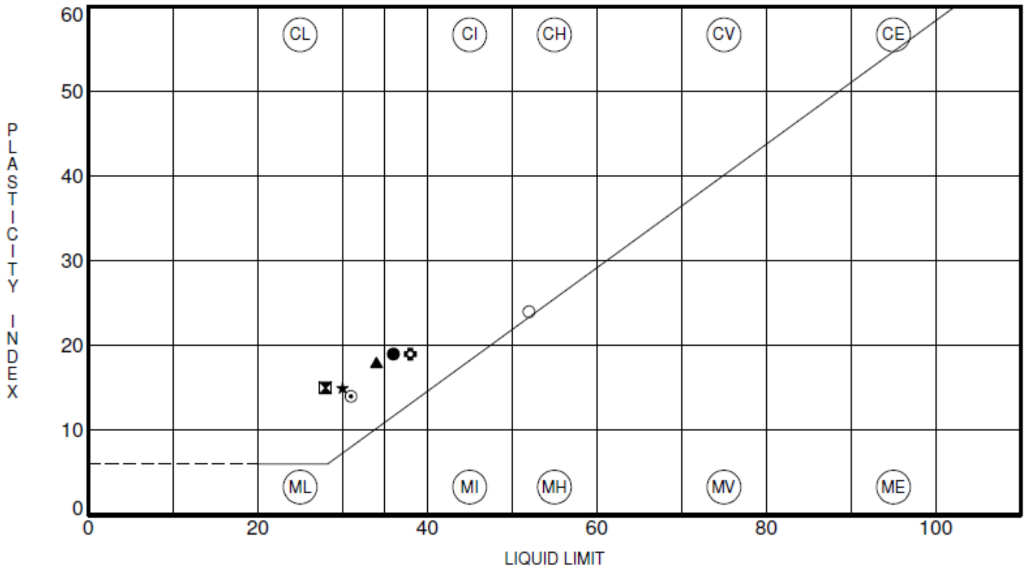
Telephone: 01609 766667
Fax: 01609 766624

Figure 21 - CASAGRANDE PLASTICITY CHART

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010



	Hole ID	Depth (m)	LL	PL	PI	Fines	Classification
●	WS1	0.50	36	17	19		
⧗	WS1	1.90	28	13	15		
▲	WS3	0.80	34	16	18		
★	WS3	2.20	30	15	15		
⊙	WS4	0.30	31	17	14		
✿	WS4	1.20	38	19	19		
○	WS4	1.70	52	28	24		

mouchel

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

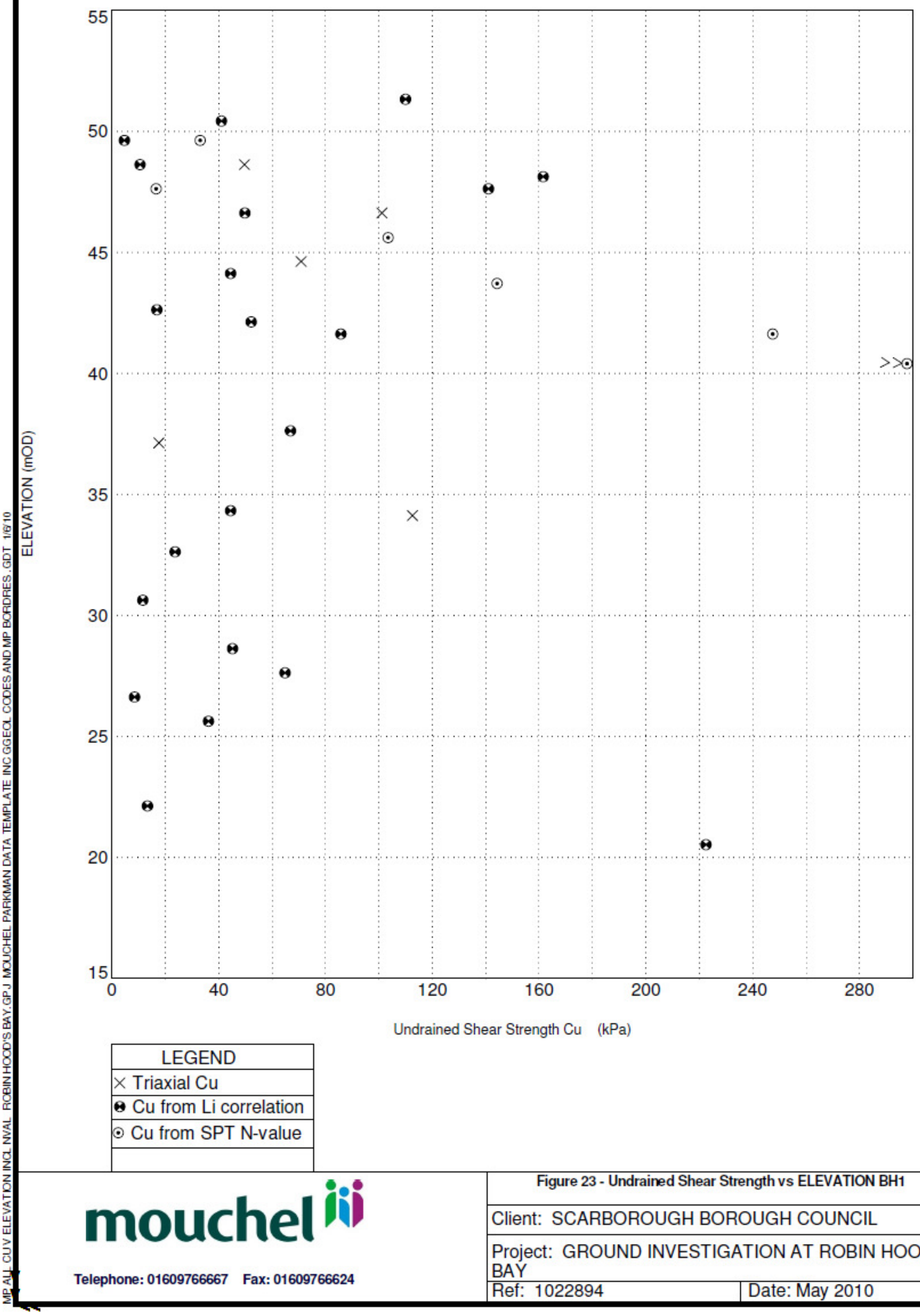
Telephone: 01609 766667
Fax: 01609 766624

Figure 22 - CASAGRANDE PLASTICITY CHART

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010



mouchel

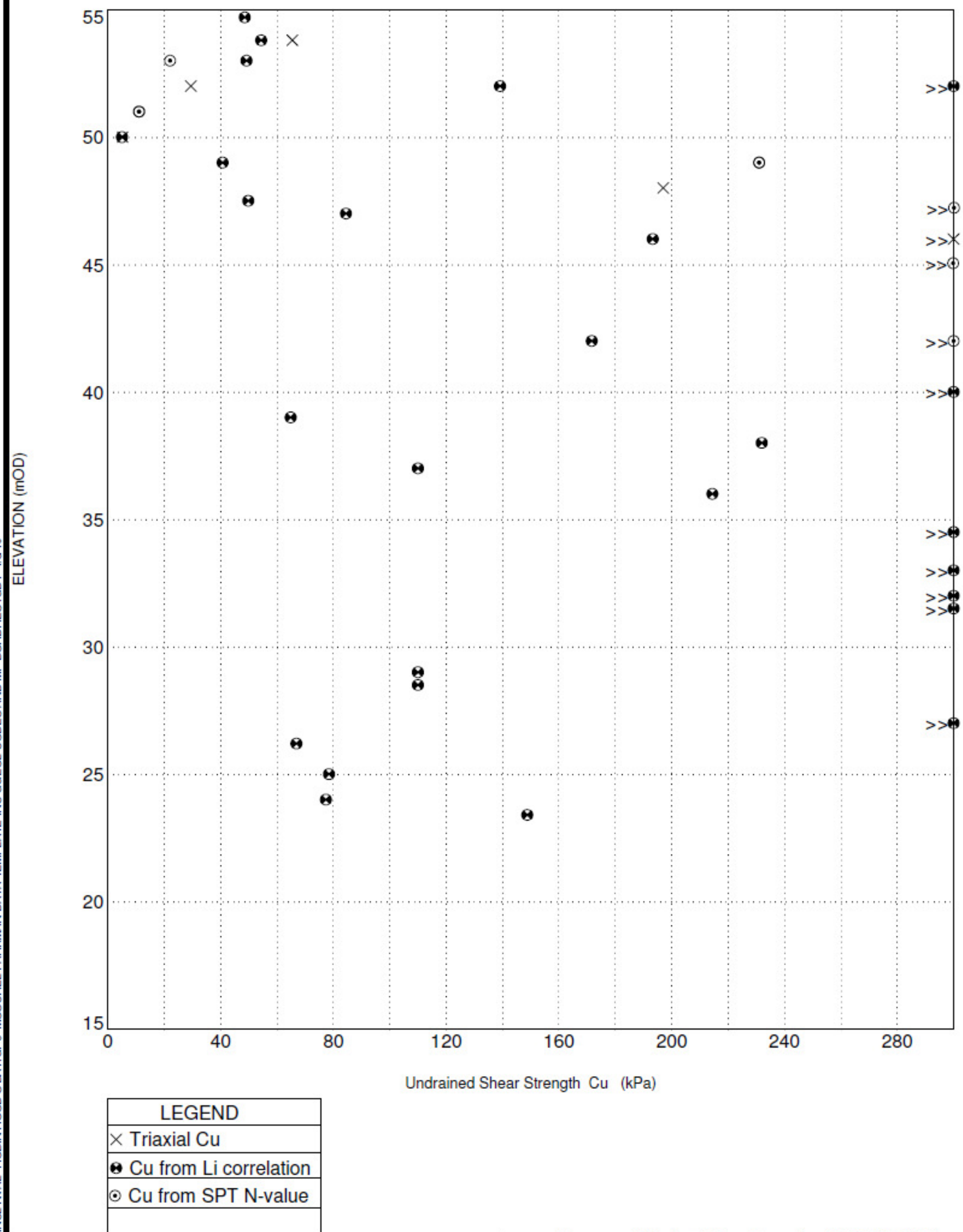
Telephone: 01609766667 Fax: 01609766624

Figure 23 - Undrained Shear Strength vs ELEVATION BH1

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

Ref: 1022894 | Date: May 2010

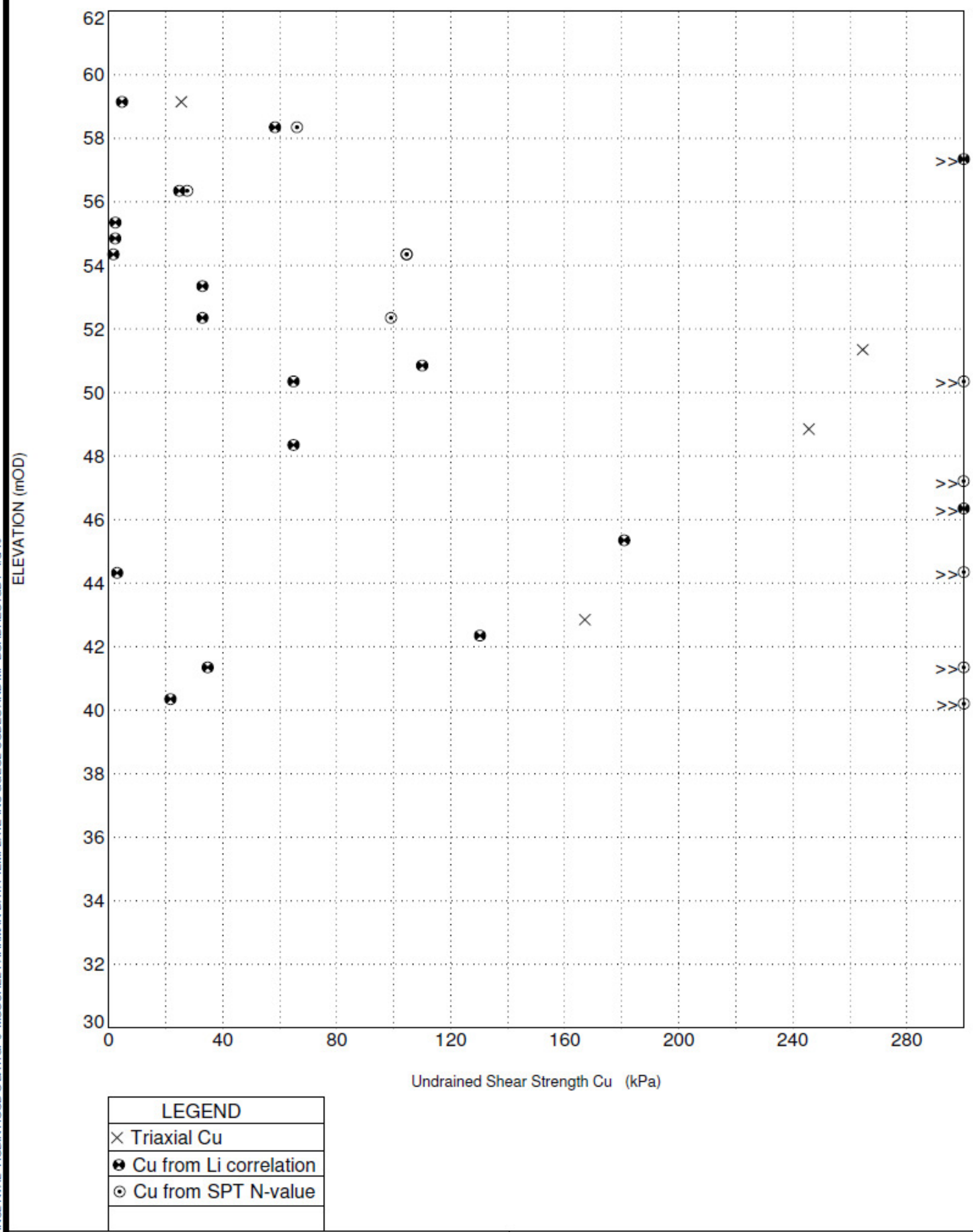


mouchel

Telephone: 01609766667 Fax: 01609766624

Figure 24 - Undrained Shear Strength vs ELEVATION BH2

Client: SCARBOROUGH BOROUGH COUNCIL	
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY	
Ref: 1022894	Date: May 2010



mouchel

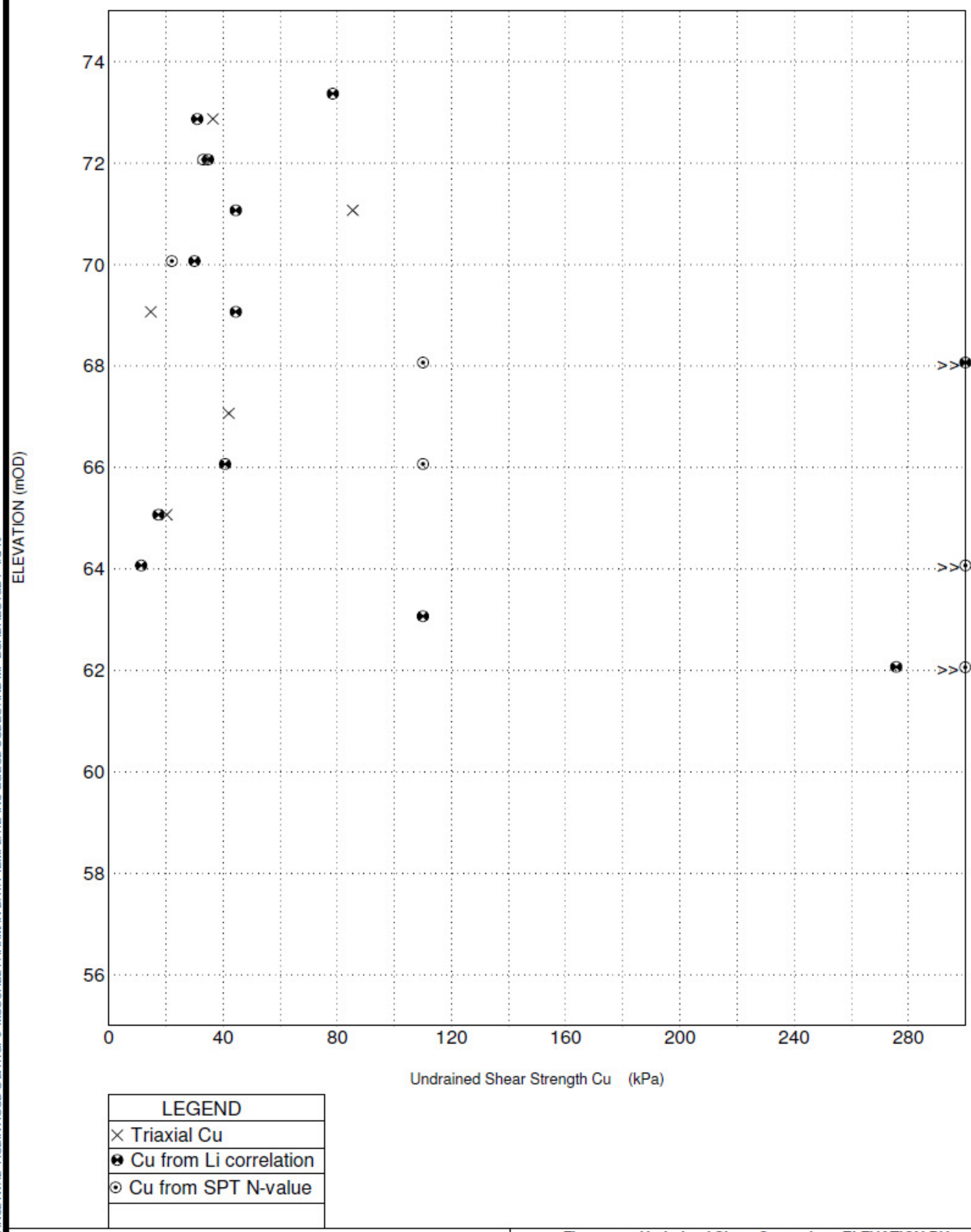
Telephone: 01609766667 Fax: 01609766624

Figure 25 - Undrained Shear Strength vs ELEVATION BH3

Client: SCARBOROUGH BOROUGH COUNCIL

Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY

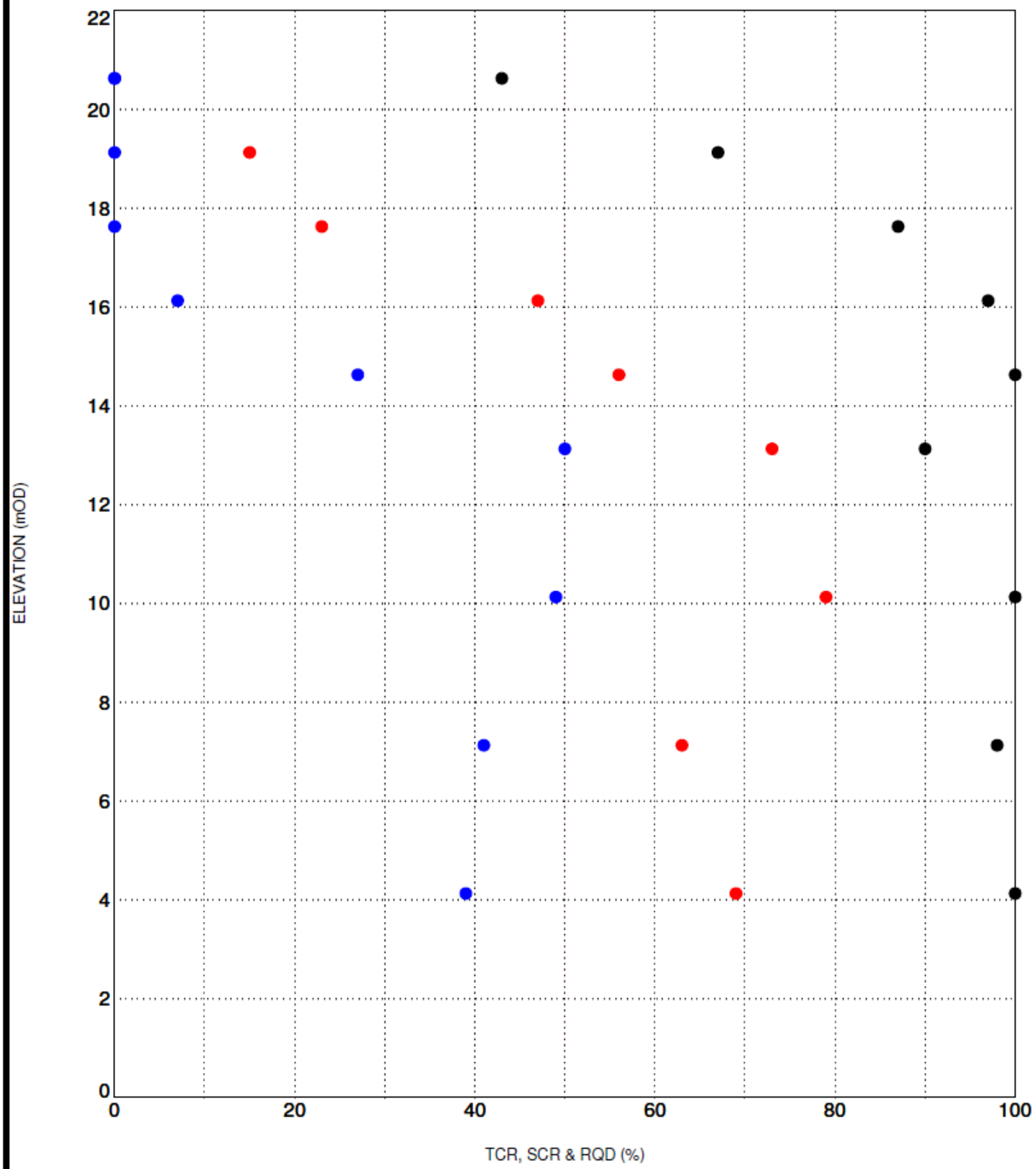
Ref: 1022894 | Date: May 2010



mouchel

Telephone: 01609766667 Fax: 01609766624

Figure 26 - Undrained Shear Strength vs ELEVATION BH4	
Client: SCARBOROUGH BOROUGH COUNCIL	
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY	
Ref: 1022894	Date: May 2010

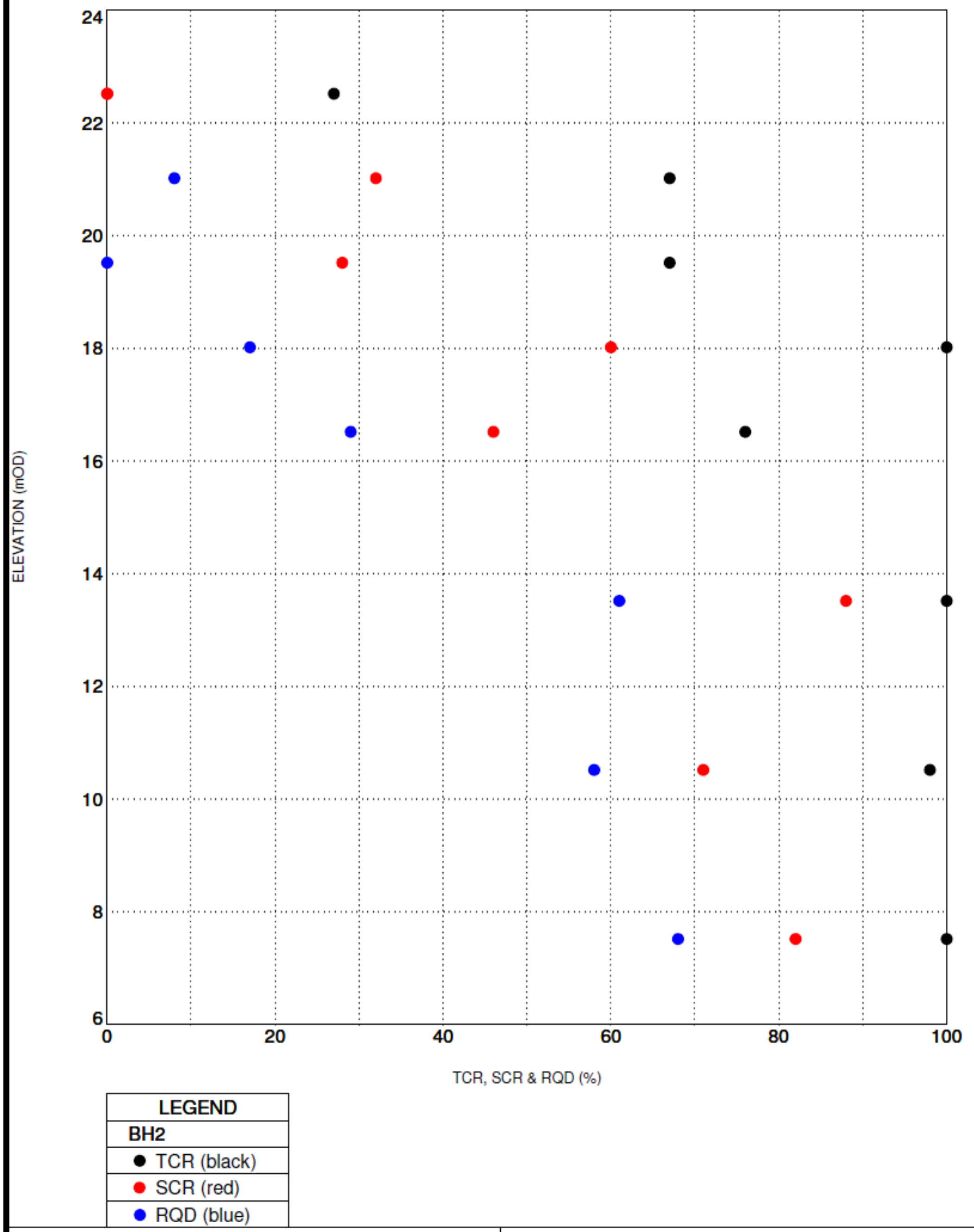


LEGEND
BH1
● TCR (black)
● SCR (red)
● RQD (blue)

mouchel

Telephone: 01609766667 Fax: 01609766624

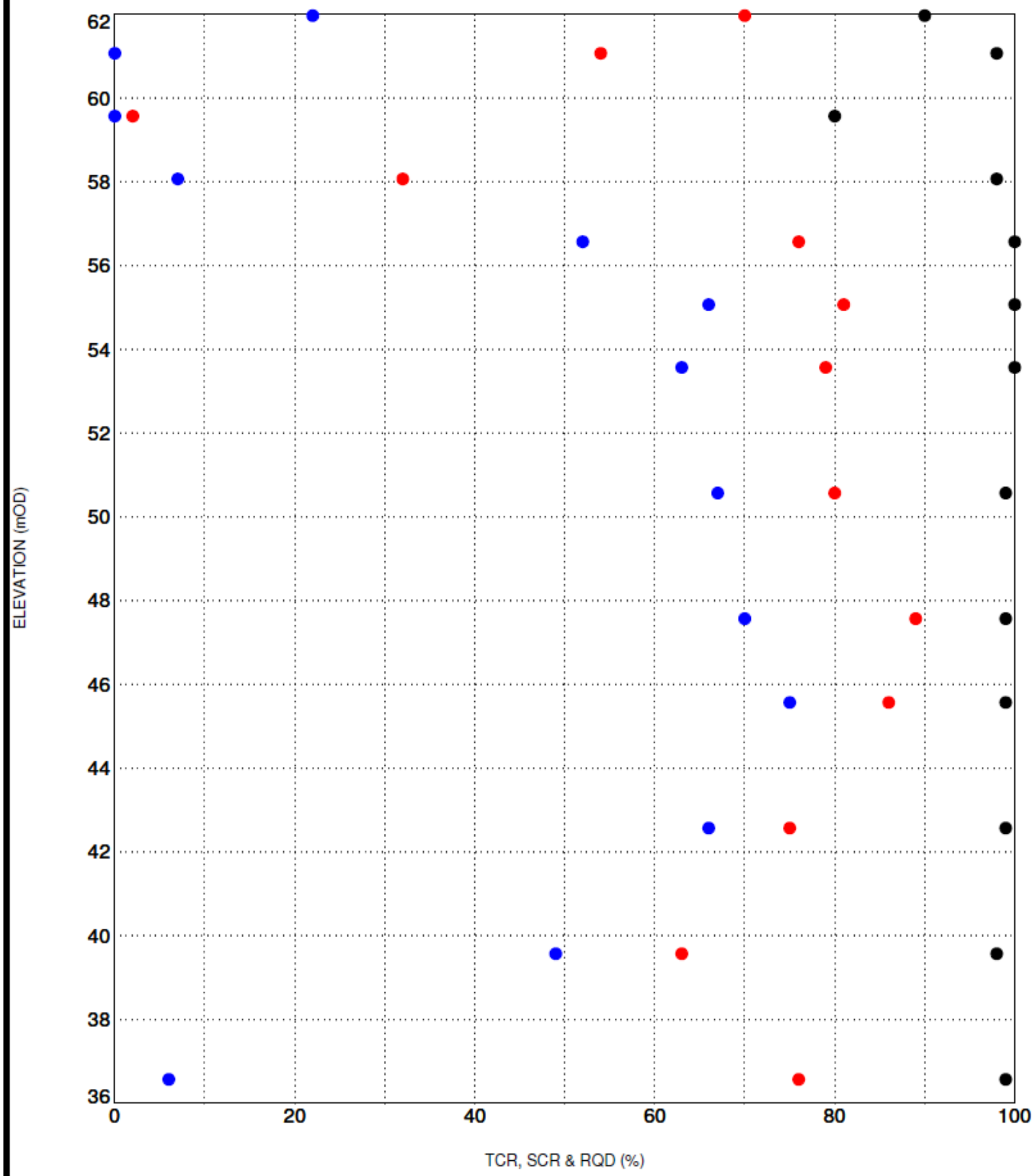
Figure 27 - TCR, SCR & RQD vs ELEVATION Bh1	
Client: SCARBOROUGH BOROUGH COUNCIL	
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY	
Ref: 1022894	Date: May 2010



mouchel

Telephone: 01609766667 Fax: 01609766624

Figure 28 - TCR, SCR & RQD vs ELEVATION BH2	
Client: SCARBOROUGH BOROUGH COUNCIL	
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY	
Ref: 1022894	Date: May 2010



LEGEND
BH4
TCR (black)
SCR (red)
RQD (blue)

mouchel

Telephone: 01609766667 Fax: 01609766624

Figure 29 - TCR, SCR & RQD vs ELEVATION BH4	
Client: SCARBOROUGH BOROUGH COUNCIL	
Project: GROUND INVESTIGATION AT ROBIN HOOD'S BAY	
Ref: 1022894	Date: May 2010

Appendix A: Historic maps

This page is left intentionally blank

Envirocheck®
A Landmark service

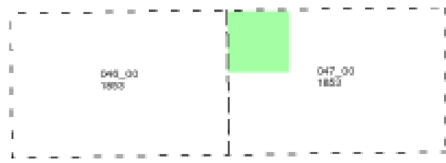
Yorkshire

Published 1853

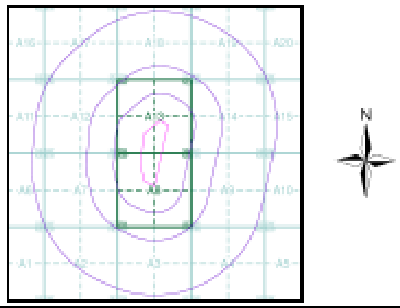
Source map scale - 1:10,560

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)



Historical Map - Slice A



Order Details

Order Number:	27073314_1_1
Customer Ref:	RHB1
National Grid Reference:	495280, 505360
Slice:	A
Site Area (Ha):	9.2
Search Buffer (m):	1000

Site Details

Site at, Robin Hood's Bay, North Yorkshire

LANDMARK® Information Group

Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

A Landmark Information Group Service v33.1 15-Jan-2009 Page 2 of 10

This page is left intentionally blank

Envirocheck®
A Landmark service

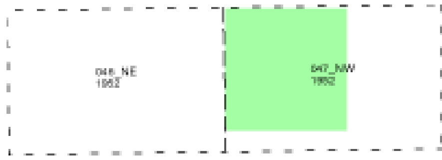
Yorkshire

Published 1952

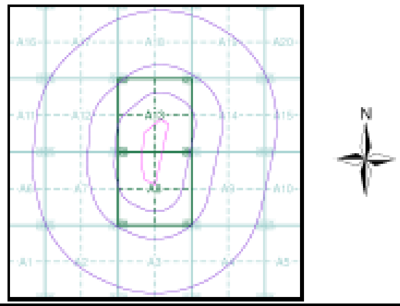
Source map scale - 1:10,560

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)



Historical Map - Slice A



Order Details

Order Number: 27073314_1_1
Customer Ref: RHB1
National Grid Reference: 495280, 505360
Slice: A
Site Area (Ha): 9.2
Search Buffer (m): 1000

Site Details

Site at, Robin Hood's Bay, North Yorkshire

LANDMARK® Information Group
Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

A Landmark Information Group Service v33.1 15-Jan-2009 Page 5 of 10

This page is left intentionally blank

Envirocheck®
A Landmark service

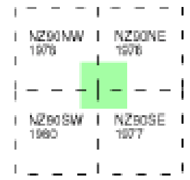
Ordnance Survey Plan

Published 1977 - 1980

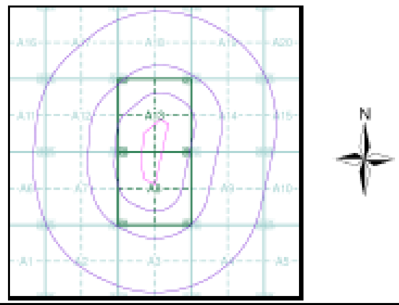
Source map scale - 1:10,000

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)



Historical Map - Slice A



Order Details

Order Number: 27073314_1_1
Customer Ref: RHB1
National Grid Reference: 495280, 505360
Slice: A
Site Area (Ha): 9.2
Search Buffer (m): 1000

Site Details

Site at, Robin Hood's Bay, North Yorkshire

LANDMARK® Information Group
Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

A Landmark Information Group Service v33.1 15-Jan-2009 Page 7 of 10

This page is left intentionally blank

Envirocheck

A Landmark service

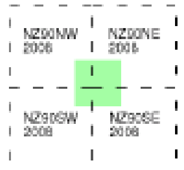
10k Raster Mapping

Published 2008

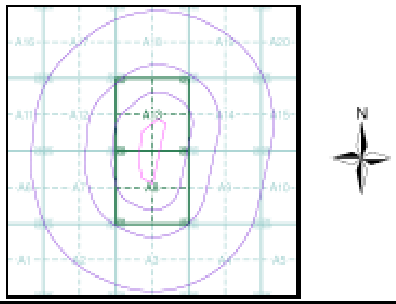
Source map scale - 1:10,000

The historical maps shown were produced from the Ordnance Survey's 1:10,000 colour raster mapping. These maps are derived from Landplan which replaced the old 1:10,000 maps originally published in 1970. The data is highly detailed showing buildings, fences and field boundaries as well as all roads, tracks and paths. Road names are also included together with the relevant road number and classification. Boundary information depiction includes county, unitary authority, district, civil parish and constituency.

Map Name(s) and Date(s)



Historical Map - Slice A



Order Details

Order Number:	27073314_1_1
Customer Ref:	RHB1
National Grid Reference:	495280, 505360
Slice:	A
Site Area (Ha):	9.2
Search Buffer (m):	1000

Site Details

Site at, Robin Hood's Bay, North Yorkshire

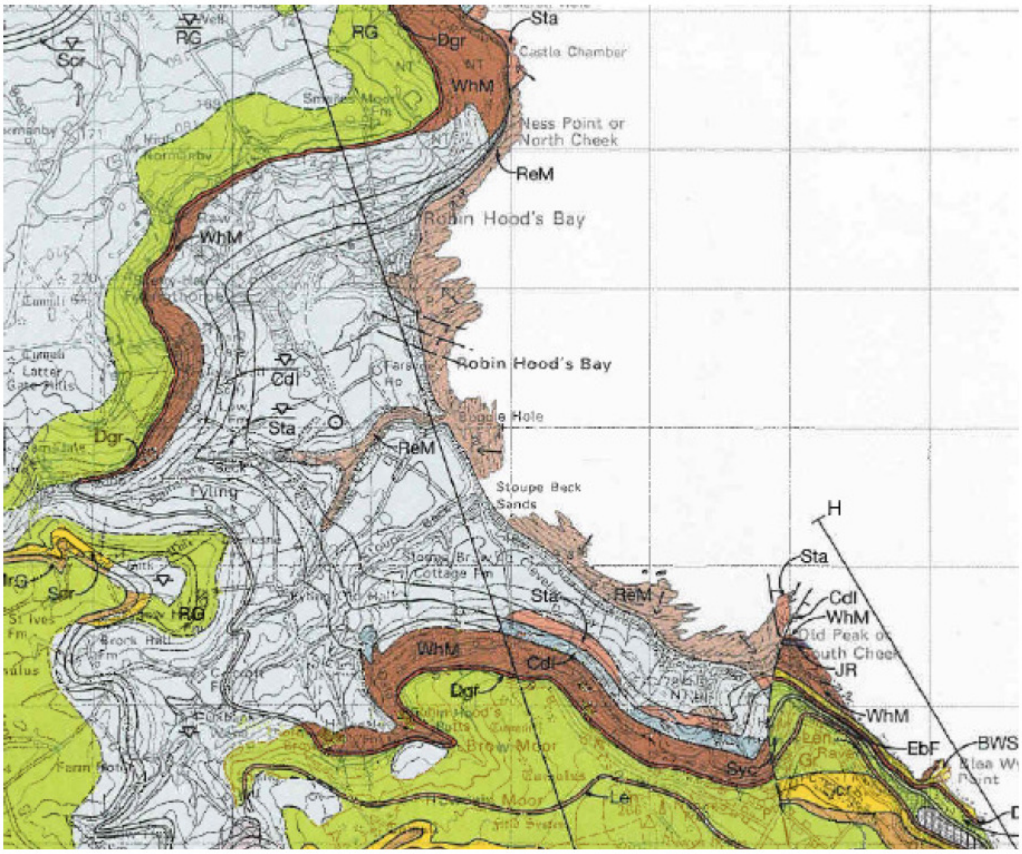
LANDMARK Information Group

Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

A Landmark Information Group Service v33.1 15-Jan-2009 Page 10 of 10

Appendix B: Envirocheck Report on CD

Appendix C: Geological Map



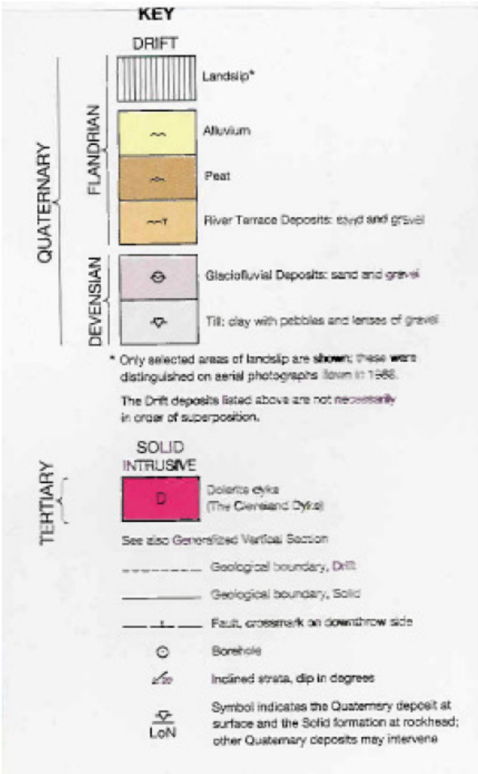
Reproduced from Sheet 35 & 44 Scarborough Solid and Drift
by permission of The British Geological Survey

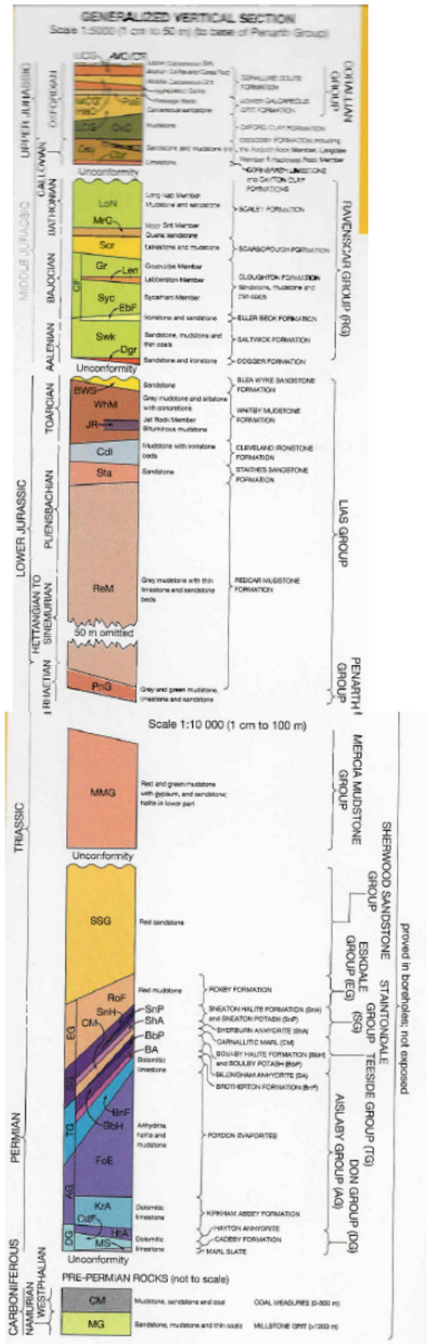
Mouchel Parkman Services Ltd.
Licence No. C04/119-CCSL

A great place to live, work & play

Not to scale

Geological Map	mouchel
Scarborough Borough Council Robin Hood's Bay Strategy Study	Reference: 1022894/GEO/R/01/01 Date: Jun 10





A great place to live, work & play

Key to Geological Map	mouchel
Scarborough Borough Council Robin Hood's Bay Strategy Study	Reference: 1022894/GEO/R/01/01 Date: Jun 10

Appendix D: Extracts from Existing Reports

This page is intentionally blank

County: North Yorkshire **Site Name: Robin Hood's Bay: Maw Wyke to Beast Cliff**

District: Scarborough

Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act, 1981, (as amended)

Local Planning Authority: North York Moors National Park, North Yorkshire County Council, Scarborough Borough Council

National Grid Reference: NZ 941082 – TA 005987 **Area:** 365.25 hectares (ac)

Ordnance Survey Sheet 1:50,000: 94, 101 **1:10,000:** NZ 90 NE, NW, SE
SE 99 NE
TA 09 NW

First Notified: (under 1949 Act): parts notified between 1954–1974

Date Notified: (under 1981 Act): parts notified between 1984–1986

Notified as Robin Hood's Bay: Maw Wyke to Beast Cliff: 26 October 1999

Other Information:
Site formerly notified under the Wildlife and Countryside Act 1981 as Maw Wyke-Millers Nab SSSI, Beast Cliff-Millers Nab SSSI and Hawsker Bottoms SSSI.

A Geological Conservation Review (GCR) Site.

Beast Cliff is nationally important for its coastal/woodland vegetation (listed in "A Nature Conservation Review" edited by D A Ratcliffe (1977), Cambridge University Press).

Robin Hood's Bay: May Wyke to Beast Cliff is nationally important for its low intertidal habitats. Brazier and Holt 1998 – Marine Nature Conservation Review – Sector 5, southeast Scotland – North East England assessment. JNCC.

The site is within the North Yorkshire Heritage Coast and within the North York Moors National Park.

Description and Reasons for Notification:
This site consists of part of the North Yorkshire coast in the vicinity of Robin Hood's Bay, north of Scarborough, from Maw Wyke and Hawsker Bottoms at the northern end to Beast Cliff at the southern end. The site is of importance for five distinct areas of geological interest, the coastal/woodland vegetation at Beast Cliff and the zonation of marine biotopes on the rocky foreshore.

Geology:
The coastal cliffs and foreshore exposures around Robin Hood's Bay and Ravenscar constitute one of Britain's classic geological localities, and have been studied from at least the 1820s.

The site includes an unrivalled and continuously exposed Lower Jurassic sequence dominated by mudrocks of the Lias Group, and capped by sandstones of the Ravenscar Group of early Middle Jurassic age. Throughout the succession there is excellent bio- and chronostratigraphic control based on a very detailed sequence of ammonite faunas. Many of these faunas form the basis for the formal definitions of Biohorizons, Subzone and Zones and the site is therefore of very great importance to European Jurassic chronostratigraphy. The area has also yielded the type specimens of the index species of many of these units.

The Lias Group, represented in ascending order by the Redcar Mudstone, Staithes, Cleveland Ironstone and Whitby Mudstone Formations contains stratotypes for several zones and horizons. This includes a very complete Sinemurian Pliensbachian boundary sequence within the Redcar Mudstone Formation, which may become a Global Stratotype Section and Point. Other highlights include a well preserved succession of biostratigraphical horizons within the Cleveland Ironstone and the most complete Toarcian succession in Britain represented by the Whitby Mudstone Formation.

This Lower Jurassic succession is also of great interest for its sedimentology and its fossil invertebrate faunas which both provide insights into the environmental conditions of the time. Occasional marine reptiles (ichthyosaurs and crocodiles) have been recovered from various levels.

The base of the Middle Jurassic sequence is well exposed around Blea Wyke and includes a relatively thick Dogger Formation with a famous and fossiliferous "Nerinea Bed" of Aalenian (Opalinum to Murchisonae Zone) age. The succeeding dominantly, non-marine Ravenscar Group is well developed including its component Saltwick, Eller Beck, Cloughton and Scarborough Formations (Aalenian to Lower Bajocian).

In the Beast Cliff area a number of plant bearing horizons occur within the Saltwick and Cloughton Formations. Many species occur which are seldom found at Yorkshire's other famous Jurassic plant localities. Many species of filicales, bennettitales, cycads and conifers are recorded from Beast Cliff; a prolific palaeobotanical locality with notable rarities.

Maritime:
The shores of Robin Hood's Bay between May Wyke and Beast Cliff are predominantly rocky, and moderately exposed to wave action. The varied geology along this coast plays a major role in creating an exceptionally wide range of habitats and associated communities for this part of the North Sea coast. Extensive examples of two rocky shore habitats are found here: moderately exposed flat bedrock and moderately exposed large and massive boulder fields. Slightly more exposed areas of the shore, such as at Whitehouse Hole are characterised by biotypes more typical of wave exposed shores.

Areas of gently dipping mudstones, shales and ironstones at the northern end of the site are characterised by complete zonation of rocky shore biotopes from the lichen-dominated *Verrucaria maura* biotope at the top of the shores, through fucoid biotopes characteristic of moderately exposed shores *Pelvetia canaliculata*, *Fucus spiralis*, *F. vesiculosus*, *F. serratus* into the kelp zone *Laminaria digitata* the latter which straddles the low water mark. In the Far Jetticks area, good quality, extensive areas of two nationally scarce red algal turf biotopes *Osmundea pinnatifida* and *Corallina officinalis* replace the more common fucoid-dominated biotopes and occupy much of the intertidal zone from the base of the cliff to the kelp zone. Here, the finely roughened bedding planes of mudstones belonging to the Cleveland Ironstone Formation provide surfaces for the firm attachment of holdfasts. The low shore kelp zone *Laminaria digitata* straddles the low water mark and forms the transition to highly rated subtidal kelp forest biotopes.

Robin Hood's Bay contrasts well with the Maw Wyke area as it is slightly more sheltered (but still falls within the moderately exposed selection unit). This area is particularly noteworthy for its rich and varied low shore communities, particularly the *Fucus serratus* and *Laminaria digitata* biotopes on bedrock and boulders. The presence of the relatively stable medium and large boulders provides additional habitats beneath and between the boulders for a wide variety of animal groups including sponges, anemones, bryozoans, crabs and shore fishes.

Along the southern section of the site, the shore between Blea Wyke and Beast Cliff is predominantly composed of large and massive boulders resting on a mudstone platform. The biology of this area again demonstrates the underlying effects of active geological processes. The upper shore lacks typical fucoids and is instead made up of ephemeral communities of green and red algae *Enteromorpha* sp., and *Porphyra* sp. This composition reflects the unstable nature of the friable upper shore talus beneath the cliffs. In the mid- and low-shore areas the boulders are characterised by typical biotopes of fucoids, kelps and red algal turfs. Areas of the shore lying below recent stumps, are dominated by dense turfs of the nationally uncommon *Rhodothamniella floridula* biotope which tolerates sediment scouring by binding sediment to form a cushion-like turf.

Hawsker Bottoms is also a key palaeobotanical and stratigraphical site and has the best inland exposure of the Scarborough Formation, here near the northern limit of its outcrop. It has provided one of the most varied fossil faunas from this portion of the Middle Jurassic, including the only corals so far recorded from this formation. The nearby Maw Wyke is an outstanding locality of national importance for the study of fossil ferns. A lens, within the Saltwick Formation, yielded particularly fine examples of the genera *Coniopteris*, *Cladophlebis* and *Phlebopteris* including fertile axes essential to systematic studies.

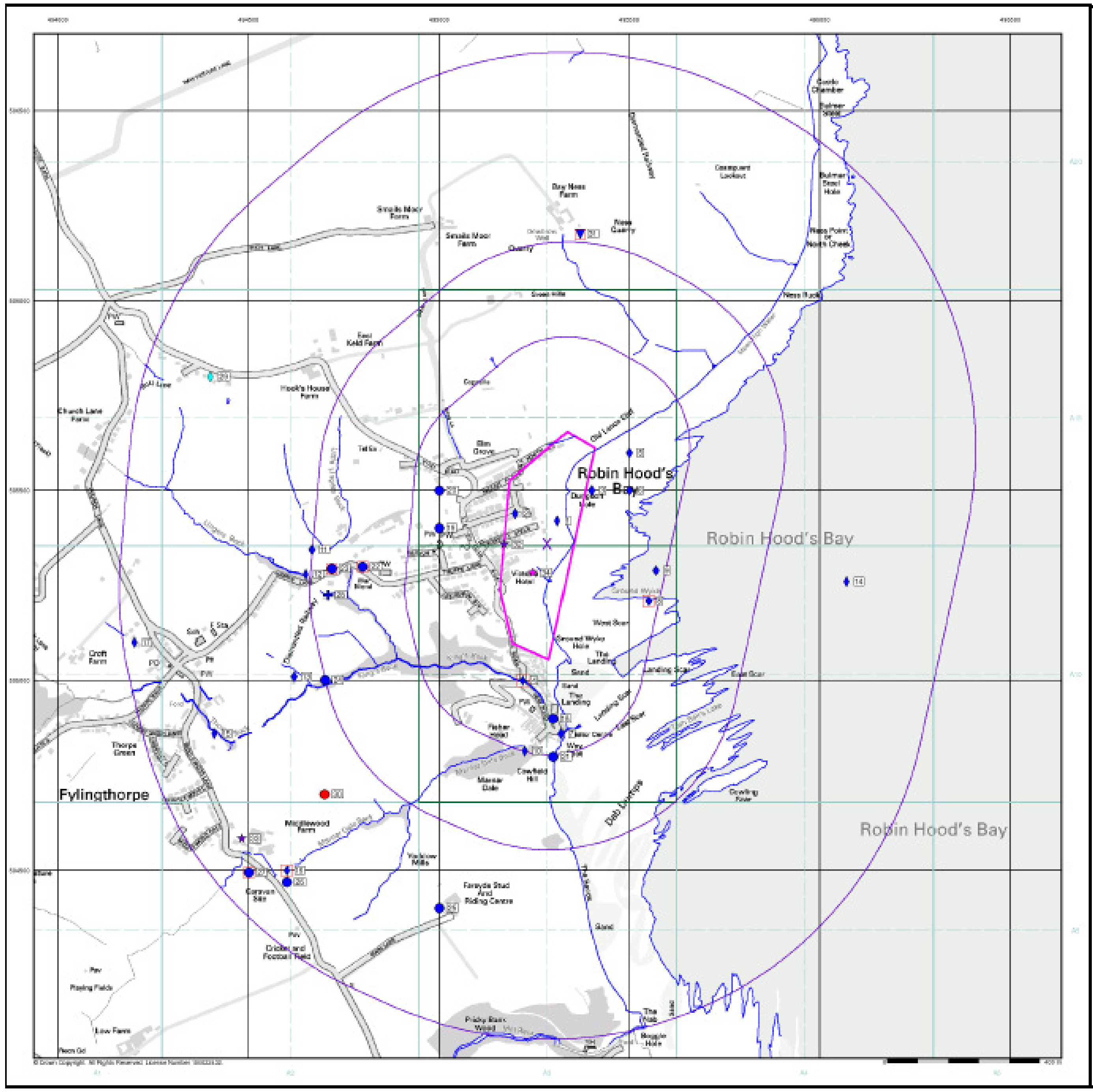
Robin Hood's Bay is an important site for coastal geomorphology for a series of well-developed shore platforms cut mainly across the outcrops of Lower Lias shales – siltstone rhythms. The surface morphology of the platforms reflects the arrangement of bedding within a broadly anticlinal structure which has been planed off. The cliffs near North Check and South Check include Middle Lias sandstones, relatively more resistant than the Lower Lias shales, whilst those within the Bay predominantly occur in Lias shale till and are locally affected by considerable mass movements. Robin Hood's Bay provides important contrasts with other platform sites, firstly through its location within the area affected by North Sea wave climates, and secondly in having been subject to glacial and post-glacial processes prior to sea-level reaching its present condition. The greater variety of interest, stratigraphical, palaeontological and geomorphological, make the Hawsker-Robin Hood's Bay-Ravenscar-Beast Cliff area one of the most famous and important for British Geology.

Biology:

Much of Beast Cliff is covered by scrub and woodland. Ash *Fraxinus excelsior* dominates the canopy with birch *Betula* spp., hazel *Corylus avellana* and field maple *Acer campestre*, although in more acidic situations oak *Quercus* aff. *robur*, rowan *Sorbus aucuparia* and holly *Ilex aquifolium* are frequent. Great wood-rush *Luzula sylvatica* is abundant on the steep flushed slopes, whilst dog's mercury *Mercurialis perennis* and opposite-leaved golden-saxifrage *Chrysosplenium oppositifolium* are plentiful in the ground flora of the terrace. Sandstone boulders support a luxuriant growth of mosses and ferns, including hart's-tongue *Phyllitis scolopendrium* and soft shield-fern *Polystichum setiferum*. Pools on the cliff shelf have been colonised by common club-rush *Schoenoplectus lacustris* and are fringed by alder *Alnus glutinosa*, willow *Salix* spp., and greater tussock-sedge *Carex paniculata*.

North of Beast Cliff the vegetation is more open and reflects alternating strata of rich and poor base-status. Typical of more calcareous clays are quaking-grass *Briza media*, glaucous sedge *Carex flacca*, kidney vetch *Anthyllis vulneraria* and grass-of-Parnassus *Parnassia palustris*, whereas heather *Calluna vulgaris*, bell heather *Erica cinerea*, crowberry *Empetrum nigrum*, goldenrod *Solidago virgaurea* and wavy hair-grass *Deschampsia flexuosa* characterise more acidic sandstone outcrops. Bracken *Pteridium aquilinum* and various shrub species such as gorse *Ulex europaeus*, broom *Cytisus scoparius*, goat willow *Salix caprea* and rowan *Sorbus aucuparia* are present in varying densities over much of the site.

Appendix E: Map showing Sensitive Land Use



Envirocheck®
A Landmark service

General

- Specified Site
- Specified Buffer(s)
- Bearing Reference Point
- Map ID
- Several of Type at Location

Agency and Hydrological

- Contaminated Land Register Entry or Notice (Location)
- Contaminated Land Register Entry or Notice
- Discharge Consent
- Enforcement or Prohibition Notice
- Integrated Pollution Control
- Integrated Pollution Prevention Control
- Local Authority Integrated Pollution Prevention and Control
- Local Authority Pollution Prevention and Control
- Local Authority Pollution Prevention and Control Enforcement
- Pollution Incident to Controlled Waters
- Prosecution Relating to Authorised Processes
- Prosecution Relating to Controlled Waters
- Registered Radioactive Substance
- River Network or Water Feature
- River Quality Sampling Point
- Substantiated Pollution Incident Register
- Water Abstraction
- Water Industry Act Referral

Geological

- BGS Recorded Mineral Site

Industrial Land Use

- Contemporary Trade Directory Entry
- Fuel Station Entry

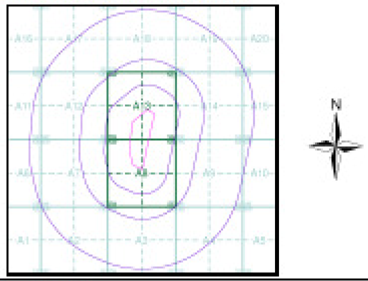
Waste

- BGS Recorded Landfill Site (Location)
- BGS Recorded Landfill Site
- EA Historic Landfill (Buffered Point)
- EA Historic Landfill (Polygon)
- Integrated Pollution Control Registered Waste Site
- Licensed Waste Management Facility (Landfill Boundary)
- Licensed Waste Management Facility (Location)
- Local Authority Recorded Landfill Site (Location)
- Local Authority Recorded Landfill Site
- Registered Landfill Site
- Registered Landfill Site (Location)
- Registered Landfill Site (Point Buffered to 100m)
- Registered Landfill Site (Point Buffered to 250m)
- Registered Waste Transfer Site (Location)
- Registered Waste Transfer Site
- Registered Waste Treatment or Disposal Site (Location)
- Registered Waste Treatment or Disposal Site

Hazardous Substances

- COMAH Site
- Explosive Site
- NIHHS Site
- Planning Hazardous Substance Consent
- Planning Hazardous Substance Enforcement

Site Sensitivity Map - Slice A



Order Details

Order Number: 27073314_1_1
Customer Ref: RHB1
National Grid Reference: 495280, 505360
Slice: A
Site Area (Ha): 9.2
Search Buffer (m): 1000

Site Details

Site at, Robin Hood's Bay, North Yorkshire

LANDMARK Information Group

Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

A Landmark Information Group Service v33.1 15-Jan-2009 Page 1 of 3

Appendix F: Site Walkover Notes

This page is left blank intentionally

21st January – Robin Hood's Bay

The Victoria Hotel was protected by High Point Rendel's stabilisation scheme, carried out in 2000/2001. This comprised the regrading, piling and drainage of the slope immediately to the south of the Victoria Hotel, and protection of the cliff line through the construction of a reinforced earth sea wall and emplacement of a rock armour revetment. This work was carried out in order to retain the road which is required for viability of the lower village.

The newly regraded and regrassed land comprises glacial till overlying a steep rock cliff. A back-scarp is present near the entrance to the area, sloping down to a benched region with picnic tables installed. Below the bench the till slopes gently down to meet the edge of the rock cliff. One row of horizontal drains were installed at the base of the till slope above the rock cliff.

Immediately to the north of the regraded area are cliffs of about 50m in height. The lower half of the cliff comprises a vertical rock face, above which is 20-25m of glacial till showing much evidence of slumping.

The now-regraded area was originally a valley due to preferential erosion of the softer mudstones which had been uplifted into the core of the anticline which centres on Robin Hood's Bay. During glaciation the centre of the valley was infilled with thicker deposits of till than the valley sides to the north and south.

The instability of the cliffs at Robin Hood's Bay has two primary causes: groundwater causes softening of the till leading to slumping and superficial landslides, while the rock cliffs are slowly retreating due to coastal erosion. Treatment must target both factors in order to be effective.

At low tide a rock shelf is exposed, largely covered in seaweed. Boulders are present on the foreshore at the base of the cliffs due to erosion of the rock cliffs. The till slopes are vegetated, largely with grasses and gorse. A small stream is evident flowing from the Old Rocket House on the cliff top and outfalling about 50m from the end of the slipway. The stream feeding the waterfall runs in a small channel which is more densely vegetated than the surrounding slope, with willow and other trees present.

Robin Hood's Bay lies in a designated SSSI area. The cliffs within the study area are of national importance geologically.

Location 1

A localised slippage was observed to the south of the waterfall and stream (at the edge of the village). A significant back-scarp is present halfway up the till slope.

An extensive area of very wet ground is present on the bench in the glacial till. Ponding of the stream on the impermeable till has caused marshy conditions and the growth of bulrushes/reeds on top of the rock cliffs.

Location 2

An extensive area of eroded/landslipped till slope lies beyond the waterfall, to the north east. A slump is present at the toe of the slope. The till cliffs are steep, with gradients at around 40 degrees. At the top of steep rock cliffs, the slumped till is soft and very wet. Some obvious pockets of more sandy material and gravel are present within the till, some with possible signs of water seepage. The rest of the clay is plastic and soft.

Local experience of the Yorkshire coast indicates that superficial, high-angled, steep landslides are the most common form of instability. Deep rotational slips, as at the Holbeck Hotel in Scarborough, are less usual. There are few big landslip locations, mostly just gradual superficial slumping.

Location 3

The footpath at the front of the housing is now a public right of way. In front of the house at the far north eastern extreme of the village only a fence separates the footpath from the top of the cliff slope. This property is therefore very close to the cliff top.

The field immediately to the north of this house is open farmland (grass) National Trust land and provides a possible borehole location (BH06). Access is provided by an unsurfaced lane to the rear of the properties and a large gate in the field boundary.

Location 4

The second house eastwards (a bungalow named “Overdale”) is about 20m from edge of cliff. It has a flat garden.

There is no access to the front of the gardens from the cliff edge south of the property Mat Tree the footpath having been closed legally in 2007. It was therefore not possible to access the top of the cliff slope between locations 4 and 8.

Location 5

The large garden of the “Kenmore” property has ridge and furrow features and is quite extensive to the cliff edge. This is a possible area for investigation, with a rough grassed area near to the edge of the cliff (but north of the hedge) as a potential borehole location (BH05).

Location 6

A rough grass field is accessed from The Close. This is a possible borehole location (BH04).

Location 7

The Old Rocket House is surrounded by steep, tree/bush covered slopes. Good access is provided via a small road along the back of the Victoria Terrace houses.

The footpath to the north was closed in 2007.

This is a possible borehole location (BH02). Another possible location (BH03) is the corner of the garden of the adjacent property named “Two Gates”.

Location 8

A shallow, stone-lined channel runs to the north side of the Old Rocket House, before joining a stream emerging between the gardens of the “Cliff Cote” and “Raven Hill” properties.

Location 9

A stream flowing rapidly southwards from further inland emerges between the gardens of the “Cliff Cote” and “Raven Hill” properties. This is culverted under the access road to the Old Rocket House in a 9 inch plastic pipe.

Location 10

The Victoria Hotel Car Park has a drain around the edge of the hard standing on the south side of the hotel. A monitoring or survey point is present, drilled into the edging of the drain. The grassed area to the front of the hotel is at a lower level, possibly due to regrading in the recent stabilisation works.

The wall on the north edge of the car park is damaged, probably due to growth of vegetation. The damage comprises several stepped cracks.

The corner of the car park is a possible borehole location (BH01).

Location 11

A short length (10m) of concrete wall is exposed (0.5m in height) on the southern portion of the recently stabilised area. It lies more than halfway down the slope from the houses at the top of the hill to the back of the new wall. This is at Ground Wyke Hole and is identified elsewhere as a sea defence. The sheet piled wall constructed to support The Esplanade has been buried in the recent stabilisation works.

A great place to live, work & play

Site Walkover Location Plan	mouchel
Scarborough Borough Council **Robin Hood's Bay Strategy Study**	**Reference: 1022894/GEO/R/01/01** **Date: Jun 10**

Site Walkover Photographs: Previous Works

Site Walkover Photograph 1

Site Walkover Photograph 2

Site Walkover Photograph 3

Site Walkover Photograph 4

Location 1

Site Walkover Photograph 5

Site Walkover Photograph 6

Location 2

Site Walkover Photograph 7

Location 4

Site Walkover Photograph 8

Dungeon Hole Photos

Site Walkover Photograph 9

Appendix G: Photographs

This page is left blank intentionally

Photograph 1: Ground material close-by window sampling area

Photograph 2: Recent slope failure near window sampling area

Photograph 3: Recent slope failure below the Rocket House (BH2)

Photograph 3: As above

Photograph 4: Waterfall adjacent to Victoria Terrace

Photograph 5: General view of Robin Hood's Bay with Victoria Terrace and Rocket House in the background

Photograph 6: General view of cliffs at window sampling area

Photograph 7: Cliffs beneath Rocket House

Photograph 8: Cliffs beneath Rocket House and borehole 2

Photograph 9: Coastline looking north.

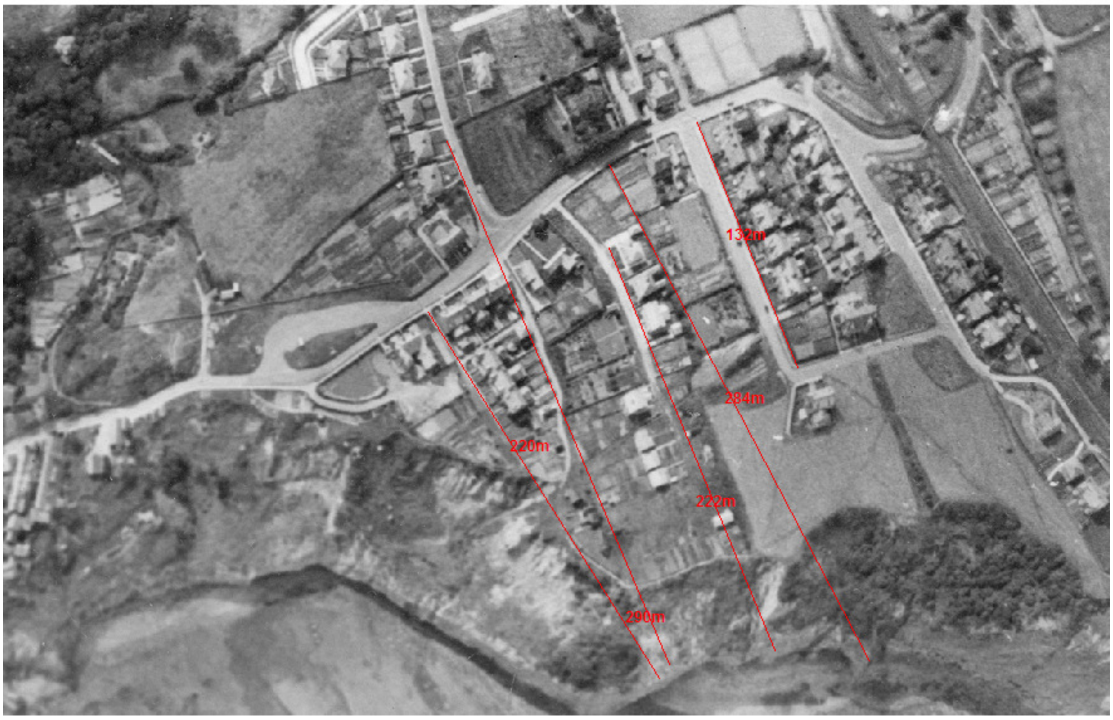
Photograph 10: Coastline of study area

Photograph 11: General view of coastline showing existing seawall south of study area

Photograph 12: Stream flowing down from rocket house to close to window sampling area.

Appendix H: Aerial Photographs

1940 – Measurement to top of cliff



1962 - Measurement to top of cliff

1940 – Measurement to top of coastal slope

1962 – Measurement to top of coastal slope

2008 – Measurement to top of coastal slope

This page is left intentionally blank