A30 Chiverton to Carland Cross
Environmental Statement

Volume 6 Document Ref 6.4 ES Appendix 9.2
WSP Ground Investigation Report

HA551502-ARP-EGT-SW-RP-LE-000005

August 2018

Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure)
Regulations 2009 (as amended)
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highways
england

A30 Chiverton to Carland Cross

Ground Investigation Report

HA551502-WSP-VGT-0000-RE-GE-00001

HAGDMS No. 29883

September 2017
Highways England

Geotechnical Certificate

Scheme Title: A30 Chiverton to Carland Cross

Geotechnical Certificate

Certificate Seq. No 002

GEOTECHNICAL CERTIFICATE

Form of Certificate to be used by the Designer for certifying the design of geotechnical works

1. We certify that the Reports*, Design Data*, Drawings* or Documents* for the Geotechnical Activities listed below have been prepared by us with reasonable professional skill, care and diligence, and that in our opinion:

   i. constitute an adequate and economic design for the project
   ii. solutions to all the reasonably foreseeable geotechnical risks have been incorporated
   iii. the work intended is accurately represented and confirms to the Employer's*/Clients* requirements
   iv. with the exception of any item listed below or appended overleaf, the documentation has been prepared in accordance with the relevant standards from the Design Manual for Roads and Bridges and the Manual of Contract Documents for Highway Works.

2. LIST OF REPORTS, DESIGN DATA, DRAWINGS OR DOCUMENTS

HA551502-WSP-VGT-0000-RE-GE-00001 A30 Chiverton to Carland Cross Ground Investigation Report

3. DEPARTURES FROM STANDARDS

None

*4. INCORPORATION OF GEOTECHNICAL DATA INTO CONSTRUCTION DETAILS

N/A.

Signed: ....
Designer (Designers Geotechnical Advisor)

Name: KD Power

Date: 07-Sept-2017

On behalf of WSP

Signed: ....
Contractor (Agent or Contracts Director)

Name: ....

Date: ....

On behalf of ....

This Certificate is:

(a) received* (see note)
(b) received with comments as follows:* (see note)
(c) returned marked "comments" as follows:* (see note)

Signed: ....
Overseeing Organisation Geotechnical Advisor

Name: ....

Date: ....

Note:

'RECEIVED' = SUBMISSION ACCOMPANYING CERTIFICATE IS ACCEPTED.
'RECEIVED WITH COMMENTS' = SUBMISSION ACCOMPANYING CERTIFICATE GENERALLY ACCEPTABLE BUT REQUIRE MINOR AMENDMENT WHICH CAN BE ADDRESSED IN SUBSEQUENT REVISIONS.
'RETURNED MARKED COMMENTS' = SUBMISSION ACCOMPANYING CERTIFICATE UNACCEPTABLE AND SHOULD BE REVISED AND RESUBMITTED.

Content

Drawings

1. Executive Summary

This report details the ground investigation undertaken for the proposed dualling of the existing single carriageway A30 between Chiverton and Carland Cross in Cornwall. It describes existing information about the site, the scope and objective of the investigation undertaken and summarises the ground conditions encountered. It also discusses material properties and presents a Geotechnical Risk Register for the project.

The prosed scheme is a predominantly off-line proposal for upgrading of the existing single carriageway to a dual carriageway highway. The existing highway will be de-trunked and become a local secondary route owned and managed by Cornwall Council.

1.1 Ground & Groundwater Conditions

Other than topsoil materials limited superficial deposits were encountered along the length of the proposed route. Where encountered they comprised Alluvium and limited occurrences of Made Ground.

Bedrock was encountered in all investigation positions and comprised both sedimentary and metamorphic rocks of the Gramscatho and Looe Basin Successions. They comprised mudstones and sandstones and interbedded phyllites and psammites. Three formations were encountered; Porthtowan Formation in investigations south of Marazanvose, Grampound Formation was encountered in positions north of Marazanvose and south of Carland Cross and Trendrean Mudstone Formation was encountered north and east of Carland Cross roundabout.

All bedrock has been classified according to weathering grade in accordance with BS EN ISO 14689-1:2003 and comprises residual soils through to fresh rock. In consideration of engineering properties, each formation can be considered as both a soil and a rock subject to the weathering grade and as such a bedrock level has been identified and discussed in detail.

Installation of groundwater monitoring standpipes was completed as part of the ground investigation, with a total of six months continuous monitoring to be concluded in September 2017.

Geotechnical risks for the scheme have been considered with those specific to structures and earthworks along the scheme included in the Geotechnical Risk Register.

1.2 Human Health Risk Assessment

Generic quantitative risk assessments (GQRAs) were undertaken to evaluate potential risks posed by soil or groundwater to human health and controlled waters receptors. The potential sources of contamination considered were Made Ground associated with the existing A30 alignment and historical mining for metals including lead, zinc and copper.

On the basis of the human health GQRA, ground conditions are not considered likely to pose a risk to human health receptors in a commercial land use scenario.

The controlled waters GQRA identified widespread exceedances of the generic assessment criteria (GAC) for lead and zinc, which is considered likely to be associated with the known historical Cargoll Mine; exceedances of polycyclic aromatic hydrocarbons (PAHs) including anthracene, benzo(a)pyrene, and fluoranthene; and detections of various petroleum hydrocarbon fractions (particularly at BH-R-032, TP-P-09, and TP-R-OO4A). It is recommended that further sampling (of soils and surface water) and risk assessment is undertaken for these substances.

2. Introduction

2.1 Objective of the Report

WSP was contracted by Highways England (HE) to undertake an appraisal of a preferred route option, for the proposed dual carriageway upgrading of the existing A30 between Chiverton and Carland Cross.

All works have been undertaken in accordance with HD22/08 (Ref. 1) and BS EN 1997-2 (Ref. 2).

The objectives of this report are to:

- Describe the ground investigation undertaken.
- Present a representative ground model along the length of the proposed scheme.
- Provide derived geotechnical parameters for design.
- Develop a geotechnical risk register for the proposed construction works.

2.2 Scope of Work

The scope of this report is to present the findings of a geotechnical ground investigation designed by WSP.

The primary objective of the work has been to investigate the ground conditions along the preferred route option to inform structural and earthworks design elements of the scheme.

The ground investigation was completed between 31st January and 24th March 2017 by site investigation contractor, Structural Soils Ltd. The findings of the ground investigation have been presented in Structural Soils Ltd – A30 Chiverton to Carland Cross, Factual Report June 2014 (Ref. 7). The Factual Report has been submitted to Highways England as a standalone report and is presented as Appendix B.

In order to meet the objectives described above, the following general scope of works was undertaken:

- An intrusive ground investigation comprising plate load testing, dynamic sampling, rotary drilling, trial pitting and soakaway testing.
- Logging of soil arisings and rock core, collection of soil and rock samples and the installation of groundwater monitoring wells fitted with groundwater data logging 'divers' for long term hourly data collection.
- In-situ geotechnical testing.
- Geotechnical and geo-environmental laboratory testing of soil and rock samples.
- Monitoring of groundwater.
- Derivation of derived geotechnical parameters for structural and earthwork design.
- Develop a geotechnical risk register for the works.

2.3 Description of the Project

The scope of the scheme is to upgrade approximately 12.5 kilometres of existing single carriageway to dual carriageway highway along the A30 between Chiverton roundabout and Carland Cross roundabout. The scope includes upgrading the junctions at Chiverton Cross, Carland Cross and the key intermediate junctions, which provide connections to the local highway network.

The upgrade consists of a predominantly off-line design with the majority of the alignment located across agricultural fields. The road trace occasionally crosses over the existing A30 and smaller county roads. The design includes 8 structures associated with the road including 5 under-bridges, 2 over-bridges and 1 accommodation bridge.

At the time of investigation the section route options were still under development between chainage 7100m and 8500m (Marazanvose section). Due to considerations to local residents and their potential sensitivity to the scheme it was determined by the client that the investigation for this section of the scheme was to be placed in abeyance until finalised route options were agreed.

In addition to the Marazanvose section a further section of works was omitted from the scope of investigation due to potential access and ecological issues. This area of concern was located between chainages 12700m and 12900m.

2.4 Site Description

The area surrounding the existing A30 carriageway is predominantly rural agricultural land with numerous renewable energy developments in the form of wind turbines and solar energy parks. There is an abandoned water filled quarry located at approximate chainage 12700m with assumed overgrown tramway emanating from the south western edge. Land surrounding the quarry has not been managed or maintained for a period of years and has a significantly different flora and fauna to the rest of the scheme typified by mature pines surrounding the quarry and extents of heath land. There are occasional residential properties located along the length of the existing highway. The scheme is in the proximity of the Cornwall and West Devon Mining Landscape World Heritage Site located 75m to the south west of the Chiverton roundabout, however, the current proposed route should not impact upon this area. The scheme is also adjacent to Chyverton Park, a registered park and garden, and the Newlyn Downs Special Area of Conservation and Cornwall Area of Outstanding Natural Beauty (AONB); in addition to numerous sites of special scientific interest and scheduled heritage features.

The site location is shown in Drawing No. 001.

The scheme starts with marker post ID 53/0 and finishes around marker post ID 66/8.

The topography for the proposed route is summarised in Table 2-1.

Table 2-1 Summarised Topography

Chainage (m)	Heights (mAOD)	General Description
600 - 900	122.23 – 147.17	Gradual uphill slope with minor gentle undulations.
900 – 1800	147.17 – 131.22	Very gentle downhill slope with minor gentle undulations.
1800 – 2700	131.22 – 142.99	Gentle uphill slope with minor gentle undulations.
2700 – 4200	142.99 – 96.33	Gradual downhill slope with minor gentle undulations
4200 – 5200	96.33 – 121.30	Gentle uphill slope with minor undulations
5200 – 6100	121.30 – 79.38	Gradual becoming steep downhill slope with minor gentle undulations.
6100 – 6600	79.38 – 100.80	Gradual uphill slope with very minor gentle undulations
6600 – 7200	100.80 – 78.48	Steep becoming gradual downhill slope with slight gentle undulations.
7200 – 7800	78.48 – 100.66	Gradual uphill slope with gentle minor undulations.
7800 – 8500	100.66 – 107.01	Flat becoming steep uphill slope with moderate undulations.
8500 - 9000	107.01 – 68.60	Steep downhill slope with minor undulations.
9000 - 13400	68.60 – 143.82	Steep becoming gentle uphill slope with minor stepped undulations becoming minor gentle undulations.
13400 - 14200	143.82 – 118.20	Gentle becoming steep uphill slope with minor gentle undulations.

2.5 Geotechnical Category

In accordance with Design Manual for Roads and Bridges, HD22/08 (Ref. 1) the scheme has been categorised as a Geotechnical Category 2 project.

2.6 Other relevant Information

A Preliminary Sources Study Report (PSSR) issued May 2017, HAGDMS Ref. No. 29326, has been utilised and referred to during the production of this report (Ref. 6).

Archaeology

All trial pitting works were supervised by an archaeologist under a watching brief to record any potential archaeological interest. Supervision was provided by provided by Cornwall Council's Archaeology Unit (Ref. 11).

Ecological Considerations

The site was surveyed by WSP ecologists prior to commencing fieldworks to ensure no protected species or their habitats were disturbed. The potential for nesting birds was identified at the later stages of ground investigation and appropriate mitigation was developed to minimise the risk to ground nesting birds. Also, a badger sett was identified in close proximity (<30m) to the proposed ground investigation position BH-R-074 which was subsequently cancelled to ensure compliance with wildlife legislation.

Surface Water Features

Several groundwater springs were identified beneath or immediately adjacent to the line of the proposed alignment of the highway.

Table 3-1 in Section 3 of the report provides a brief description of each area of spring and potential conflicts with the proposed scheme.

Soft Ground

Table 2-2 Summary of soft ground locations

Approximate Chainage (m)	Details
3500 – 4000	Notably softer ground conditions during ground investigation works. Locally lower than surrounding topography. Landowner indicated locally wet (soft) conditions not drying out until mid to late summer.
6000	Some soft ground encountered at the base of the valley during ground investigation fieldworks.
7000	Soft ground during winter months. Possibly as a result of surrounding topography and surface
9250	Land surrounding stream at base of small valley extremely soft. Tenant indicated all year round issue.
10380 - 10550	Land surrounding ponds extremely soft. Tenant indicated all year round issue.

Significant Services

There is a high pressure gas main located beneath the footprint of the proposed highway at various locations along the design route. There is a notable interaction in the proximity of the replacement Carland Cross roundabout and around Nanteague farm. The gas main is shown on the constraints Drawing No. 11.

An abandoned oil pipeline is located between approximate chainages 11700m and 12200m at a skewed angle beneath the proposed line of the highway. During fieldworks it was confirmed via verbal communications with St Mawgan’s airbase that the pipeline was no longer in use and had been flushed with sections removed. Therefore, the service is believed to be no longer operational though will need to be removed or protected during highway construction. See Drawing No. 11 for location.

Mining

During the fieldworks landowner Frank Matthews anecdotally identified an abandoned mine shaft on his land. The shaft is located at approximate chainage 12070m and approximately 35m south of the proposed centreline.

3. Existing Information

3.1 General

Information for this chapter has been developed from the PSSR issued by WSP, May 2017 (Ref. 6) and updated from field observations during the ground investigation works.

3.2 Topographical Maps

Site wide topographic surveys were undertaken along the length of the preferred route, these were completed in early 2017.

The topography of the site is typified by undulating agricultural fields separated by hedgerows, as summarised in Table 2-1.

3.3 Geological Maps and Memoirs

The region comprises a varied geology, but is mainly underlain by Upper Palaeozoic rocks of Devonian age. The Variscan Orogeny, a mountain building event which commenced in the Devonian, deformed and variably folded and faulted these rocks. Minor granite intrusions of later Carboniferous to early Permian age occur near the coast and Cenozoic deposits are present locally around St Agnes in the west. The regional strikes are generally east–west to northeast-southwest. Many of the mineral veins and mines in this region follow parallel to these strikes as referenced by the British Geological Society, (1990) Falmouth, solid & drift, sheet 352, scale 1:50,000. (Ref. 8) and British Geological Society, (2011) Newquay, bedrock & superficial, sheet 346, scale 1:50,000 (Ref. 9).

3.4 Local Geology

The published geology of the area indicates that it is dominated by well fractured Mid Devonian interbedded mudstones, slates, siltstones and sandstones. The strata in the region have a prevailing dip to the south, but the rocks have been strongly deformed and folded. There are numerous intrusive dykes recorded crossing this area. Mineralisation in the area occurs in planar structures known as lodes, which occupy former fissures in the bedrock.

The published geology is fully described in the PSSR (Ref. 6).

3.5 Superficial Deposits

Reference to BGS map sheets (Ref. 8) and (Ref. 9) and the BGS Geology of Britain viewer (Ref. 10) indicates the following superficial deposits for the local area:

- Alluvial Deposits - comprising of coarse silty gravels and, fine silt and clay.
- Head Deposits - comprising of gravelly sand, these deposits were formed from the material accumulated by downslope movements including landslide, debris flow, solifluction, soil creep and hill wash.

3.6 Solid Geology

Reference to BGS map sheets (Ref. 8) and (Ref. 9) and the BGS Geology of Britain viewer (Ref. 10) indicate the following bedrock geology for the local area:

- **Porthtowan Formation** - interbedded slates and turbidite sandstones. This underlies most of the area from Chiverton to Marazanvose.
- **Grampound Formation** – interbedded sandstone and sub-ordinate siltstones, including thick to very thick beds of the Treworgans Sandstone Member. This underlies most of the area from Marazanvose to Carland Cross.
- **Trendrean Mudstone Formation** - grey mudstone with siltstone laminations and occasional sandstone beds. This underlies the site just to the north-east of Carland Cross.
- Intrusive Dykes - quartz –porphyry, (known locally as Elvans) cross the Porthtowan Formation trending east-west.
- A number of metalliferous rich mineral seams cross the area. Minerals include; lead, silver, copper, zinc, iron and tin. The seams tend to follow the strike of the bedrock geology.

3.7 Hydrology

Surface Water Features

Generally, the existing road alignment runs along a surface watershed where the road follows along a ridge line. The River Gannel and its tributaries flow to the north and the Rivers Kenwyn, Tresillian and Allen and tributaries flow to the south.

Several smaller surface water features are also located at the chainages shown in

Table 3-1 below.

Table 3-1 Summary of significant surface water features

Approximate Scheme Chainage (m)	Feature Details
89000	Stream crossing perpendicular beneath existing and proposed highway.
92250	Stream crossing perpendicular beneath existing and proposed highway.
10380 - 10550	Ponds used for livestock drinking water supply.
11025	Springs utilised for drinking water via stream collection and pumping system to filtration system feeding two residential properties. The source of this spring is the superficial deposits to the north of the springs, extending northwards to the crest of the ridge.
12680 - 12760	Flooded disused / abandoned quarry
13575 - 13700	Spring located in valley immediately north of proposed highway alignment. Spring collection and tank system in operation feeding livestock and properties at West Nancemere Farm. The source of this spring comprises superficial deposits extending to the south towards the crest of the ridge. The original catchment has been reduced by the construction of the A30 up to the Carland Cross junction, Carland Cross Windfarm and the changes in agricultural practices. This has resulted in reduced flows, evident in the abandoned tanks in the higher reaches of the spring line/stream.
13500 - 13750	Toe drainage associated with existing highway embankment. Proposed earthwork to interact.

Water Abstractions – sub-surface

There are no known current groundwater or potable water abstraction points in the vicinity of the study area; however, there are numerous historical abstraction licences relating to the farms within the study area.

Water Abstractions – surface

There is a potable spring fed abstraction point located at approximate chainage 11025. The spring, with a pumped collection system, feeds residential properties at Honeycombe Farm and Honeycombe Barn immediately south of the scheme.

Similarly there is a spring fed abstraction immediately north of chainage 13600. This feeds farming properties including the nearby West Nancemere Farm.

3.8 Hydrogeology

The Environment Agency (EA) classifies the entirety of the site as a Secondary A aquifer for both superficial and bedrock geology (Ref. 12).

3.9 Aerial Photographs

Ariel Photography has not been reviewed as part of this report and no aerial photography was undertaken during this phase of the ground investigation.

3.10 Records of Mines and Mineral Deposits

The study area lies on the boundary of two mining districts; the Chacewater mining district to the south-west and the St Agnes mining district to the northeast. The resources mined are generally metalliferous. In the early days of mining, this district was prospected by means of pits excavated to bedrock to uncover lodes that were not visible at the surface. In order to continue exploration at depth, shafts were sunk with horizontal stopes and passages driven away from the shafts exploiting the mineral lodes.

Historic maps show a number of disused lead, silver, copper, zinc, iron and tin mining sites throughout the study area; although no evidence was observed beneath the proposed alignment.

Information provided by HAGDMS (Ref. 6) show:

- Conclusive metalliferous mining is present throughout most of the study area.
- There are a number of potential areas that have been historically mined for a variety of minerals and materials within the study area; and
- A number of man-made mining cavities are identified, mostly the resource is unknown but with occasional lead and copper mines.

Cornwall Consultants Ltd conducted a Mining Activity Report in 2002 (Ref. 6) and Hyder Consulting Ltd contracted Peter Brett Associates to undertake a DEFRA non-coal mining database search for the Chiverton Cross to Carland Cross stretch of the A30 in 2003 (Ref. 6).

Both Reports concurred with one another and indicated that there were 33 recorded Copper (C) and Lead (L) mining locations within a 300m radius of the existing A30 and that a number of them may extend beneath the road alignment.

Prior to 1872, there was no requirement for metalliferous mines in Cornwall to keep accurate records and abandonment plans of mines and so the extent of mining in the area prior to this date is largely unrecorded. It may be assumed that where workable deposits are present, unrecorded mining may have taken place within the study area and this may present a risk of localised subsidence in the immediate vicinity.

Historical maps (Ref. 6) indicate that a number of quarrying and mining activities have taken place in the study area. Many of the pits and shafts identified on the historical maps are now in-filled and all of them are disused. The 2016 Groundsure Report (Ref. 6) identifies most of these features and the lodes they worked as potentially in-filled land.

During ground investigation works a probable abandoned mine shaft was identified at chainage 12080m, approximately 20m south of the proposed toe of the highway embankment. BH-R-030 was drilled and extended to 15.0m depth to investigate the potential presence of workings. No voiding or loss of flush was encountered. While this is believed to have been a ‘blind’ prospect due to the lack of spoil and associated structures, etc., it is recommended that further investigation is undertaken around this location to identify any potential workings and their orientation.

3.11 Land Use and Soil Survey Information

The predominant land use for the site is rural / agricultural. Agricultural activities are a mix of livestock grazing on pasture, arable crop production and equine paddock. Field boundaries are typically separated by traditional Cornish banks.

3.12 Archaeological and Historical Investigations

All trial pitting activities were supervised by an archaeologist provided by Cornwall Council Archaeological Unit under a watching brief. Details and records of any findings have been reported separately. Further archaeological trial trenching is scheduled to be undertaken in late summer 2017.

3.13 Existing Ground Investigations

Several phases of ground investigation have been undertaken and are summarised in the PSSR undertaken by WSP, May 2017 (Ref. 6).

3.14 Consultation with Statutory Bodies and Agencies

WSP have, during the course of the scheme and its development, liaised with key stake holders such as Highways England, the Environment Agency, Cornwall Council and, land owners and occupiers, along with local residents.

4. Field and Laboratory Studies

4.1 Walkover Survey

A walkover survey of the route was undertaken during production of the Preliminary Sources Study Report (PSSR) (Ref. 6) further walkover surveys have been undertaken to inform the site investigation works.

A scheme wide walkover was also completed by WSP ecologists to inform any ecological constraints with regards to proposed ground investigation positions.

4.2 Geomorphological and Geological Mapping

No geomorphological and geological mapping was undertaken as part of the scheduled field works.

4.3 Ground Investigation

The objective of the ground investigation was to provide sufficient information to progress preliminary design of the proposed Chiverton to Carland Cross improvements, as well as to provide founding information for proposed structures along the route, reusability of excavated material and identify any potential contamination issues.

The ground investigation was designed based on existing information as detailed earlier in this report and within the PSSR (Ref. 6).

The following aspects were investigated in order to inform the detailed design of the scheme and avoid/reduce geotechnical risk as far as reasonably possible:

- Confirm the sequence of Made Ground, if any present.
- Establish natural strata present.
- Establish groundwater conditions.
- Establish geotechnical and geo-chemical properties of the geological material present.
- To assess the aggressive chemical environment for buried concrete.
- To assess any ground contamination suspected of being present.

The ground investigation was designed by WSP with a specification of ground investigation works produced in accordance with BS EN-1997-2 ‘Geotechnical Design Part 2’ (Ref. 13), HD22/08 (Ref. 1) and the UK Specification for Ground Investigation, 2nd Edition (Ref. 14). The form of contract was the ICC Infrastructure Conditions of Contract: Ground Investigation Version (Ref. 15).

The ground investigation was undertaken at the site between 31st January and 24th March 2017 by site investigation Contractor, Structural Soils Ltd. At the time of writing long term ground water monitoring is ongoing with only two months of monitoring data available. The tertiary monitoring results will be reported with the factual report for the supplementary ground investigation.

Drawing No. 2 details the locations of all completed exploratory positions.

All ground investigation fieldwork and laboratory testing was carried out in accordance with the recommendations of BS:5930-A2 ‘Code of Practice for Site Investigation’ (Ref. 16), BS10175 ‘Investigation of Potentially Contaminated Sites: Code of Practice’ (Ref. 17) and EN-1997-2 ‘Geotechnical Design Part 2’ (Ref. 13).

The locations of all exploratory borehole positions were cleared by the Contractor utilising a permit to dig system that incorporated the use of a Cable Avoidance Tool (CAT) and signal generator (Genny). In addition to CAT & Genny clearance, trial pit locations were scanned prior to excavation with Ground Penetrating Radar (GPR) as an additional precaution to identify any unrecorded services or buried features.

At borehole locations inspection pits were excavated by hand to 1.2mbgl to inspect for buried services following the completion of the CAT & Genny survey. Disturbed samples were taken and retained for laboratory testing.

All boreholes were drilled with a tracked multi utility rotary drill rig. All holes commenced using dynamic sampling techniques to refusal, typically at the soil/rock interface and extended into bedrock using rotary coring techniques. Where required, temporary casing was used to support the borehole.

Machine-excavated trial pits were carried out following completion of a CAT & Genny survey and Ground Penetrating Radar (GPR) survey. Disturbed samples were taken and retained for laboratory testing. All machine dug pits were either excavated to refusal, design termination depth or terminated due to instability of side walls.

A total of 13 No. groundwater monitoring installations were installed across the length of the scheme. The details for each installation can be found with the Engineer’s logs (Ref. 7) and the location of each can be found on Drawings No. 2.

Table 4-1 Exploratory Holes Completed as part of the A30 Ground Investigation

Exploratory Hole Type	Number of exploratory Holes
Dynamically sampled with rotary core follow on	73
Machine Excavated Trial Pit	103

A total of 25 exploratory holes locations, 13 boreholes and 12 trial pits, were cancelled during the ground investigation works. These are detailed in Table 4-2 below.

Table 4-2 Exploratory Holes Cancelled During the A30 Ground Investigation

Exploratory Hole Type	Exploratory Hole Number	Reason for Cancellation
Borehole	BH-R-001	TM requirements
Borehole	BH-S-002	TM requirements
Trial Pit	TP-R-001	TM requirements
Trial Pit	TP-S-001	Soft ground conditions and crop in field
Borehole	BH-S-004	TM requirements
Borehole	BH-S-006	TM requirements
Borehole	BH-S-007	TM requirements
Trial Pit	TP-R-002	TM requirements
Trial Pit	TP-R-022	TM requirements
Borehole	BH-S-016	Not required due to 4 other BHs drilled for structure
Borehole	BH-S-013	Not required due to 4 other BHs drilled for structure
Trial Pit	TP-R-042	Dense woodland
Borehole	BH-S-033	Dense woodland
Trial Pit	TP-R-067	Soft ground conditions and crop in field
Trial Pit	TP-R-071	Soft ground conditions and crop in field
Trial Pit	TP-R-072	Soft ground conditions and crop in field
Trial Pit	TP-R-073	Soft ground conditions and crop in field
Borehole	BH-S-034	Four other BHs drilled for structure
Borehole	BH-S-037	Four other BHs drilled for structure
Borehole	BH-R-074	Adjacent to spring, ecological constraints
Trial Pit	TP-R-090	Soft ground conditions and crop in field
Trial Pit	TP-R-089	Soft ground conditions and crop in field
Borehole	BH-S-050	Four other BHs drilled for structure
Borehole	BH-S-047	Four other BHs drilled for structure
Trial Pit	TP-S-011	Soft ground conditions and crop in field

Ground Investigation Factual Reporting

A copy of the Factual Report prepared by Structural Soils Ltd, detailing the ground investigation completed January to March 2017 was submitted to Highways England as a standalone document (Ref. 7). This report contains all Engineer's exploratory hole logs, field tests and result of laboratory testing.

In-situ Testing

Table 4-3 below details a summary of in-situ testing completed during the ground investigation.

Table 4-3 In-Situ Testing Completed as part of the A30 Ground Investigation

In-Situ Test Type		Number of Tests
Standard Penetration Test (SPT)	Dynamically sampled	123
	Rotary Follow On	64
Hand Shear Vane (HSV)		14 (typically set of three at each test location)
Plate Load Test (for CBR)		24
Permeability Test in Borehole		2
Soil Infiltration Testing		8

Standard Penetration Tests (SPTs) were completed to determine the in-situ relative density of the encountered ground, where appropriate, and were carried out within all boreholes in accordance with BS EN ISO 22476-3:2005 (Ref. 18). As a result of the expected weak bedrock the number of SPT drives for test termination was increased to 100 blows in all rotary drilled boreholes.

A total of 24 No. in-situ plate load tests (PLT) were undertaken to provide California Bearing Ratio (CBR) values at a range of locations in order to assess typical pavement construction requirements. Typically a pair of tests was undertaken at each location to check for ground variability and averaged figures are presented in Table 4-10. A machine excavated pit was used to complete each test following the completion of a CAT survey. All tests were completed in accordance with BS 1377-9:1990 Clause 4.1 (Ref. 19)

Where fine soils were encountered within trial pits, in-situ hand shear vane tests were carried out in accordance with BS5930:2015 (Ref. 16).

8 No. soil infiltration tests were completed in accordance with the guidelines set out within BRE Special Digest 365 – Soak-away design (Ref. 20).

Where permeability tests were undertaken within borehole installations, the works were completed in accordance with BS 5930:2015 (Ref. 16)

In-situ Test Results

HAND SHEAR VANE TESTING

Topsoil

A single Hand Shear Vane (HSV) was conducted within fine topsoil materials, the result of which is presented in Table 4-4 below.

Table 4-4 Summary of Hand Shear Vane Testing within Topsoil Material

Exploratory Hole ID	Depth (m bgl)	Test level (m AOD)	Average Peak Value (kPa)	Average Residual Value (kPa)
TP-R-056	0.3	67.63	73	33

Alluvium

A total of 2 No. HSVs were conducted within fine Alluvium soil deposits, the results of which are presented in Table 4-5 below.

Table 4-5 Summary of Hand Shear Vane Testing within Alluvium Deposits

Exploratory Hole ID	Depth (m bgl)	Test level (m AOD)	Average Peak Value (kPa)	Average Residual Value (kPa)
TP-P-009	0.55	75.06	86	34
TP-P-009	0.75	74.86	37	17

Grampound Formation Residual (Grade 5) Soil

A total of 9 No. HSVs were conducted within Grampound Formation (fine) residual soil deposits, the results of which are presented in Table 4-6 below.

Table 4-6 Summary of Hand Shear Vane Testing within Grampound Formation Residual Soil Materials

Exploratory Hole ID	Depth (m bgl)	Test level (m AOD)	Average Peak Value (kPa)	Average Residual Value (kPa)
TP-P-014	0.3	66.55	121	Not undertaken
TP-R-055	1.3	71.7	99	43
TP-R-055	2	71.0	133	61
TP-R-056	0.7	67.23	95	39
TP-R-056	1.8	66.13	177	77
TP-R-056	2.3	65.63	156	Not undertaken
TP-S-008	0.40	109.85	76^{+}	Not undertaken
TP-S-008	0.5	109.75	88*	Not undertaken
TP-R-056	2.3	108.66	102*	Not undertaken

*Denotes single determination

$^{+}$Denotes average of two determinations.

Porthtowan Formation – Residual (Grade 5) Soil

A total of 3 No. HSVs were conducted within Porthtowan Formation (fine) residual soil deposits, the results of which are presented in Table 4-7 below.

Table 4-7 Summary of Hand Shear Vane Testing within Porthtowan - Grade 5 Materials

Exploratory Hole ID	Depth (m bgl)	Test level (m AOD)	Average Peak Value (kPa)	Average Residual Value (kPa)
TP-R-027	0.45	105.55	86*	Not undertaken
TP-R-101	0.8	79.12	98	53
TP-R-101	0.9	79.02	97	52

*Denotes single determination

STANDARD PENETRATION TESTING

Standard penetration testing was undertaken in all weathering grades of the solid geology encountered, from Grade 5 residual soils to Grade 0 fresh rock. Only the results for Grades 3 to 5 are reported below, as the results for Grade 0 to Grade 2 generally refused. It should be noted that the total number SPTs undertaken are reported in addition to those undertaken in Grade 3 to Grade 5 material.

Porthtowan Formation

A total of 117 No. SPTs were undertaken within the Porthtowan Formation (PTF), of which 85 were undertaken in Grade 3 to Grade 5 material. The SPT results for the Grade 3 to Grade 5 Porthtowan Formation are presented in Table 4-8 below.

Table 4-8 Summary of Extrapolated SPT N-Values within the Porthtowan Formation

Weathering Grade	Grade 4&5		Grade 3
	Fine Soil	Coarse Soil	
No. of SPT Tests	20	50	15
Mean N-Value	18	21	96
Median N-Value	15	19	57
Maximum N-Value	36	51	150
Minimum N-Value	10	4	17

Grampound Formation

A total of 64 No. SPTs were undertaken within the Grampound Formation (GMP), of which 46 were undertaken in Grade 3 to Grade 5 material. The SPT results for the Grade 3 to Grade 5 Grampound Formation are presented in Table 4-9 below.

Table 4-9 Summary of Extrapolated SPT N-Values within the Grampound Formation

Weathering Grade	Grade 4&5		Grade 3
	Fine Soil	Coarse Soil	
No. of SPT Tests	5	32	9
Mean N-Value	18	16	27
Median N-Value	24	24	25
Maximum N-Value	31	38	47
Minimum N-Value	12	12	16

Trendrean Mudstone Formation

A total of 5 No. SPTs were undertaken within the Trendrean Formation (TMF). Only two of these were undertaken within the Grade 4 and 5 materials, the residual soils, giving an N value of 13 in fine grained soil and an N value of 21 in course grained soil. Those undertaken in higher grade material all reached maximum blows before the completion of the test.

PLATE LOAD TESTING

A total of 25 No. in-situ plate load CBR tests were undertaken as part of the site works. The results of this testing is summarised in Table 4-10 below.

Table 4-10 Summary of In-situ Plate Load Testing

Heading	Depth	Equivalent CBR Value (%)*	Strata
TP-R-003	0.3	1.9	G4 PTF - Coarse
TP-R-012	0.5	3.7	G5 PTF - Fine
TP-R-014	0.5	7.05	G4 PTF - Coarse
TP-R-016	0.3	2.8	G5 PTF - Fine
TP-R-018	0.5	9.45	G5 PTF - Fine
TP-R-021	0.5	13.3	G5 PTF - Coarse
TP-R-025	0.5	8.35	G5 PTF - Coarse
TP-R-028	0.5	5.5	G5 PTF - Fine
TP-R-039	0.5	5.85	G5 PTF - Coarse
TP-R-041	0.5	5.6	G5 PTF - Coarse
TP-R-043	0.5	5	G5 PTF - Coarse
TP-R-045	0.5	7	G5 PTF - Coarse
TP-R-065	0.5	1.8	G5 GMP - Fine
TP-R-069	0.5	9.7	G5 GMP - Coarse
TP-R-070	0.5	2.85	G5 GMP - Fine
TP-R-075	0.5	4.75	G4 GMP - Coarse
TP-R-077	0.5	3.7	G5 GMP - Coarse
TP-R-079	0.38	8.4	G4 GMP - Coarse
TP-R-079	0.5	4.8	G4 GMP - Coarse
TP-R-082	0.5	7.8	G5 GMP - Coarse
TP-R-084	0.5	8.6	G5 GMP - Coarse
TP-R-094	0.5	5.9	G5 TDF - Coarse
TP-R-095	0.5	6.4	G5 TDF - Coarse
TP-S-002	0.5	1.85	G5 PTF - Fine
TP-S-004	0.5	10.5	G4 PTF - Fine

SOIL INFILTRATION TESTING

A total of 8 No. soil infiltration tests were completed in 8 No. trial pit locations as part of the site works. The results of the testing are presented in the Factual Report. Table 4-11 below, summarises the test results.

Table 4-11 Summary of soakaway test results

Trial pit test No.	Infiltration rate m/s	Strata
TP-P-001	1.4×10^{-4}	G4/5 PTF - Coarse
TP-P-004	3.84×10^{-4}	G5 PTF - Fine
TP-P-005	2.96×10^{-4}	G4 PTF - Coarse
TP-P-009	Abandoned due to rising groundwater	G5 PTF - Fine
TP-P-013	1.63×10^{-5}*	G5 PTF - Fine
TP-P-014	No drop in water level	G5 PTF - Coarse
TP-P-015	3.59×10^{-5}	G5 PTF - Coarse
TP-P-017	2.29×10^{-3}	G5 PTF - Fine

*estimated from an extrapolated test curve.

PERMEABILITY

2 No. groundwater permeability rising head tests were completed in a number of groundwater monitoring installations during the ground investigation. The results are presented in the Factual Report.

4.4 Drainage Studies

No drainage studies were undertaken.

4.5 Pile Tests

No pile tests were undertaken.

4.6 Other Field Work

An archaeological watching brief for all intrusive activities was maintained through the period of ground investigation (Ref. 11).

4.7 Laboratory Investigation

All laboratory geotechnical testing was scheduled by WSP and undertaken by accredited laboratories, UKAS and MCERTS, under the direction of Structural Soils Ltd.

All geotechnical tests were undertaken in accordance with BS1377:1990 ‘Methods for Test of Soils for Civil Engineering Purposes, Part 1 to 8’ (Ref. 19) and ISRM 2007-2014 (Ref. 29), unless stated otherwise on laboratory test certificates.

A summary of the geotechnical testing undertaken during the ground investigation is detailed below in Table 4-12.

Table 4-12 Summary of geotechnical laboratory testing

Laboratory Test	Quantity
Moisture Content	111
Atterberg Determination (Liquid Limit, Plastic Limit and Plasticity Index)	110
Particle Size Distribution	112
Density by Immersion	9
Linear Density	10
Particle Density	45
Consolidated Drained Shear Box	35
Dry Density / Moisture Content Relationship	42
Consolidated Drained Shearbox (small)	35
Point Load	871
Uniaxial Compressive Strength (rock)	3
Slake Durability	33
BRE Chemical Analysis (full)	109

All results of geotechnical laboratory testing are included within the ground investigation Factual Report prepared by Structural Soils Ltd.

5. Ground Summary

The following ground summary is based on the factual data presented in the Structural Soils Ltd ground investigation Factual Report (Ref. 7), the information summarised in Section 4 and existing information previously detailed in Section 3 of this report.

The ground investigation undertaken generally confirms the published geology. Any local variations encountered along the proposed alignment are discussed in this section of the report.

The ground conditions encountered are discussed below in more detail.

5.1 Topsoil

Topsoil was described in most investigation positions to a maximum depth of 0.9m though typically encountered to a depth of less than 0.5mbgl.

5.2 Made Ground

Limited Made Ground was encountered during ground investigation works. It was encountered to a maximum depth of 0.9mbgl. Made Ground was encountered as part of the access track construction in BH-R-040C and BH-R-041. BH-R-030 encountered Made Ground to 0.65mbgl possibly associated with mine workings/waste from the adjacent possible mine shaft.

Made Ground was only encountered in two trial pits, TP-P-009 and TP-R-088A, to a maximum depth of 0.5mbgl. TP-R-088A is adjacent to Carland Cross windfarm and is likely derived from associated earthworks and access track formation. TP-P-009 is at the base of a small valley and possibly associated with landowner access tracks.

5.3 Superficial Deposits

Alluvium

Limited superficial deposits were encountered during the ground investigation. Alluvium was identified in the following trial pits TP-P-009, TP-P-013 and possible Alluvium in TP-R-060. It was also identified in the following boreholes BH-S-018 and BH-S-020. All these positions coincided with valley floor locations in close proximity to surface water features.

Head

Despite being mapped on the published geology, at approximate chainages 8900, 9230, 11000, 13050, no Head deposits were identified during the works.

5.4 Porthtowan Formation

The Porthtowan Formation (PTF) was encountered in all investigation positions between chainages 0000m and 7100m, essentially all positions drilled west of Marazanvose. The geology of the PTF includes interbedded slaty mudstone (grey and grey-green), sandstone along with foliated psammites and phyllites. Subordinate sandstone beds are up to 2m thick, typically turbidites.

While quartz-porphyry dykes have been mapped in the Porthtowan Formation none were encountered during the works.

Where the PTF was encountered, it comprised materials encompassing the six weathering grade classifications identified in BS EN 14689-1, from residual soils (Grade 5) through to fresh rock (Grade 0).

The base of these deposits was not determined; however they were explored to a maximum depth of 16.0mbgl in BH-S-022.

For the purpose of defining the formation with regards to its engineering properties, it has been considered as both a soil and a rock, according to its weathering grade. The horizon at which the formation is considered a rock has been recognised as the interface between Grade 4 and Grade 3 weathered material. Section 6 discusses the PTF in accordance with its weathering grade.

5.5 Grampound Formation

The Grampound Formation (GMP) was encountered in all investigation positions between chainages 8500m and 13600m, that is all positions drilled east of Marazanvose as far as Carland Cross roundabout. The geology of the GMP includes thinly interlaminated grey slaty mudstone and mid-grey siltstone, weathering yellowish green, with sporadic thin beds of sandstone and sparse lenticular limestone. Metamorphosed strata were also encountered comprising foliated psammites and phyllites.

Where the GMP was encountered it comprised materials encompassing the six weathering grade classifications identified in BS EN 14689-1:2003 (Ref. 5), from residual soils (Grade 5) through to fresh rock (Grade 0).

The base of these deposits was not determined; however they were explored to a maximum depth of 24.6mbgl in BH-S-036.

For the purpose of defining the formation with regards to its engineering properties, it has been considered as both a soil and a rock, according to its weathering grade. The horizon at which the formation is considered a rock has been recognised as the interface between Grade 4 and Grade 3 weathered material. Section 6 discusses the GMP in accordance with its weathering grade.

5.6 Trendrean Mudstone Formation

The Trendrean Mudstone Formation (TMF) was encountered in all investigation positions between chainages 13600m and 14400m, that is all positions drilled west of Carland Cross Roundabout. Published geology for the TMF includes dark grey slates and siltstones with varying proportions of sandstone. However, no sedimentary geology was encountered during the ground investigation, only metamorphic strata consisting of phyllite was observed.

While quartz-porphyry dykes have been mapped in the Trendrean Mudstone Formation none were encountered during the works.

Where the TMF was encountered it comprised materials encompassing three of the weathering grade classifications identified in BS EN 14689-1 (Ref. 5), from residual soils (Grade 5) through to fresh rock (Grade 0). It should be noted that the weathering profile of TMF typically comprised Grade 4/5 weathered material directly overlying Grade 2 weathered materials.

The base of these deposits was not determined; however they were explored to a maximum depth of 7.3mbgl in BH-R-041.

For the purpose of defining the formation with regards to its engineering properties, it has been considered as both a soil and a rock, according to its weathering grade. The horizon at which the formation is considered a rock has been recognised as the interface between Grade 4 and Grade 3 weathered material. Section 6 discusses the Trendrean Mudstone Formation in accordance with its weathering grade.

5.7 Groundwater Summary

A 6 month groundwater monitoring programme has been implemented, monitoring all of the installed boreholes, 13 No. in total. Data logging ‘divers’ have been installed at each location and at the time of writing a single download of data had been undertaken on 8th – 9th June 2017. As well as the data download, the ground water level has also been dipped and recorded. The diver data along with the water depth (m bgl) by dipping is presented within the Factual Report.

A summary of the groundwater and installation details can be seen in Table 5-1 to Table 5-5. For comparison with the proposed embankment and cuttings, the groundwater levels have been plotted on the geological cross sections as seen in Drawings 004 to 009.

It must be noted that installation design of the groundwater installation was based on the engineer describing material and depths to the Site Supervisor immediately after the borehole completion. This initial description, along with its depth may have been different to the final description provided in the engineering logs. Completed Engineer’s logs can be found in the Factual Report.

Porthtowan Formation

Table 5-1 Summary of Groundwater from borehole data - Porthtowan Formation

Exploratory location	Depth to Groundwater						Remarks
	During Drilling		From monitoring data				
			03/04/2017		08/06/2017		
	m bgl	mAOD	m bgl	mAOD	m bgl	mAOD	
BH-R-002	5.90	140.66	-	-	-	-	Water depth recorded on completion of borehole
BH-S-001	13.00	141.30	-	-	-	-	
BH-S-003	4.70	134.92	-	-	-	-	
BH-S-005	9.20	134.45	8.73	134.92	-	-	Installation inaccessible 08/06/2017, due to landowner permissions.
BH-R-004	4.80	138.82	4.55	139.07	Dry	Dry	
BH-R-008	3.40	104.19	-	-	-	-	Water depth recorded on completion of borehole
BH-R-009	3.20	104.07	-	-	-	-	
BH-R-010	4.20	102.94	3.76	103.38	5.23	101.91	
BH-S-012	-	-	Dry	Dry	Dry	Dry	No groundwater encountered during drilling or subsequent groundwater monitoring.
BH-R-106	3.20	115.40	-	-	-	-	Water depth recorded on completion of borehole
BH-R-012	4.80	99.04	-	-	-	-	
BH-R-013	-	-	Dry	-	Dry	-	No groundwater encountered during drilling or subsequent groundwater monitoring.
BH-S-019	-	-	4.09	77.69	5.07	76.71	
BH-R-108	3.60	97.68	-	-	-	-	Water depth recorded on completion of borehole
BH-R-017	3.20	76.15	-	-	-	-	Water depth recorded on completion of borehole

Table 5-2 Summary of Groundwater monitoring Installations – Porthtowan Formation

Exploratory location	Response zone (m bgl)	Strata Screened
BH-S-005	3.00 – 15.00	Moderately weathered phyllite from 3.00 to 4.90m, below which slightly weathered foliated phyllite and psammite to 15.0m
BH-R-004	3.00 – 5.00	Highly weathered sandstone
BH-R-010	2.00 – 5.60	Moderately weathered psammite from 2.0 to 3.50m, below which completely to highly weathered phyllite and psammite from 3.50 to 5.60m
BH-S-012	1.00 – 7.00	Granular soil from 1.0 to 1.80, below which moderately becoming slightly weathered phyllite and psammite with depth to 7.00m
BH-R-013	3.00 – 6.00	Slightly weathered interbedded sandstone and mudstone with a weaker moderately weathered mudstone band between 3.70 and 4.30m
BH-S-019	0.80 – 6.50	Fine soil from 0.80 to 0.90m, below which granular soil between 0.90 to 2.90m, below which moderately to slightly weathered foliated phyllite and psammite with depth to 6.50m
BH-R-017	4.50 – 7.50	Highly weathered sandstone with bands of Fine soil between 6.00 to 6.30m, 6.50 to 6.70m and 7.00 to 7.50m

Grampound Formation

Table 5-3 Summary of Groundwater from borehole data – Grampound Formation

Exploratory location	Depth to Groundwater						Remarks
	During Drilling		From monitoring data				
			03/04/2017		08/06/2017		
	m bgl	mAOD	m bgl	mAOD	m bgl	mAOD	
BH-S-032	-	-	Dry	Dry	Dry	Dry	No groundwater encountered during drilling or subsequent groundwater monitoring.
BH-R-026	6.00	107.60	-	-	-	-	Water depth recorded on completion of borehole
BH-S-035	6.60	107.30	-	-	-	-	
BH-S-036	5.08	106.22	4.78	Dry	5.27	Dry	Water strike at 5.28 rising to 5.08 after 20mins
BH-S-039	5.60	106.42	-	-	-	-	Water depth recorded on completion of borehole
BH-R-027	-	-	4.32	116.08	6.42	113.98	
BH-R-030	2.00	119.09	-	-	-	-	Water strike at 4.00m rising to 3.60m after 20mins
BH-R-031	2.10	123.19	-	-	-	-	Water strike at 2.80 rising to 2.10 after 20mins
BH-R-032	2.60	123.69	-	-	-	-	Water depth recorded on completion of borehole
BH-R-014	2.20	144.92	-	-	-	-	Water depth recorded on completion of borehole
BH-S-040	4.80	141.02	-	-	-	-	
BH-S-041	4.70	142.68	-	-	-	-	
BH-S-042	-	-	8.47	138.33	Dry	Dry	
BH-S-045	5.70	139.94	-	-	-	-	Water depth recorded on completion of borehole
BH-S-046	7.60	135.37	-	-	-	-	
BH-S-048	7.20	135.15	-	-	-	-	
BH-S-049	8.20	135.57	7.00	136.77	Dry	Dry	
BH-S-051	6.80	135.89	-	-	-	-	Water depth recorded on completion of borehole
BH-S-052	7.40	138.52	-	-	-	-	

Table 5-4 Summary of Groundwater monitoring Installations – Porthtowan Formation

Exploratory location	Response zone (m bgl)	Strata Screened
BH-S-032	1.50 – 5.50	Granular soil from 1.50 to 2.20m, below which interbedded slightly weathered sandstone and siltstone to 5.50m
BH-S-036	8.00 – 24.60	Slightly weathered (8.0 to 9.20m) moderately weathered (9.20 to 16.40m) and fresh (16.40 to 24.60m) foliated phyllite and psammite
BH-R-027	4.40 – 7.40	Slightly weathered foliated psammite and phyllite
BH-S-042	3.00 – 9.00	Slightly weathered interbedded siltstone and sandstone between 3.0 to 5.0m, below which slightly weathered phyllite and psammite to 9.0m
BH-S-049	5.50 – 9.00	Slightly weathered becoming fresh foliated phyllite and psammite at 7.30m

Trendean Formation

The only groundwater installation within the Trendrean Mudstone Formation was BH-R-041. The groundwater level recorded during the first round of monitoring was 5.66mbgl (132.26mAOD) and was recorded as dry during the second round of monitoring.

Table 5-5 Summary of Trendrean Mudstone Formation Groundwater monitoring installations

Exploratory location	Response zone (m bgl)	Strata Screened
BH-R-041	1.00 – 7.30	Fine soil between 1.0 to 1.20m below which granular soil to 1.60m. Completely weathered phyllite and disturbed quartzite to 3.00 below which slightly weathered to fresh phyllite at 5.70m.

6. Ground Conditions and Material Properties

6.1 General Assumptions

Undrained shear strength, c_u

The undrained shear strength has been derived using the correlation with SPT N values. When deriving the undrained shear strength from SPT N-values, the following formula by Stroud has been utilised:

$c_u = f_1 \times N_{60}$ (from SPT tests)

Where f_1 is a factor related to the Plasticity Index of the material and can be deduced from Figure 31, CIRIA report 143 'the Standard Penetration Test (SPT); Methods and Use' (Ref. 22). However, it should be noted that this correlation is only reliable for insensitive, over consolidated clays.

For the purpose of this report and based upon recorded plasticity data, an f1 value of 5 has been used.

Unit weight, g

The unit weight for each stratum has been obtained using information from laboratory testing and Figure 1 from BS8002:2015 (Ref. 25).

Coefficient of volume compressibility, m_v

Coefficient of volume compressibility, m_v, values for weathering Grades 4&5 materials have been obtained from typical values quoted in Carter and Bentley (Ref. 26).

Young's Modulus, drained, E´, and undrained, E_u

Young's modulus (drained), E´, value has been based upon Stroud & Butler's relationship $E'_v/N = 1$ (Ref. 23).

Young's modulus (undrained), E_u, values for weathering Grade 4&5 materials have been derived from correlations presented in Figure 26 of CIRIA 143 (Ref. 22).

Unconfined Compressive Strength, q_c

Unconfined compressive strength (UCS) values have been derived from the correlation with point load strengths (Is_{50}). The point load values have been separated into the type of test undertaken. This is because in the axial test, the core is loaded parallel to the longitudinal axis of the core, and is therefore the most comparable to the UCS test. Using Tomlinson (Ref. 21) a correlation factor of 23 has been adopted for the sedimentary mudstone, siltstone and phyllite whereas for the sedimentary sandstone and psammite a correlation factor of 24 has been used.

6.2 Topsoil

A single hand shear vane test and limited laboratory testing was undertaken on Topsoil materials.

A single hand shear vane testing indicated a peak undrained shear strength of 73kPa in accordance with BS 5930 with a residual strength of 33kPa.

2 No. dry density/moisture content tests were undertaken with optimum moisture contents of 20 & 24% against an initial moisture content of 23 & 30% respectively.

6.3 Alluvium

Due to the shallow nature of Alluvium materials (i.e. less than 1.0mbgl) encountered in boreholes, no SPT testing was undertaken.

Hand shear vane testing indicated an undrained shear strength of 37kPa and 86kPa in accordance with BS 5930 with residual strengths of 17kPa and 34kPa. A plot of all recorded c_u values is presented in Figure 6-1.

A Casagrande chart shown in Figure 6-2 indicates intermediate to high plasticity silt materials.

No particle size distribution (PSD) testing was undertaken on Alluvium materials.

A single drained shear box measurement was undertaken. A peak angle of shear resistance of 31° was recorded, with a recorded peak effective cohesion of 5kN/m^2.

6.4 Porthtowan Formation

Table 6-1 Summary of Porthtowan Formation in-situ testing

	SPT		Hand Shear Vane Testing		Plate Load testing No. of tests	
	No. of tests	N Value*[1] Range	No.	Cu(kPa) range	No.	CBR % range
Grade 4&5 Fine	18	10 – 36	3	86 - 97	8	1.9-13.3
Grade 4&5 Coarse	50	5 - 51	-	-	6	1.85-10.5
Soil / Rock Interface						
Grade 3	15	17-150	-	-	-	-
Grade 2	11	29-272	-	-	-	-
Grade 1	16	32-333	-	-	-	-
Grade 0	5	76-545	-	-	-	-

*[1] - includes extrapolated values
*[2] - excludes two values considered to be anomalous

An SPT profile for the Porthtowan Formation is presented as Figure 6-4 and a plot of all recorded Hand Shear Vane results is presented in Figure 6-5.

Table 6-2 Summary of Porthtowan laboratory testing

	PSD's No.	MC / Atterberg No. Of Tests			Dry Density / Moisture Content			Drained Shear Box			Slake Durability Testing		Aggressivity Classification	Point Load Testing	
		No.	MC % Range	PI Range	No.	OMC Range %	IMC Range %	No.	Cohesion kN/m^2 c´	Friction Angle ° Φ´	No.	Range %		No.	Range $I_s(50)$
Grade 5 - Fine	11	47	1-38	6-29	7	8.9-16	15-17	14	0-10	20-41.5	-	-	DS-1 / AC-1d	-	-
Grade 5 - Coarse	15	5	8.7-15	6-15	11	12-19	8.3-22	3	5-7	29.3-33.5	2	91.4-97.8	DS-1 / AC-1d	-	-
Grade 4 - Fine	-	6	3-20	11-22	-	-		2	1&3	31 & 31.5	-	-	DS-1 / AC-1d	-	-
Grade 4 - Coarse	24	-	-	-	6	11-14	8.8-14	3	1-3	25.5 – 29.7	2	47.5&94.2	DS-1 / AC-1d	-	-
Soil / Rock Interface															
Grade 3	9	-	-	-	2*	12&13	9&15	1	14	32	8	53.5-96	DS-1 / AC-1d	50	0.01-1.76
Grade 2	2	-	-	-	1*	14	10	1	6	31	8	71.8-95.2	DS-1 / AC-1d	111	0-1.91
Grade 1	-	-	-	-	-				-	-	-	-	DS-1 / AC-1d	201	0-2.75
Grade 0	-	-	-	-	-				-	-	1	96.9	DS-1 / AC-1d	61	0.01-1.23

* Denotes testing undertaken on samples recovered from trial pits

As shown in Table 6-1 above, a total of 18 No. SPTs, excluding 2 anomalous test results, with N values ranging from 10-36, were undertaken within fine soils from weathering Grade 4 and 5 material of the Porthtowan Formation. The recorded SPT N-values of 1 and 72 in BH-R-101 and BH-R-008 respectively have been omitted from further analysis as they were deemed unrepresentative of this strata. As a result, an N-Value range of 10-36 along with a median value of 15 have been taken forward for analysis purposes.

As the tests were undertaken in fine strata, the corrected N-values can be correlated to the undrained shear strength values using the method shown in Section 6.1. Based on SPT N-Value results; it is anticipated to have a derived undrained shear strength value in the range of 50-100KPa as shown in Figure 6-3.

The majority of particle size distribution (PSD) tests were carried out on recovered samples of coarse Grade 5 and Grade 4 materials. Grading curves for coarse and fine materials are presented as Figure 6-6 and 6-7 respectively.

A total of 57 No. moisture content and Atterberg Limit determination tests were conducted with results showing no apparent relationship between moisture content and depth. Results indicated moisture contents typically below the plastic limit.

The Casagrande chart shown in Figure 6-8 indicates predominantly low to medium plasticity silts.

A total of 24 No. drained shear boxes were undertaken. Values for peak angle of shear resistance and peak effective cohesion values are shown in the table above. Peak angle of shearing resistance and recorded peak effective cohesion values are plotted in Figure 6-9 and Figure 6-10 respectively.

Chemical testing to determine the aggressive nature of the material indicated that a Design Sulphate Class of DS-1 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1 should be adopted for all concrete in contact with the Porthtowan Formation. There are however two instances, within granular soil found at TP-R-017 (chainage 2700m) and slightly weathered material found in BH-R-007 (chainage 3600m) which, due to their pH values of 5.39 and 4.95 respectively, has a Design Sulphate class of DS-1 and a ACEC classification of AC-2z.

A total of 28 No. dry density/moisture content relationship determination tests were undertaken on granular and fine material with weathering Grade 4 and 5, highly weathered Grade 3 material and moderately weathered Grade 2 material. Across the four weathering grades 17 No. samples tested had an initial moisture content within ±2% of the optimum moisture content.

As no suitable samples were recovered to enable UCS testing of the Porthtowan formation it has not been possible to undertake an assessment of the relationship between directly measured UCS values and point load test values. Tomlinson (Ref. 21) quotes a q_c/I_{s50} value of 23 for mudstone, siltstone and phyllite and 24 for sandstone and psammite. These values have been used to correlate point load I_{s50} values and are presented in Figures 6-11 to 6-26.

Slake Durability Index determination testing was scheduled on samples typically located within areas of cut. The Index values ranged from 47.5% to 97.8% but were generally ≥90%. Figure 6-27 shows the Slake Durability Index depth profile for the formation.

6.5 Grampound Formation

Table 6-3 Summary of Grampound Formation in-situ testing

	SPT		Hand Shear Vane Testing		Plate Load testing No. of tests	
	No. of tests	N Value Range	No.	Cu(kPa) range	No.	CBR % range
Grade 4&5 Fine	5	12 - 31	11	76 - 177	6	1.8-2.85
Grade 4&5 Coarse	32	12 - 38	-	-	2	3.7-9.7
Soil / Rock Interface						
Grade 3	11	29-272	-	-	-	-
Grade 2	16	32-333	-	-	-	-
Grade 1	5	76-545	-	-	-	-
Grade 0	1	250	-	-	-	-

An SPT profile for the Grampound Formation is presented as Figure 6-28. A plot of all recorded Hand Shear Vane results c_u values in kPa is presented in Figure 6-29.

Table 6-4 Summary of Grampound Formation laboratory testing

	PSD's No.	MC / Atterberg No. Of Tests			Dry Density / Moisture Content			Drained Shear Box			Slake Durability Testing		Aggressivity Classification	Point Load Testing		UCS Testing	
		No.	MC % Range	PI Range	No.	OMC Range %	IMC Range %	No.	Cohesion kN/m^2 c´	Friction Angle ° Φ´	No.	Range %		No.	Range $I_s(50)$	No.	Range MPa
Grade 5 - Fine	1	23	9.8-29	11-27	2	13&18	13&18	6	4-17	24 – 33	-	-	DS-1 / AC-1d	-	-	-	-
Grade 5 - Coarse	16	2	12&14	25&15	1	16	16	1	2	31.5	2	92.7&96.9	DS-1 / AC-1d	-	-	-	-
Grade 4 - Fine	-	4	12-16	9-19	-	-	-	1	8	27.5	-	-	DS-1 / AC-1d	-	-	-	-
Grade 4 - Coarse	17	2	21&27	23&24	-	-	-	-	-	-	1	67.8	DS-1 / AC-1d	-	-	-	-
Soil/Rock Interface																	
Grade 3	7	-	-	-	8*	10-15	7.5-17	-	-	-	5	84.7-95.7	DS-1 / AC-1d	4	0.02-0.62	-	-
Grade 2	2	-	-	-	-	-	-	-	-	-	4	86.1-95.1	DS-1 / AC-1d	52	0-2.51	-	-
Grade 1	-	-	-	-	-	-	-	-	-	-	-	-	DS-1 / AC-1d	306	0-3.41	3	8.6-17.3
Grade 0	-	-	-	-	-	-	-	-	-	-	-	-	-	23	0.01-4.65	-	-

* Denotes testing undertaken on samples recovered from trial pits

As shown in Table 6-3 above, a total of 5 No. SPTs, with N values ranging from 12-31, were undertaken within fine soils from material of the Grampound Formation with weathering Grade 4 and 5.

As the tests were undertaken in fine strata, the corrected N-values can be correlated to undrained shear strength using the method described in Section 6.1. Based on the SPT N values contained in Table 6-4 the fine soil is anticipated to have a derived undrained shear strength value in the range of 60-100KPa.

The majority of the particle size distribution (PSD) tests were carried out on recovered samples of coarse Grade 5 and Grade 4 materials. Separate grading curves for coarse and fine materials are presented as Figure 6-30 &

Figure 6-31 respectively.

A total of 31 No. moisture content and Atterberg Limit determination tests were conducted with results showing no apparent relationship between moisture content and depth. Results indicated moisture contents typically below the plastic limit.

The Casagrande chart shown in

Figure 6-32 indicates low to intermediate plasticity clays, with the majority of results indicating low to high plasticity silts.

A total of 8 No. drained shear boxes were undertaken. Values for peak angle of shear resistance and recorded peak effective cohesion values are shown in the table above. Recorded peak angle of shearing resistance and recorded peak effective cohesion values are plotted in Figure 6-33 and

Figure 6-34 respectively.

Chemical testing to determine the aggressive nature of the material indicated that a Design Sulphate Class of DS-1 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1 should be adopted for all concrete in contact with the GMF. There are however two instances, within highly weathered material found at TP-R-086a (chainage 13100m) and TP-R-087 (chainage 13150m) which, due to their pH values of 5.37 and 5.22 respectively, has a Design Sulphate Class of DS-1 and a ACEC classification of AC-2z.

A total of 11 No. dry density/moisture content relationship tests were undertaken on granular and fine material belonging to weathering Grade 5 and highly weathered Grade 3 material. Across the two weathering grades, 8 No. samples tested had an initial moisture content within ±2% of the optimum moisture content. This indicates that the majority of materials would be at or around the optimum moisture with little if any treatment required for any proposed earthworks.

During the interpretation of rock testing data an analysis was undertaken to assess the relationship between q_c and Is_{50} values obtained through point load testing and directly measured UCS values. Tomlinson (Ref. 21) quotes a q_c/Is_{50} value of 23 for mudstone, siltstone and phyllite and 24 for sandstone and psammite.

Recorded UCS values are presented in Figure 6-35, with values derived from point load Is_{50} values presented in Figure 6-35 through to Figure 6-46.

Slake Durability Index determination testing was scheduled on samples typically located within areas of cut. The Index values ranged from 67.8% to 96.9% but were generally ≥90%.

Figure 6-47 shows the Slake Durability Index depth profile for the formation.

6.6 Trendrean Mudstone Formation

In-situ testing

An SPT profile for the Trendrean Mudstone Formation (TMF) is presented as Figure 6-48.

Plate load tests providing California Bearing Ratio (CBR) results were undertaken on weathering Grade 5 coarse materials with values of 5.9% and 6.4% were recorded.

Particle size distribution (PSD) tests were carried out on recovered samples of coarse Grade 5 and Grade 4 materials. Grading curves are presented in

Figure 6-49.

A single moisture content and Atterberg Limit determination test was conducted. The result showed a moisture a natural moisture content of 11% with a plastic limit of 25% and a PI of 18%.

The Casagrande chart shown in Figure 6-50 indicates an intermediate plasticity clay.

A single SPT, with an N value of 13, was undertaken within fine soils from weathering Grade 4 and 5 material of the TMF. As the test was undertaken in fine strata, the corrected N-value can be correlated to undrained shear strength values using the method inSsection 6.1. Based on this single result TMF fine soils are anticipated to have a derived undrained shear strength value of 65 kPa. This value value should be treated with caution if applying to the whole of the fine soils within weathering Grade 4 and 5 materials from the TMF.

A single drained shear box measurement was undertaken. A peak angle of shear resistance, φ', of 27° was recorded, with a peak effective cohesion value, c´, of 14kPa. A single SPT N-Value of 21 was recorded in the coarse grained Grade 4/5 material; this value correlates to a friction angle, φ', of 33° (Ref. 30).

Table 6-5 Summary of Trendrean Formation laboratory testing

	PSD's No.	MC / Atterberg No. Of Tests	Dry Density / Moisture Content			Drained Shear Box		Slake Durability Testing		Aggressivity Classification	Point Load Testing	
			No.	OMC Range %	IMC Range %	Cohesion kN/m²	Friction Angle °	No.	Range		No.	Range $I_s(50)$
Grade 5 - Fine	-	1	-	-	-	14	27	-	-	DS-1 / AC-1d	-	-
Grade 5 - Coarse	4	-	1	15	15	14	27	-	-	DS-1 / AC-1d	-	-
Grade 4 - Coarse	1	-	-	-	-	-	-	-	-	DS-1 / AC-1d	-	-
Soil / Rock Interface												
Grade 3	-	-	1*	11	9.9	-	-	1	93.9	DS-1 / AC-1d	-	-
Grade 2	1	-	-	-	-	-	-		-	-	-	-
Grade 1	-	-	-	-	-	-	-		-	DS-1 / AC-1d	16	0.03-3.07
Grade 0	-	-	-	-	-	-	-		-	-	8	0.16-2.12

* Denotes testing undertaken on samples recovered from trial pits

A total of 2 No. dry density/moisture content relationship determination tests were undertaken on granular weathering Grade 5 material along with highly weathered Grade 2 material. The samples tested had an initial moisture content within ±1.1% of the optimum moisture content. This indicates materials would be at or around the optimum moisture with little if any treatment required for any proposed earthworks.

Chemical testing to determine the aggressive nature of the material indicated that a Design Sulphate Class of DS-1 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1 should be adopted for all concrete in contact with the TMF.

As no suitable samples were recovered to enable UCS testing of the TMF it has not been possible to undertake an assessment of the relationship between directly measured UCS values and point load test values. Tomlinson (Ref. 21) quotes a q_c/Is_{50} value of 23 for mudstone and siltstone (phyllite). These values have been used to correlate point load Is_{50} values and are presented in Figure 6-51 and Figure 6-52.

Further SPT testing was undertaken on weathering Grade 2 TMF. 3 No. test results of extrapolated N-Values of 300 to 600 were recorded, approximating to a UCS of 6-20MPa (Ref. 22).

A single Slake Durability Index determination test was undertaken on Grade 3 Phyllite material located in an area of proposed cut. An Index value of 93.9% was returned.

6.7 Summary of Geotechnical Parameters

Derived geotechnical parameters have been determined based on in-situ and laboratory testing undertaken across the site. Where this has not been possible, published data and relationships have been used to derive geotechnical values. Table 6-6 details material parameters for soils encountered and Table 6-7 to Table 6-9 detail rock parameters for bedrock material.

Table 6-6 Derived Geotechnical Parameters of Soils

	SPT N-Value		C_U(KPA)		Plasticity Index (*Ip*)		Φ´ $_P$ (°)		c´ $_P$ (KPA)		E´ (MPA)	E_U (MPA)	Slake Durability	
	Range	Derived	Range	Derived	Range	Derived	Range	Derived	Range	Derived	Range	Derived	Range	Derived
Alluvium	-	-	37-86*	37	14-27[a]	27[a]	31[a+]	31[a+]	5[a+]	1[a+]	-	-	-	-
							Porthtowan Formation							
Grade 4/5 - Fine	10 - 36	13-20[b]	50 – 180[2]	50-100[b]	6-29[a]	15[a]	20-41.5[d]	26-35	0-10[d]	0	19-29[3]	42[3]	-	-
Grade 4/5 - Coarse	4 - 51	15-20[b]	-	-	-	-	27.9-41.2[7]	31.6-33.1	1-7[d]	0	9-12[4]	-	92.7&96.9	92.7+
							Grampound Formation							
Grade 4/5 - Fine	12 - 31	13-20[b]	60 – 155[2]	60-100[b]	9 – 27[a]	21[a]	24-33[d]	25-29	4-17[d]	0	18-27[3]	44[3]	-	-
Grade 4/5 - Coarse	12 - 38	15-30[b]	-	-	-	-	30.6-38.2[7]	31.6-36.0	2[+d]	0	9-18[4]	-	-	-
							Trendrean Mudstone Formation							
Grade 4/5 - Fine	13[+]	13[+]	65[2+]	65[+]	18[a+]	18[a+]	27[+d]	27[+]	14[+d]	0	17[3]	39[3]	-	-
Grade 4/5 - Coarse	21[+]	21[+]	-	-	-	-	33[7]	33[+]	-	-	12[4]	-	-	-

	mv (m^2/MN)		OMC (%)	Max. dry density (Mg/m^3)	CBR (%)	Unit Weight (Mg/m^3)
	Range	Derived	Derived	Derived	Derived	Range
Alluvium	0.3-1.5[1]	1.5[1]	-	1.5[1]	-	2.0[5]
				Porthtowan Formation		
Grade 5 - Fine	0.1 – 0.3[1]	0.3[1]	8.9 – 16[ab]	1.86 – 1.92[ab]	3.7-9.45	2.0[5]
Grade 5 - Coarse	-	-	12 - 19[ab]	1.74 – 1.99[ab]	5-13.5	2.0[5]
Grade 4 - Fine	0.1 – 0.3[1]	0.3[1]	-	-	10.5	2.0[5]
Grade 4 - Coarse	-	-	11 - 14[ab]	1.93 – 2.02[ab]	1.9&7.05	2.0[5]
				Grampound Formation		
Grade 5 - Fine	0.1 – 0.3[1]	0.3[1]	15.5[a+]	1.86[a+]	1.8&7.45	2.0[5]
Grade 5 - Coarse	-	-	16[a+]	1.84[a+]	3.7-9.7	2.0[5]
Grade 4 - Fine	0.1 – 0.3[1]	0.3[1]	-	-	-	2.0[5]
Grade 4 - Coarse	-	-	-	-	4.75-6.6	2.0[5]
				Trendrean Mudstone Formation		
Grade 5 - Fine	0.1 – 0.3[6]	0.3[6]	-	-		2.0[5]
Grade 5 - Coarse	-	-	15[a+]	1.89[a+]	5.9&6.4	2.0[5]
Grade 4 - Fine	0.1 – 0.3[6]	0.3[6]	-	-	-	2.0[5]
Grade 4 - Coarse	-	-	-	-	-	2.0[5]

[+] - Value derived from single determination, use with caution.
* - Obtained from in-situ hand shear vane
a – Value has been derived based upon laboratory data.

1 - Derived using Carter and Bentley, 1991 (Ref. 26)
2 - Derived using CIRIA report 143, 1995 (Ref. 22)
3 - Derived using Stroud & Butler, 1975 (Ref. 23)
4 - Bowles, 1997 (Ref. 27)
5 – BS8002:2015 (Ref. 25)

b – Based on median as deemed most appropriate value.	6 – ReWaRD user guide (Ref. 28)
c – Derived from average.	7 – Derived using Peck, Hanson and Thorburn, 1974. (Ref. 30)
d – Derived from shearbox testing	
e - For parameters exhibiting increase with depth, z = depth below ground level (m)	

Table 6-7 Derived Geotechnical Parameters of Rock – Porthtowan Formation

PARAMETER	SPT N-VALUE		c_u (kPa)		φ'_p (°)		φ'_{res} (°)		c´ (kPa)	Unit Weight (Mg/m³)
	Range	Derived	Range	Derived	Range	Derived	Range	Derived	Derived	
Grade 3	17-150	50-100	-	-		-	-	-	0	2.1[6]
Grade 2	29 - 272	80-150	-	-	-	-	-	-	0	2.2[6]
Grade 1	32 - 333	100-175	-	-	-	-	-	-	0	2.3[6]
Grade 0	76 - 545	120[b]	-	-	-	-	-	-	0	2.4[6]

PARAMETER	UCS (MPa)						Slake Durability Index (%)
	Axial*		Diametrical*		Irregular*		
	Range	Derived	Range	Derived	Range	Derived	Derived
Grade 3 - Phyllite	1.15-40.48	1.15-3.0	0.23-3.68	1.0-2.5	0.23-15.64	3-5	94.9&96.0
Grade 3 - Psammite	0.24-6.48	0.5	0.48	0.5	0.72-8.64	1	53.5-92.9
Grade 3 – Sandstone	0.72-0.96	0.72	-	-	0.92-3.12	1-2	-
Grade 3 - Mudstone	0.46	0.46	0.46	0.46	-	-	-
Grade 2 - Phyllite	0.23-17.94	2.0 + (Z-3)	0-7.13	1.0 + (Z-3)	0.23-18.17	1-5	94.5-95.2
Grade 2 - Psammite	0.72-12.24	1	0-3.36	1	0.48-45.84	1-3	89.7
Grade 2 - Sandstone	0.72-2.16	0.72	0.48	0.48	0.48-2.4	1	71.8-95.0
Grade 2 - Mudstone	0.23-8.51	0.23	0.23-0.46	0.23	0.23	0.23	-
Grade 1 - Phyllite	0.69-41.63	1-4	0-9.43	1-2	0.46-63.25	1-3	-
Grade 1 - Psammite	0.72-17.04	1-5	0.24-14.88	1-5	0-12.96	1-3	-
Grade 1 - Sandstone	0.48-34.08	2-5	0.24-16.56	1-3	1.92-6.24	2	-
Grade 0 - Phyllite	0.69 – 28.3	2.5-7.5	0.46-12.42	2.5-7.5	0.23-9.20	5	96.9
Grade 0 - Psammite	4.08-8.40	4	2.4-16.8	2.4	-	-	-

+ - Value derived from single determination, use with caution.
* - point load orientation
a – Value has been derived based upon laboratory data.
b – Based on median as deemed most appropriate value.
c – Derived from average.
d – Derived from shearbox testing
e - For parameters exhibiting increase with depth, z = depth below ground level (m)

1 - Derived using Carter and Bentley, 1991 (Ref. 26)
2 - Derived using CIRIA report 143, 1995 (Ref. 22)
3 - Derived using Stroud & Butler, 1975 (Ref. 23)
4 - Bowles, 1997 (Ref. 27)
5 – BS8002:2015 (Ref. 25)
6 – ReWaRD user guide (Ref. 28)
7 – Derived using Peck, Hanson and Thorburn, 1974. (Ref. 30)

Table 6-8 Derived Geotechnical Parameters of Rock – Grampound Formation

PARAMETER	SPT N-VALUE		c_u (kPa)		φ´p (°)		φ´res (°)		c´ (kPa)	UNIT WEIGHT (Mg/m^3)
	Range	Derived	Range	Derived	Range		Range	Derived	Derived	
Grade 3	16 - 47	20-35	-	-	-	21[6]	-	-	-	2.1[6]
Grade 2	28 - 240	30-50	-	-	-	22[6]	-	-	-	2.2[6]
Grade 1	29 – 428	50-150	-	-	-	23[6]	-	-	-	2.3[6]
Grade 0	250	250[+]	-	-	-	24[6]	-	-	-	2.4[6]

PARAMETER	UCS (MPa)						Slake Durability Index (%)
	Axial*		Diametrical*		Irregular*		
	Range	Derived	Range	Derived	Range	Derived	Derived
Grade 3 - Phyllite	0.46-14.26	0.46	0.69-2.3	0.69	-	-	89-94.7
Grade 3 - Sandstone	-	-	-	-	-	-	84.7 & 95.7
Grade 2 - Phyllite	0.46-54.51	1	0.23-12.19	1.5	0.23-36.8	1-7.5	91 & 94.3
Grade 2 - Psammite	1.68-7.68	2	0.0-0.24	0.24	0.48-60.24	1	-
Grade 2 – Mudstone / sandstone	-		-		-		95.1[+]
Grade 2 – Mudstone	-		-		-		86.1[+]
Grade 1 - Phyllite	0.23-58.42	2-10	0.23-32.66	1-5	0.23-77.28	1-8	-
Grade 1 - Psammite	3.12-81.84	2.5-7.5	0-18.24	2	2.16-56.4	3-7.5	-
Grade 1 - Sandstone	0.48-9.12	1.5	0.96-9.84	2-5	0.96-11.76	2-5	-
Grade 1 - Siltstone	1.15-13.11	1.15	1.15-6.44	1-3	1.38-18.86	5-10	-
Grade 1 - Mudstone	1.61	1.61	1.15	1.15	0.46-2.76	1	-
Grade 0 - Phyllite	3.22-68.31	3.22	1.15-8.97	1.15	106.95	1	-
Grade 0 - Psammite	0.48-38.16	2.5-5	0.24-6.48	1-2.5	2.4-3.36	2.5-5	-

[+] - Value derived from single determination, use with caution.
* - point load orientation
a – Value has been derived based upon laboratory data.
b – Based on median as deemed most appropriate value.
c – Derived from average.
d – Derived from shearbox testing
e - For parameters exhibiting increase with depth, z = depth below ground level (m)

1 - Derived using Carter and Bentley, 1991 (Ref. 26)
2 - Derived using CIRIA report 143, 1995 (Ref. 22)
3 - Derived using Stroud & Butler, 1975 (Ref. 23)
4 - Bowles, 1997 (Ref. 27)
5 – BS8002:2015 (Ref. 25)
6 – ReWaRD user guide (Ref. 28)
7 – Derived using Peck, Hanson and Thorburn, 1974. (Ref. 30)

Table 6-9 Derived Geotechnical Parameters of Rock – Trendrean Mudstone Formation

PARAMETER	SPT N-VALUE		c_u (kPa)		φ'_p (°)		φ'_{res} (°)		c´ (kPa)	UNIT WEIGHT (Mg/m³)
	Range	Derived	Range	Derived	Range	Unit Weight (Mg/m3)	Range	Derived	Derived	
Grade 3			-	-	-	-	-	-	-	2.1[6]
Grade 2			-	-	-	-	-	-	-	2.2[6]
Grade 1	200 - 600	200-400	-	-	-	-	-	-	-	2.3[6]
Grade 0			-	-	-	-	-	-	-	2.4[6]

PARAMETER	UCS (MPa)						Slake Durability Index (%)
	Axial*		Diametrical*		Irregular*		
	Range	Derived	Range	Derived	Range	Derived	Derived
Grade 3 - Phyllite	-	-	-	-	-	-	93.89
Grade 1 - Phyllite	3.91-17.48	2	3.68-9.89	3.68	7.36-48.76	7.36	-
Grade 0 - Phyllite	2.07-70.61	2.07	0.69-65.09	1-2	2.07-3.68	2.07	-

\+ - Value derived from single determination, use with caution.
* - point load orientation
a – Value has been derived based upon laboratory data.
b – Based on median as deemed most appropriate value.
c – Derived from average.
d – Derived from shearbox testing
e - For parameters exhibiting increase with depth, z = depth below ground level (m)

1 - Derived using Carter and Bentley, 1991 (Ref. 26)
2 - Derived using CIRIA report 143, 1995 (Ref. 22)
3 - Derived using Stroud & Butler, 1975 (Ref. 23)
4 - Bowles, 1997 (Ref. 27)
5 – BS8002:2015 (Ref. 25)
6 – ReWaRD user guide (Ref. 28)
7 – Derived using Peck, Hanson and Thorburn, 1974. (Ref. 30)

Figure 6-1 Hand Shear Vane Readings – Alluvium

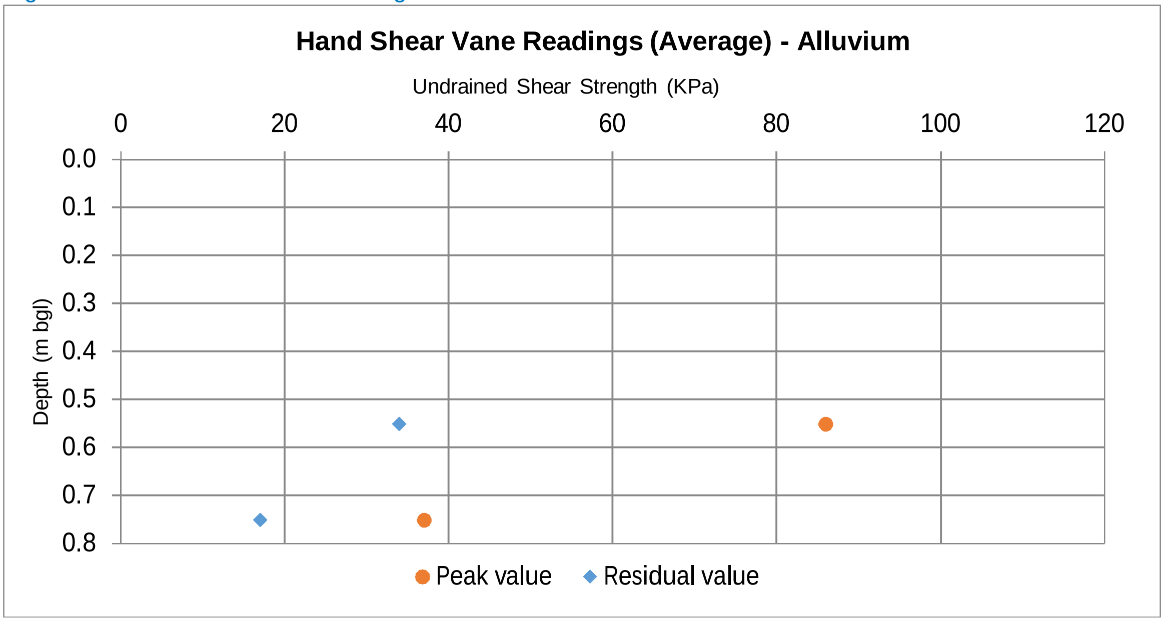


Figure 6-2 Casagrande Chart – Alluvium

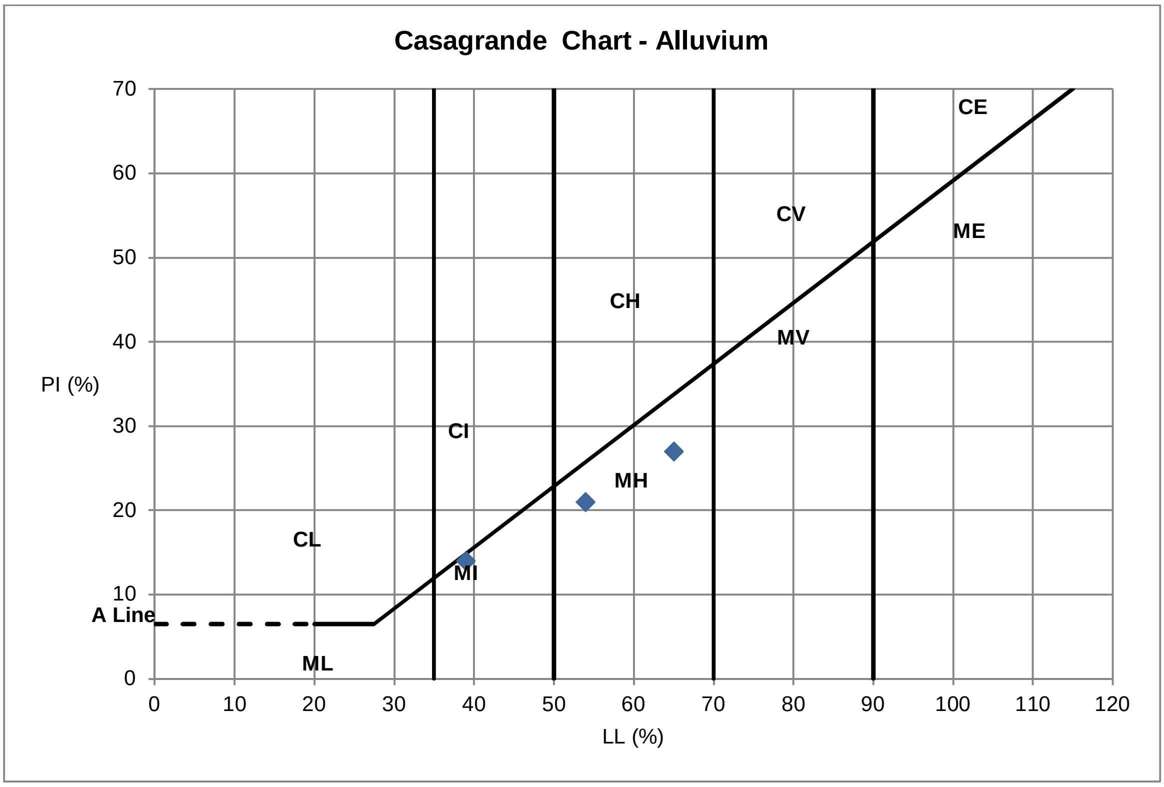


Figure 6-3 Undrained Shear Strength, Cu vs depth - fine soils from weathering Grade 4&5 material

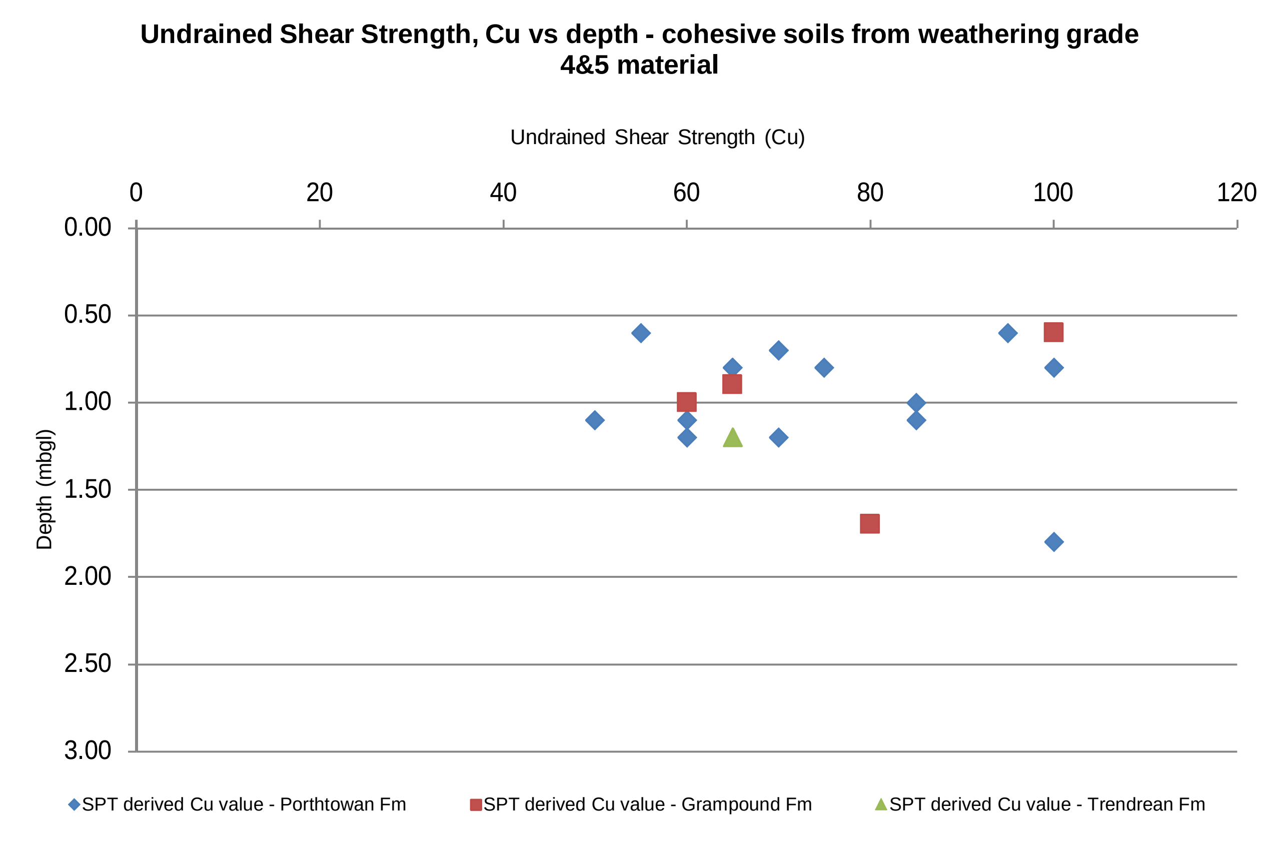


Figure 6-4 Recorded SPT N-Values versus Depth – Porthtowan Formation

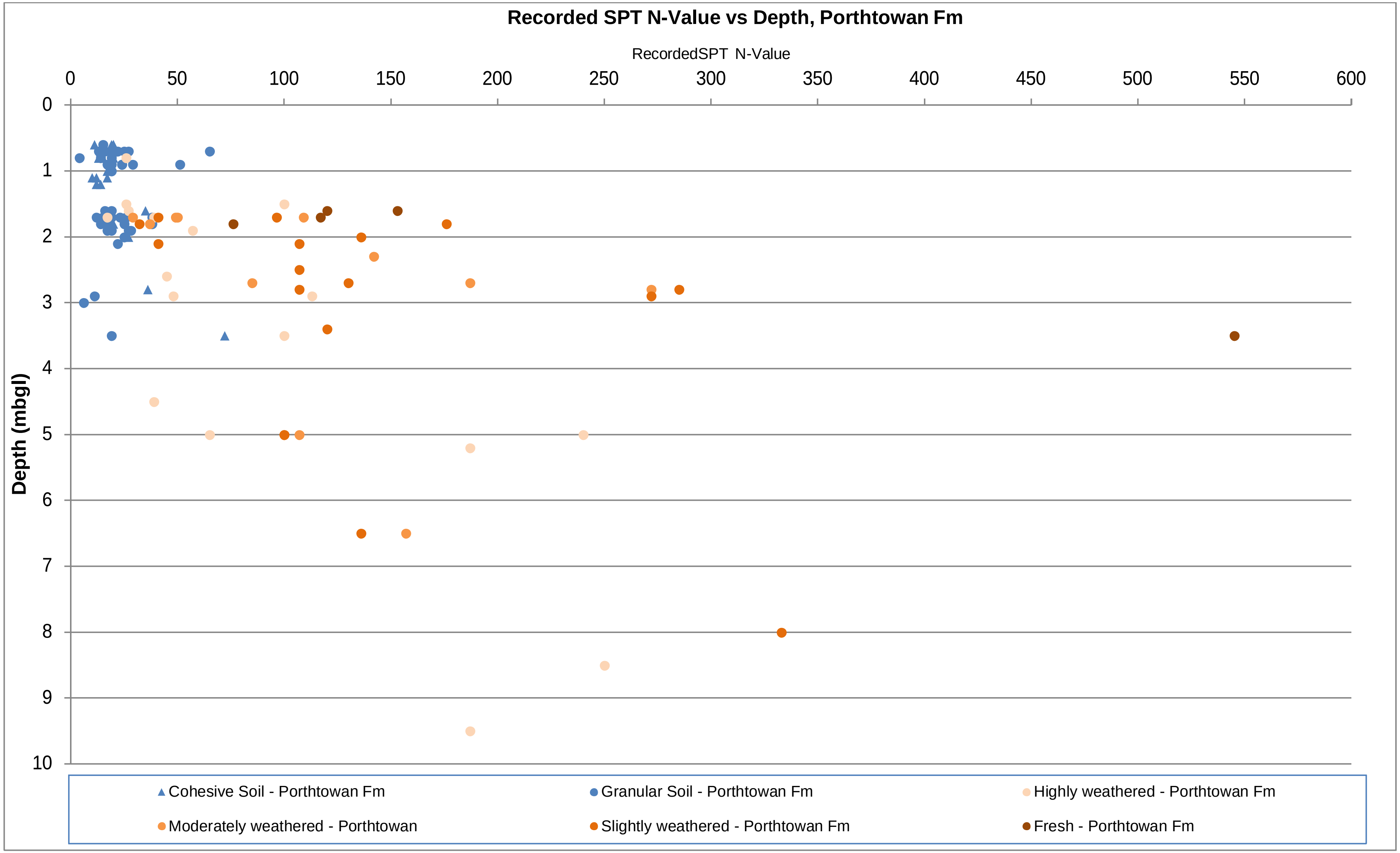


Figure 6-5 Hand Shear Vane Readings – Porthtowan

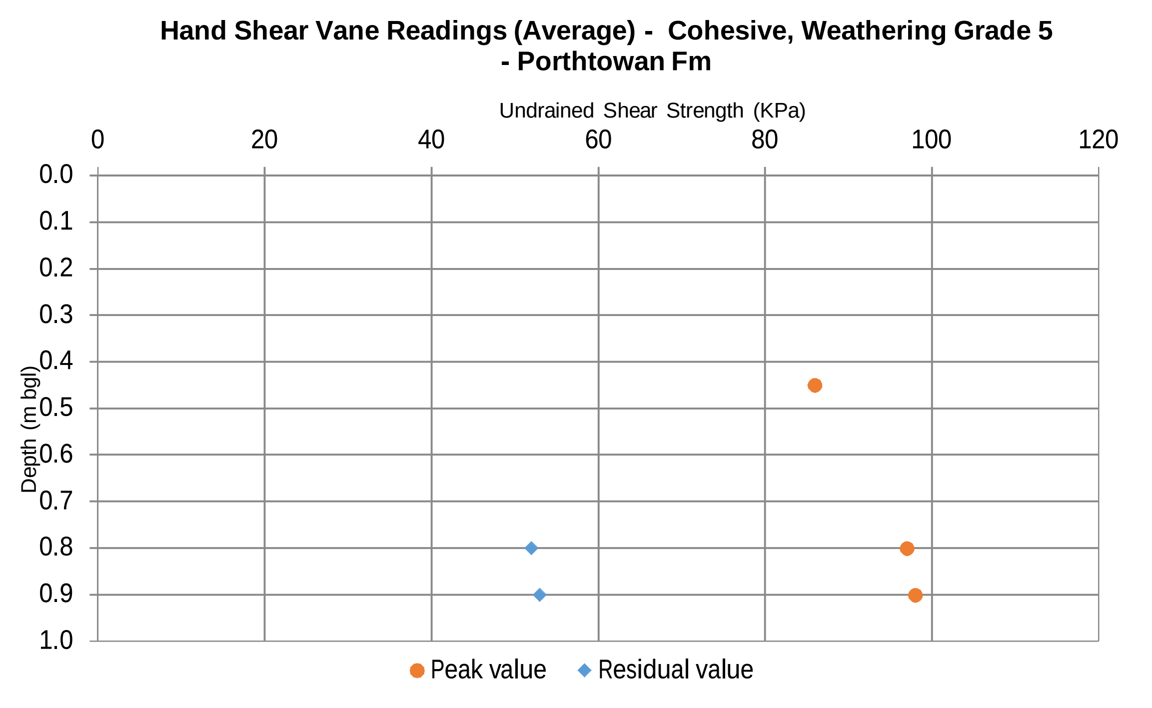


Figure 6-6 Particle Size Distribution Grading Curve – Porthtowan Formation – Coarse Grade 4&5

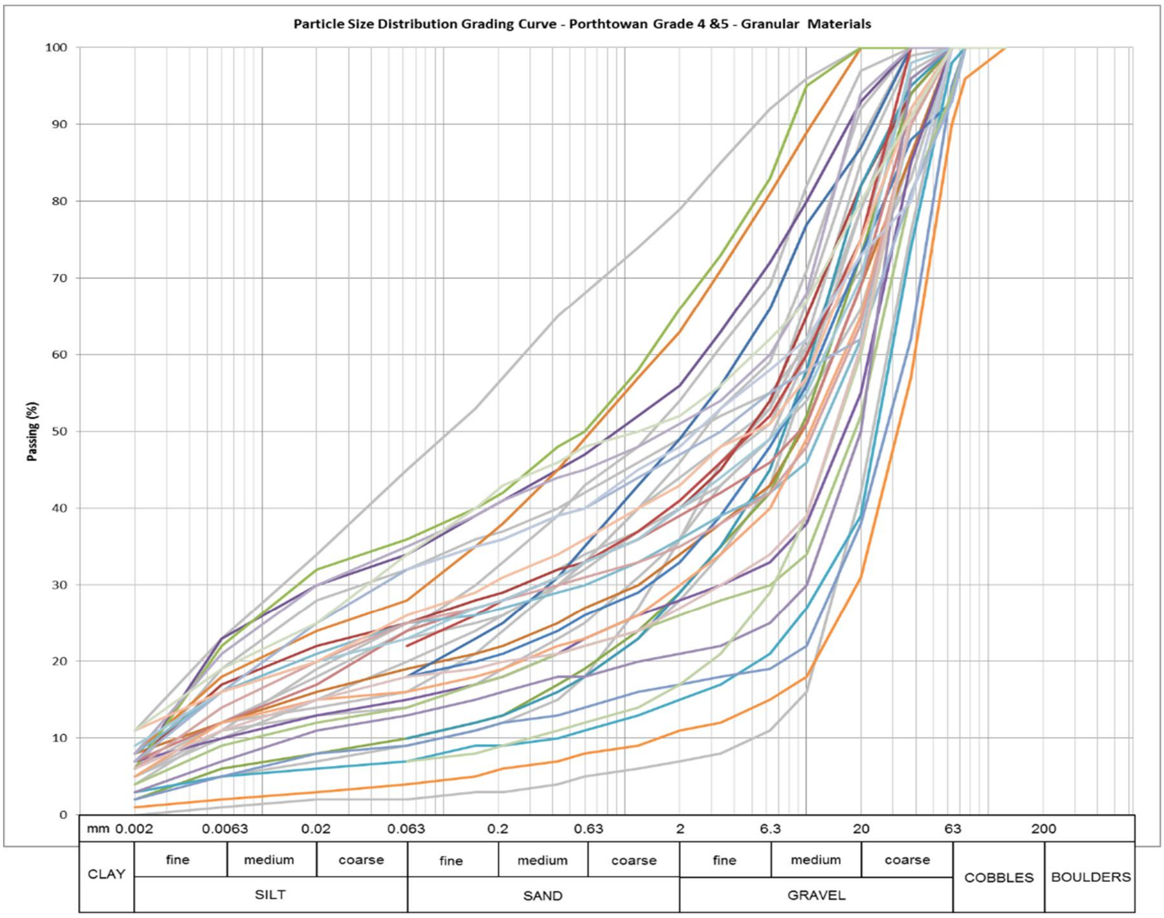


Figure 6-7 Particle Size Distribution Grading Curve – Porthtowan Formation – Fine Grade 4&5

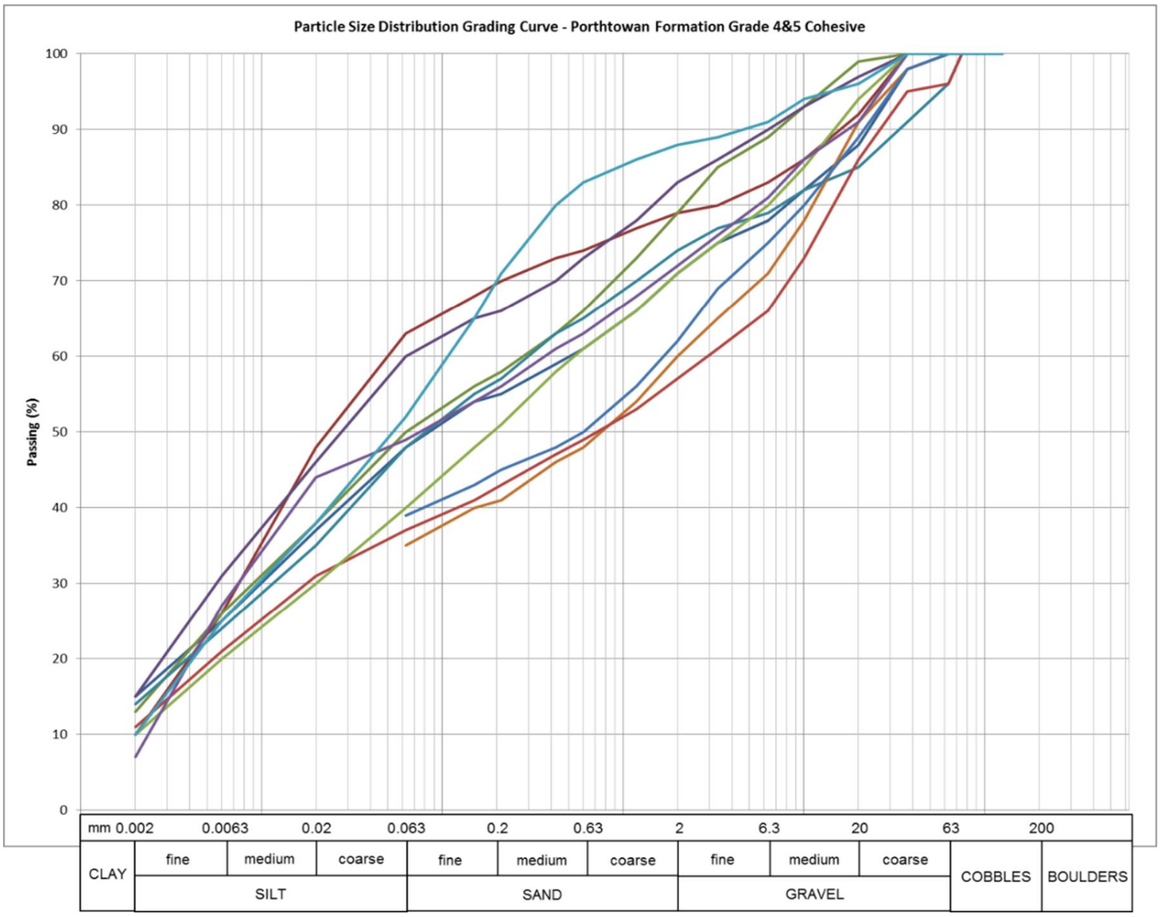


Figure 6-8 Casagrande Chart – Porthtowan Formation Grade 4&5 material

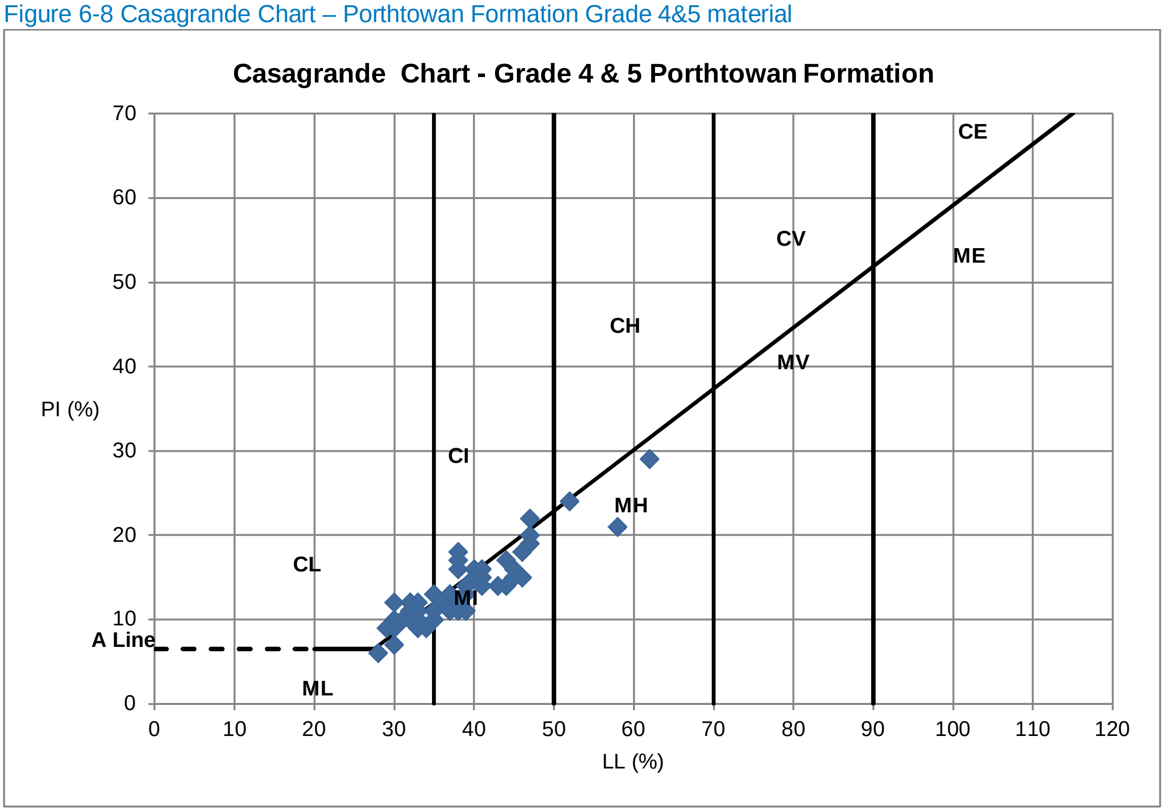


Figure 6-9 Summary of Shear Box Test Results Peak angle of Shear Resistance– Porthtowan Formation

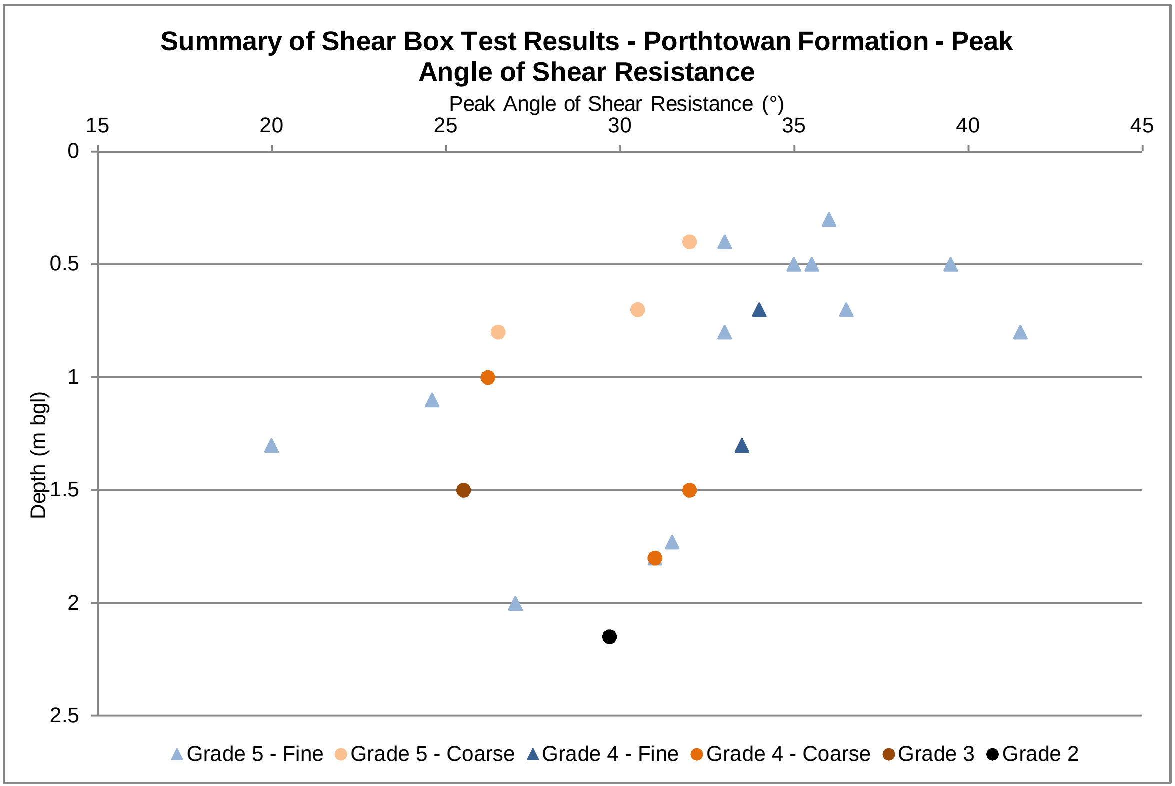


Figure 6-10 Summary of Shear Box Test Results Peak effective Cohesion Intercept – Porthtowan Formation

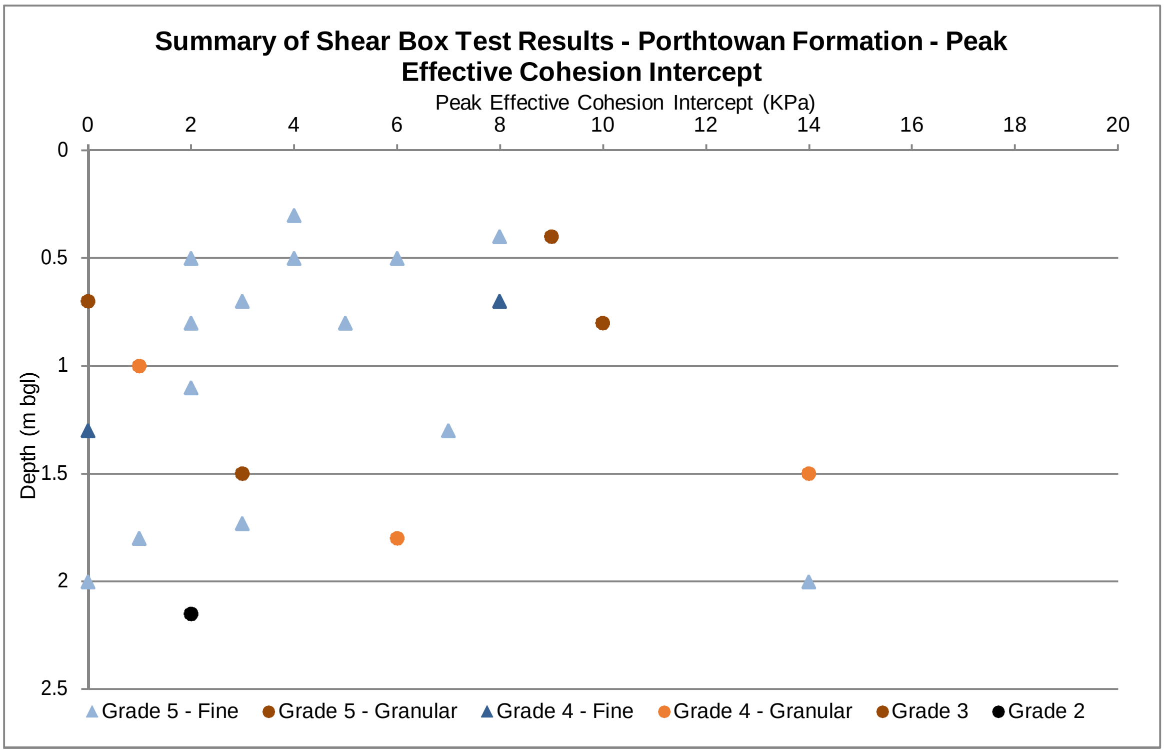


Figure 6-11 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 0 – All Strata

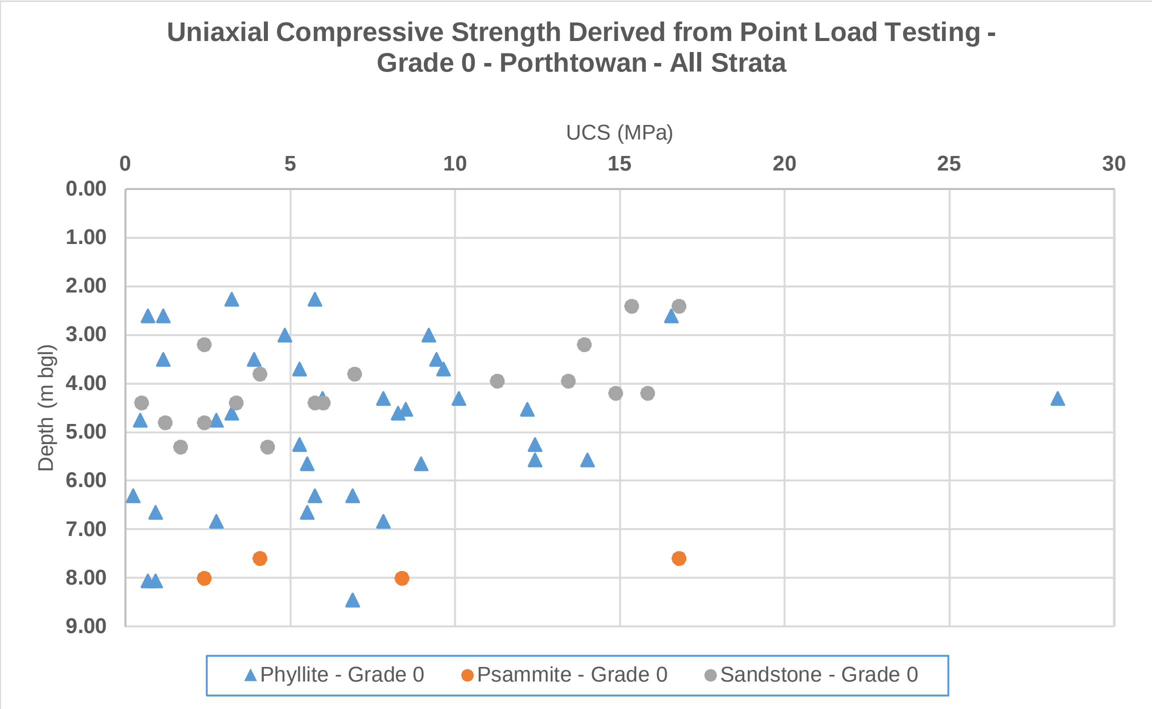


Figure 6-12 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 0 – Phyllite

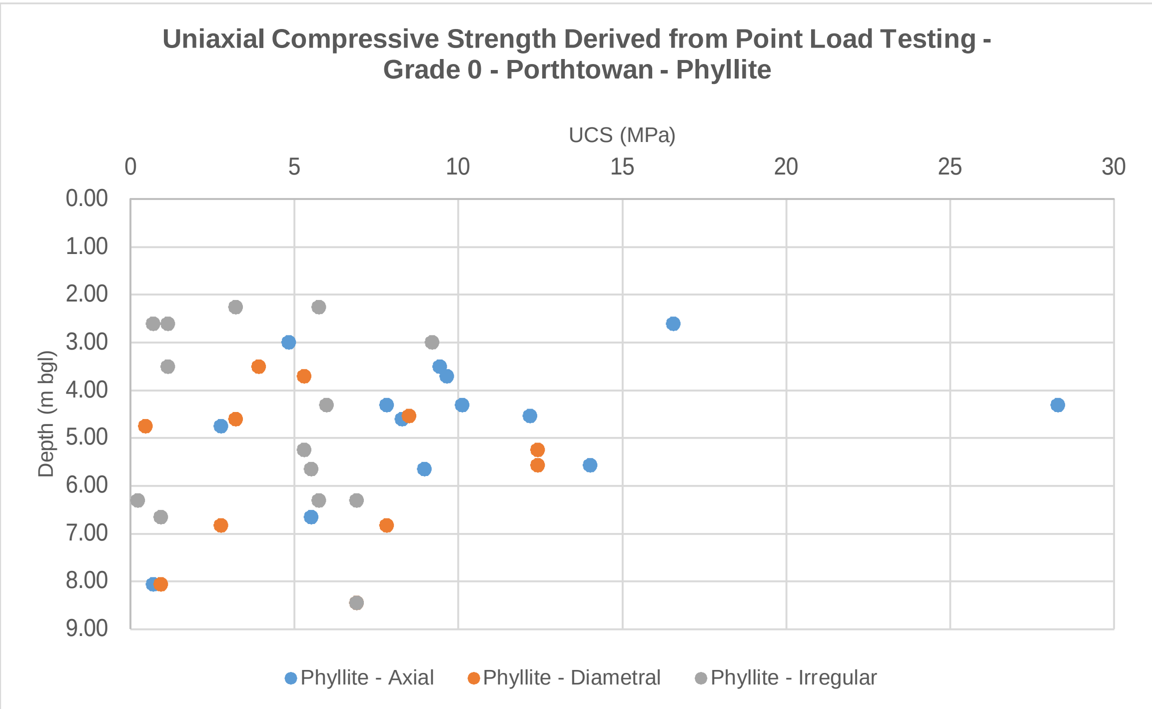


Figure 6-13 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 0 – Psammite

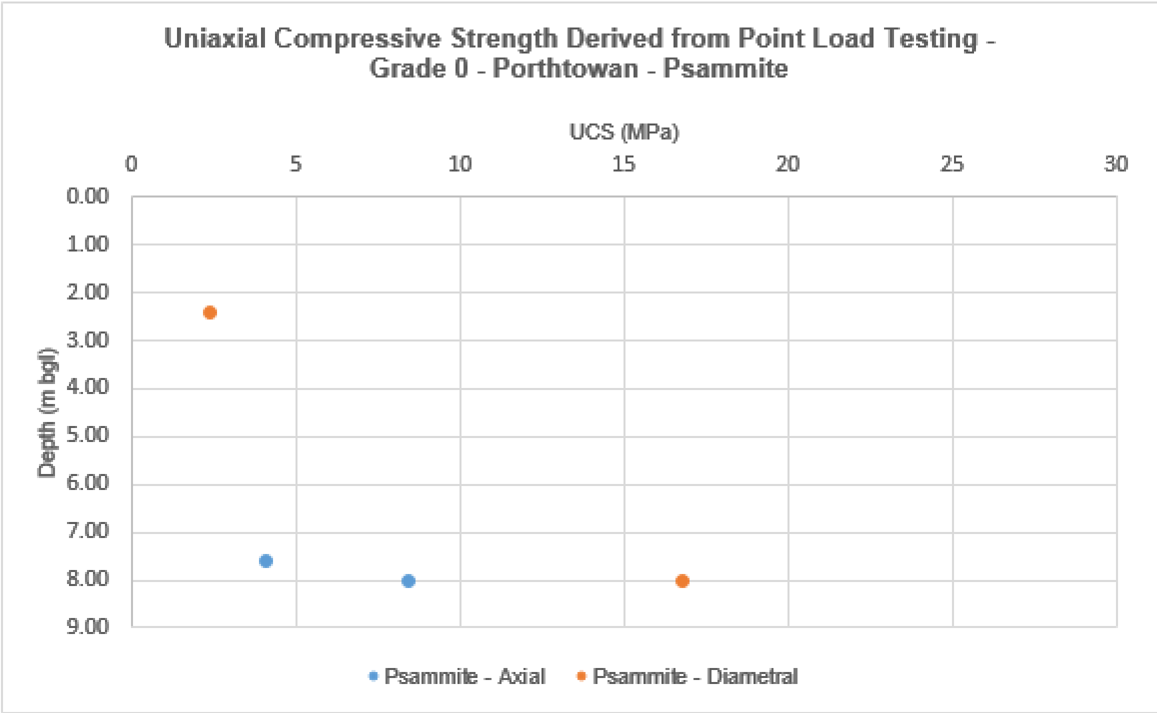


Figure 6-14 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 1 – All Strata

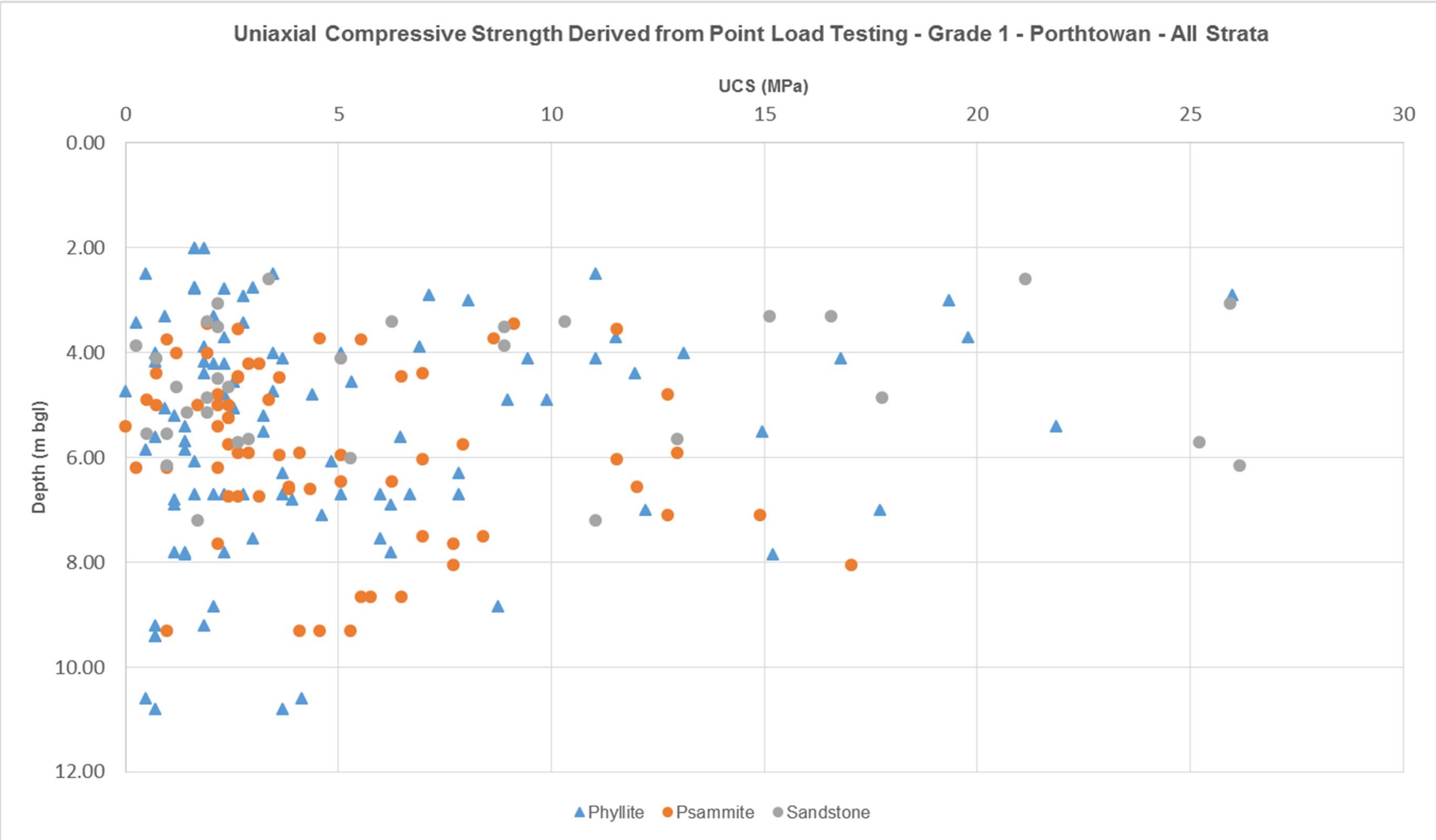


Figure 6-15 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 1 – Phyllite

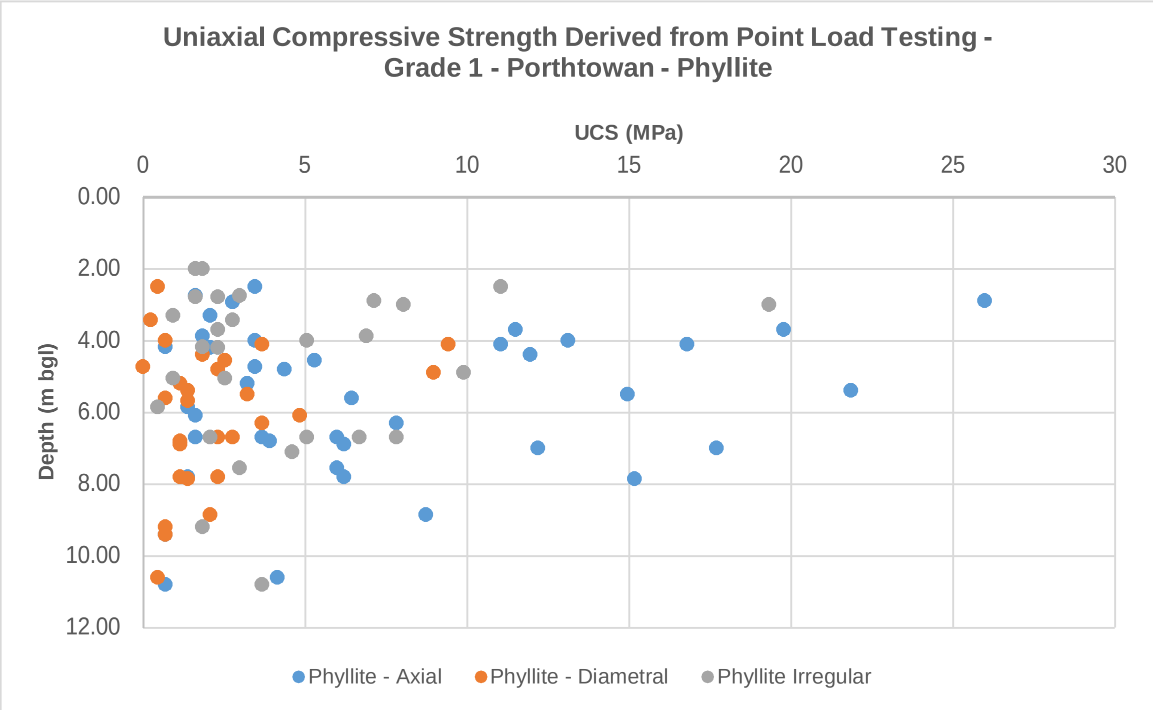


Figure 6-16 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 1 – Psammite

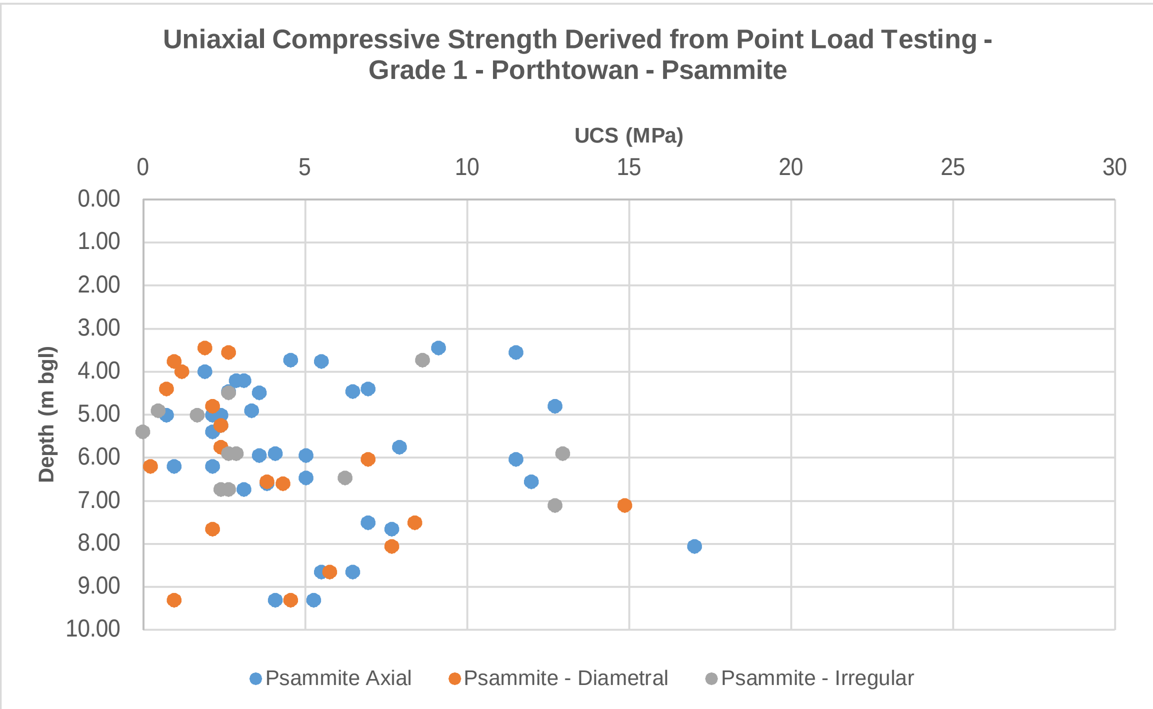


Figure 6-17 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 1 – Sandstone

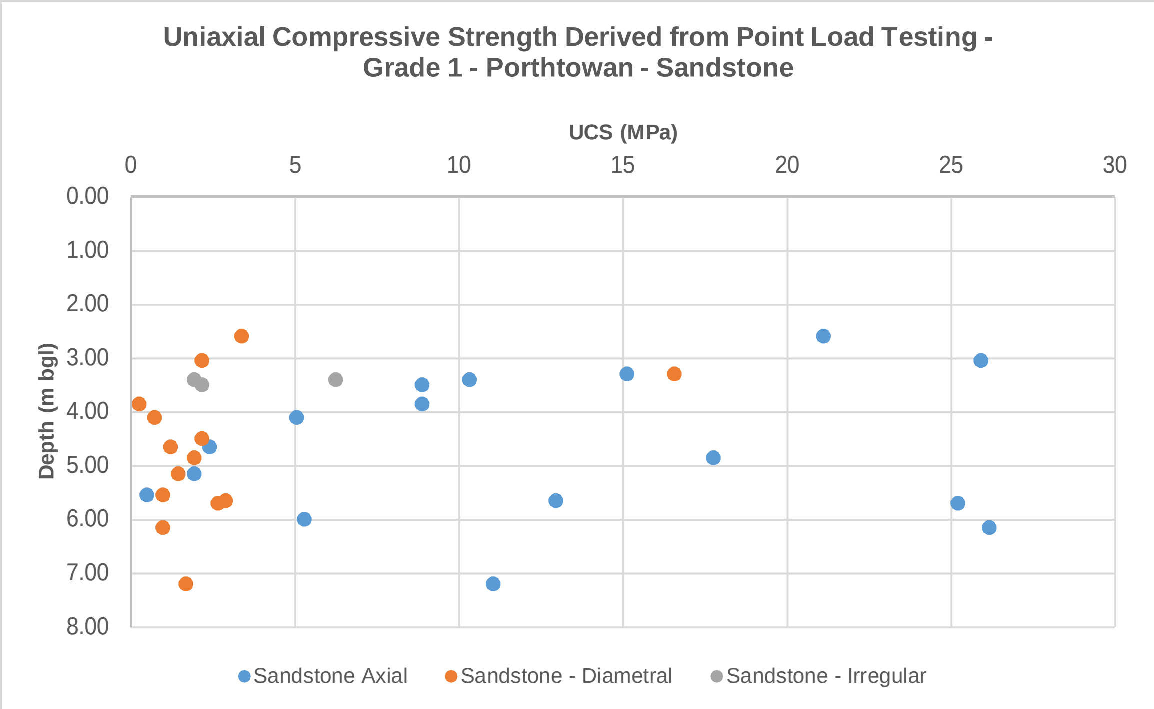


Figure 6-18 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 2 – All Strata

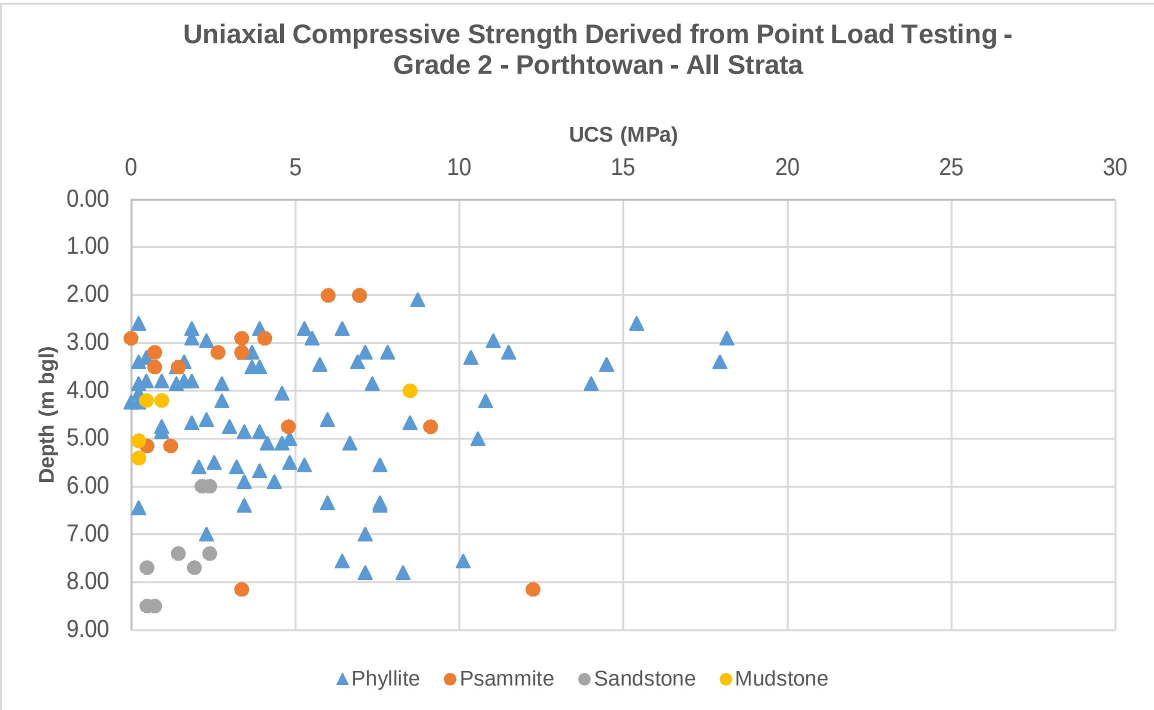


Figure 6-19 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 2 – Phyllite

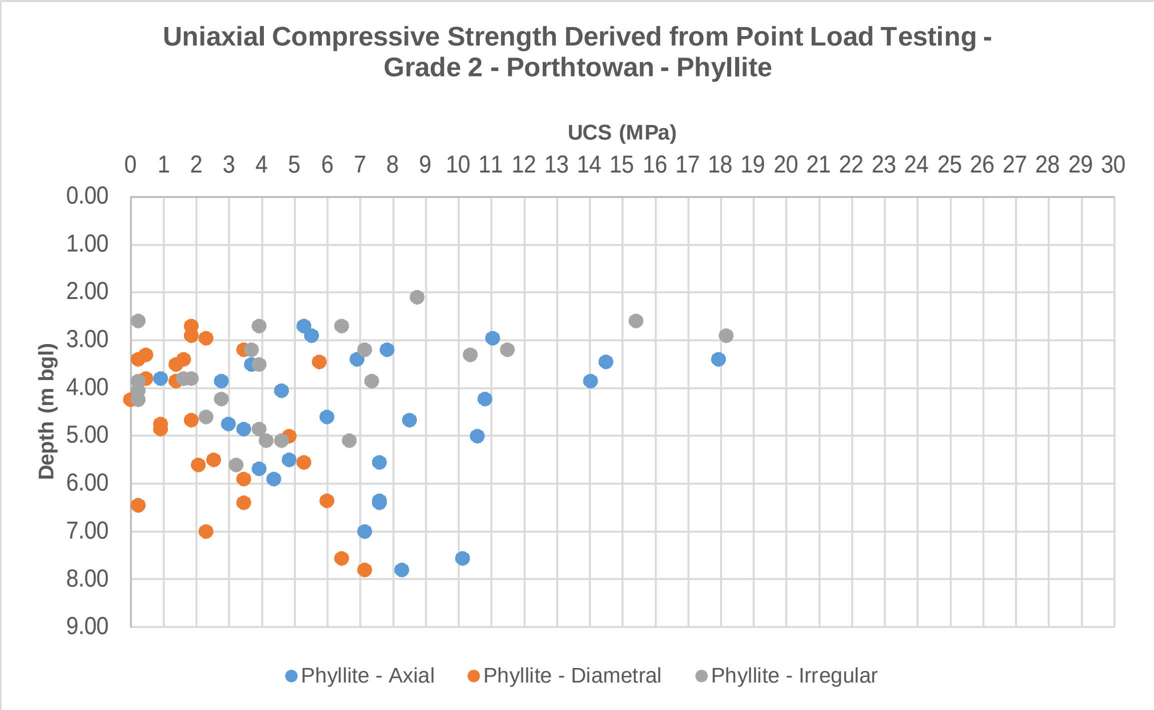


Figure 6-20 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 2 – Psammite

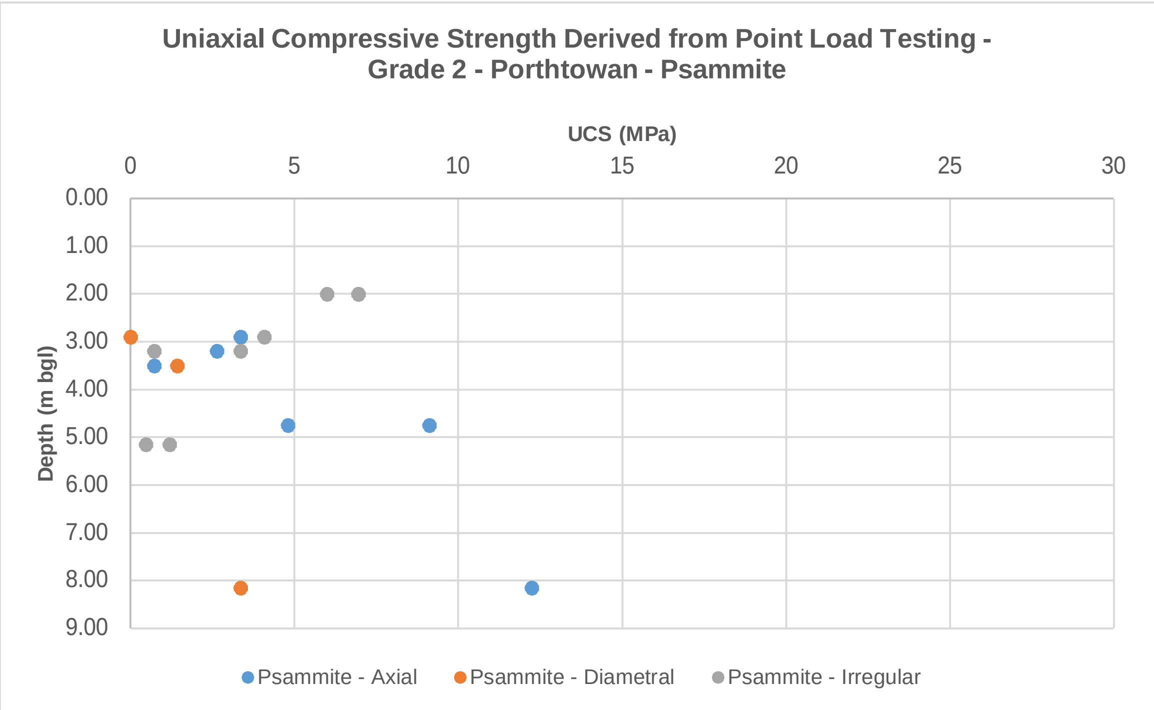


Figure 6-21 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 2 – Sandstone

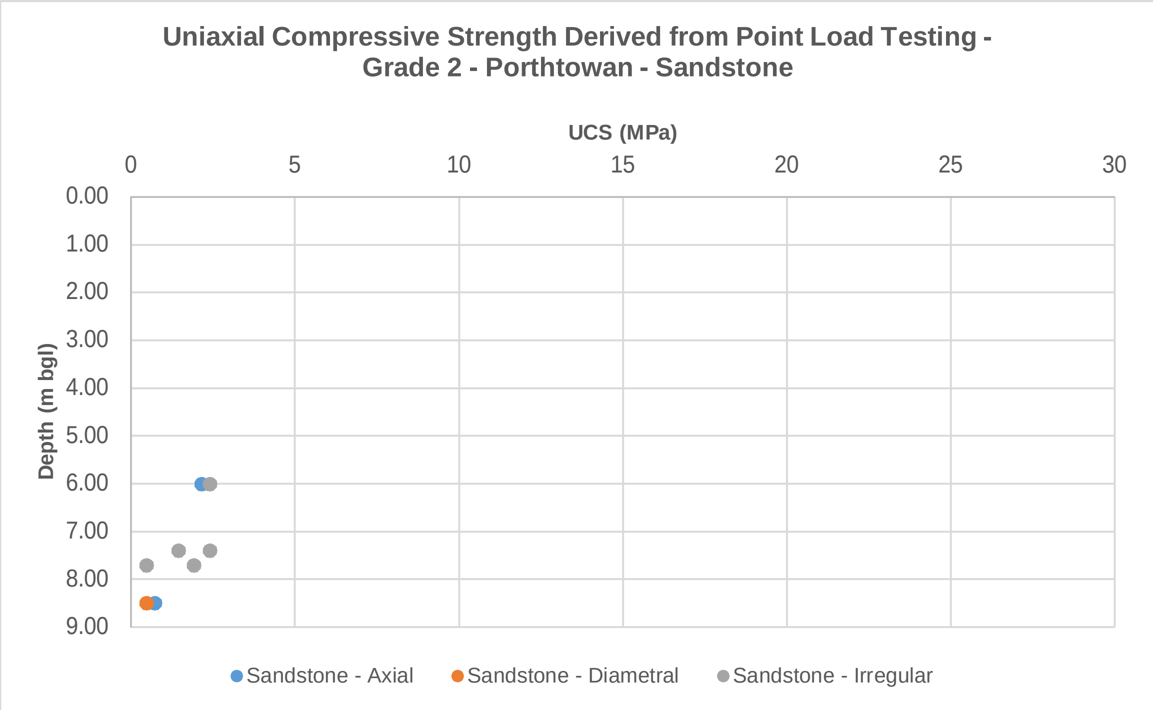


Figure 6-22 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 2 – Mudstone

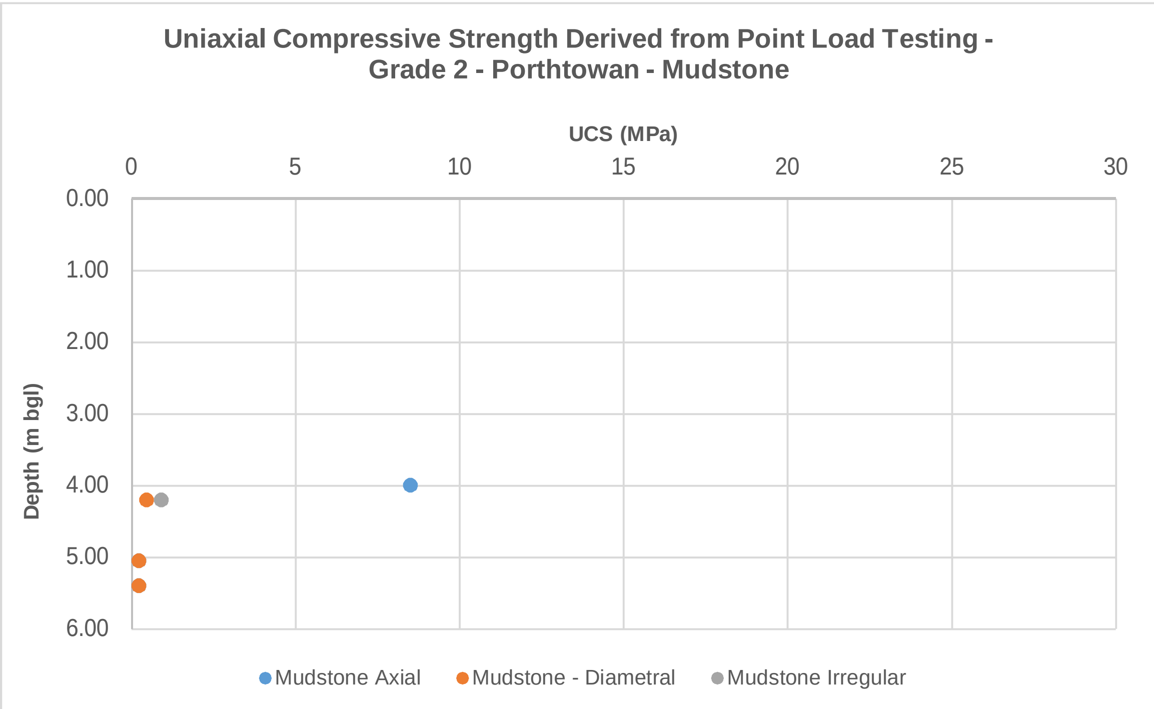


Figure 6-23 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 3 – All Strata

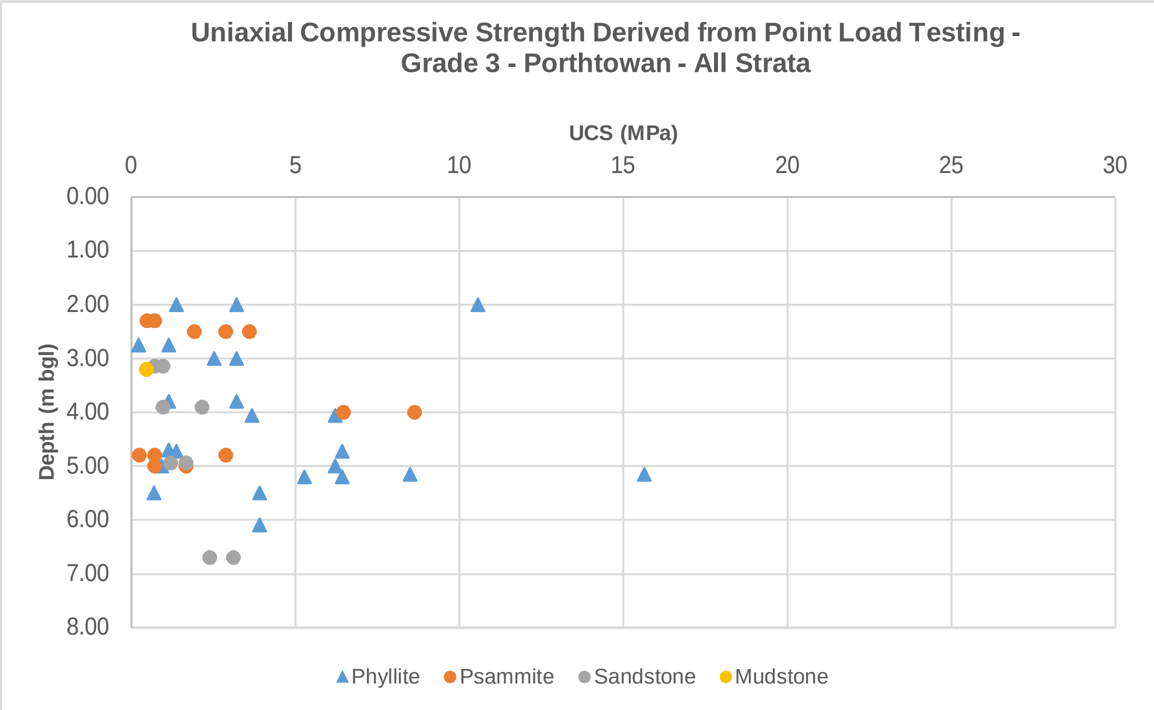


Figure 6-24 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 3 – Phyllite

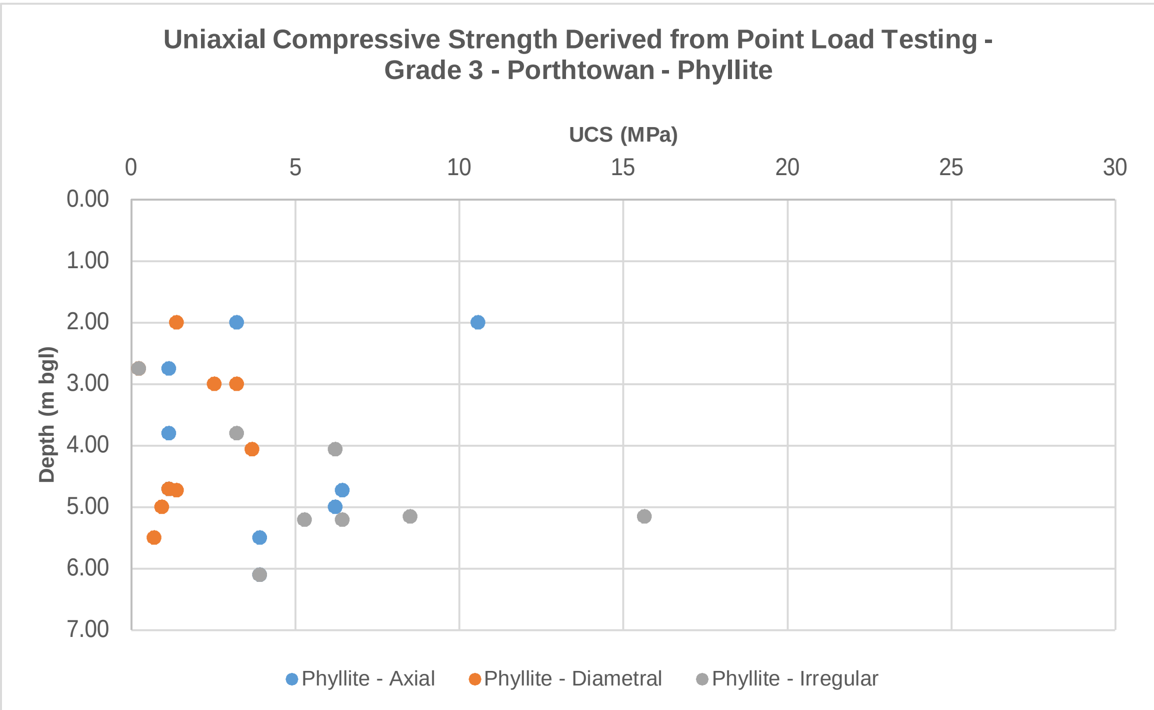


Figure 6-25 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 3 – Psammite

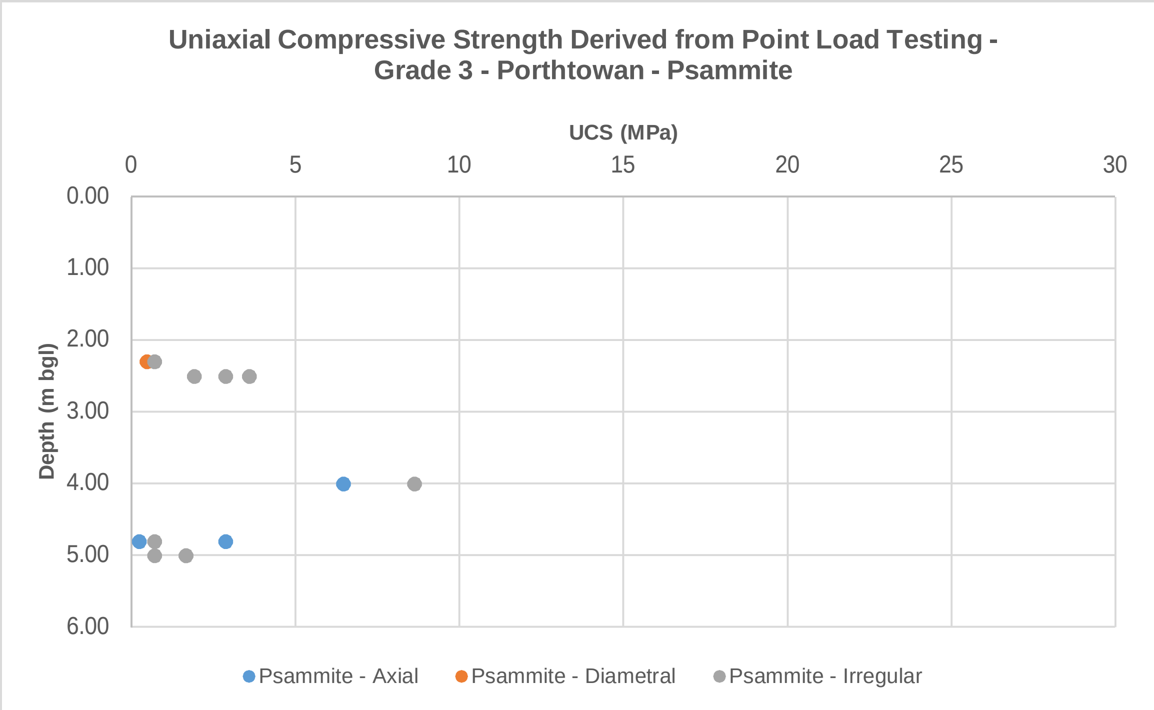


Figure 6-26 Uniaxial Compressive Strength Derived from Point Load Testing – Porthtowan Formation – Grade 3 – Sandstone

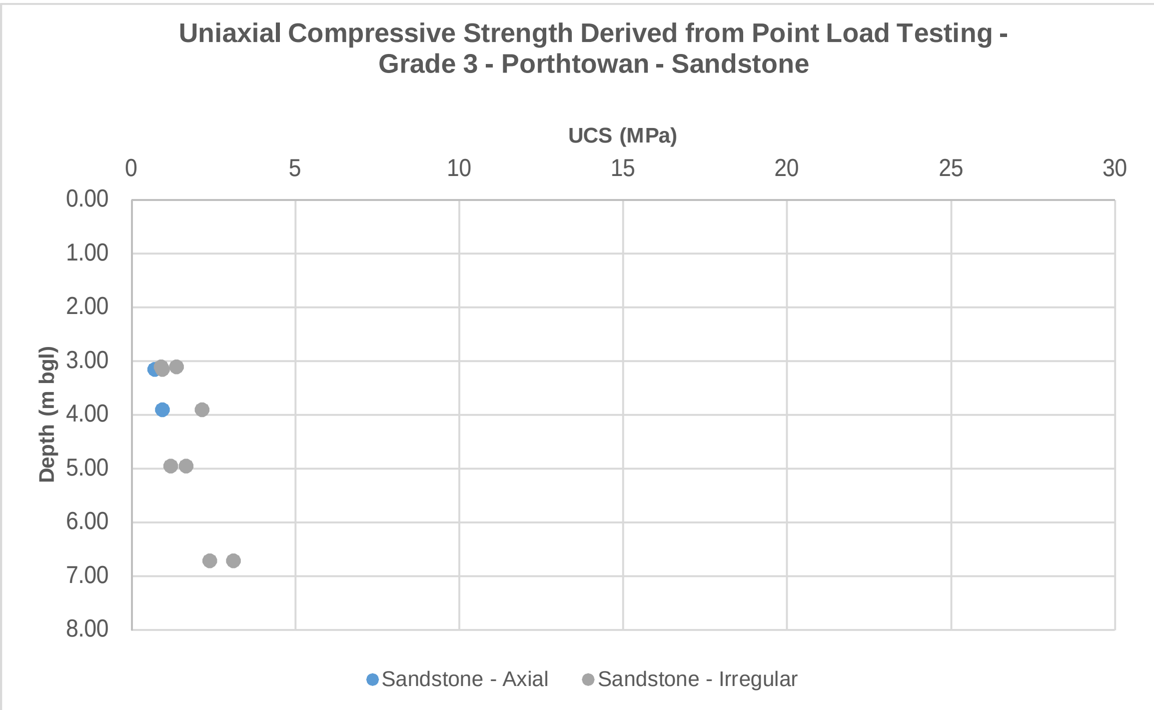


Figure 6-27 Slake Durability – Porthtowan Formation

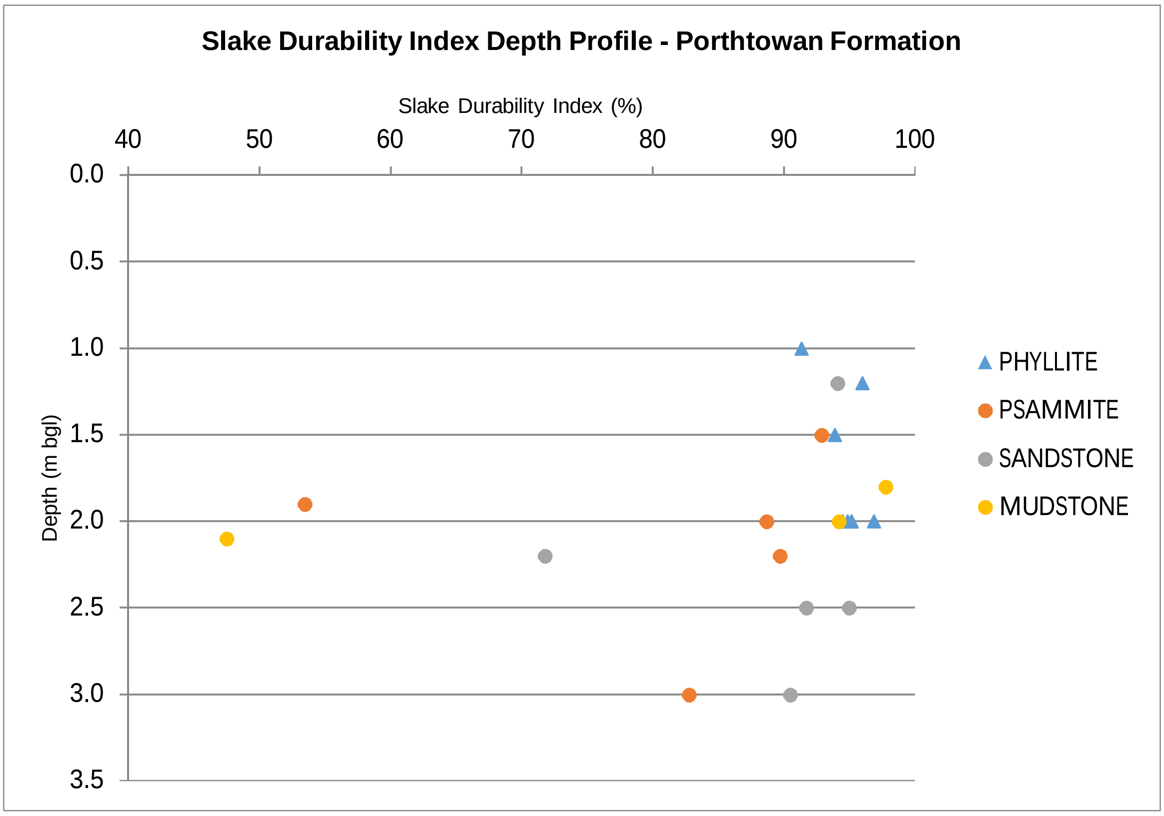


Figure 6-28 Recorded SPT N-Values versus Depth – Grampound Formation

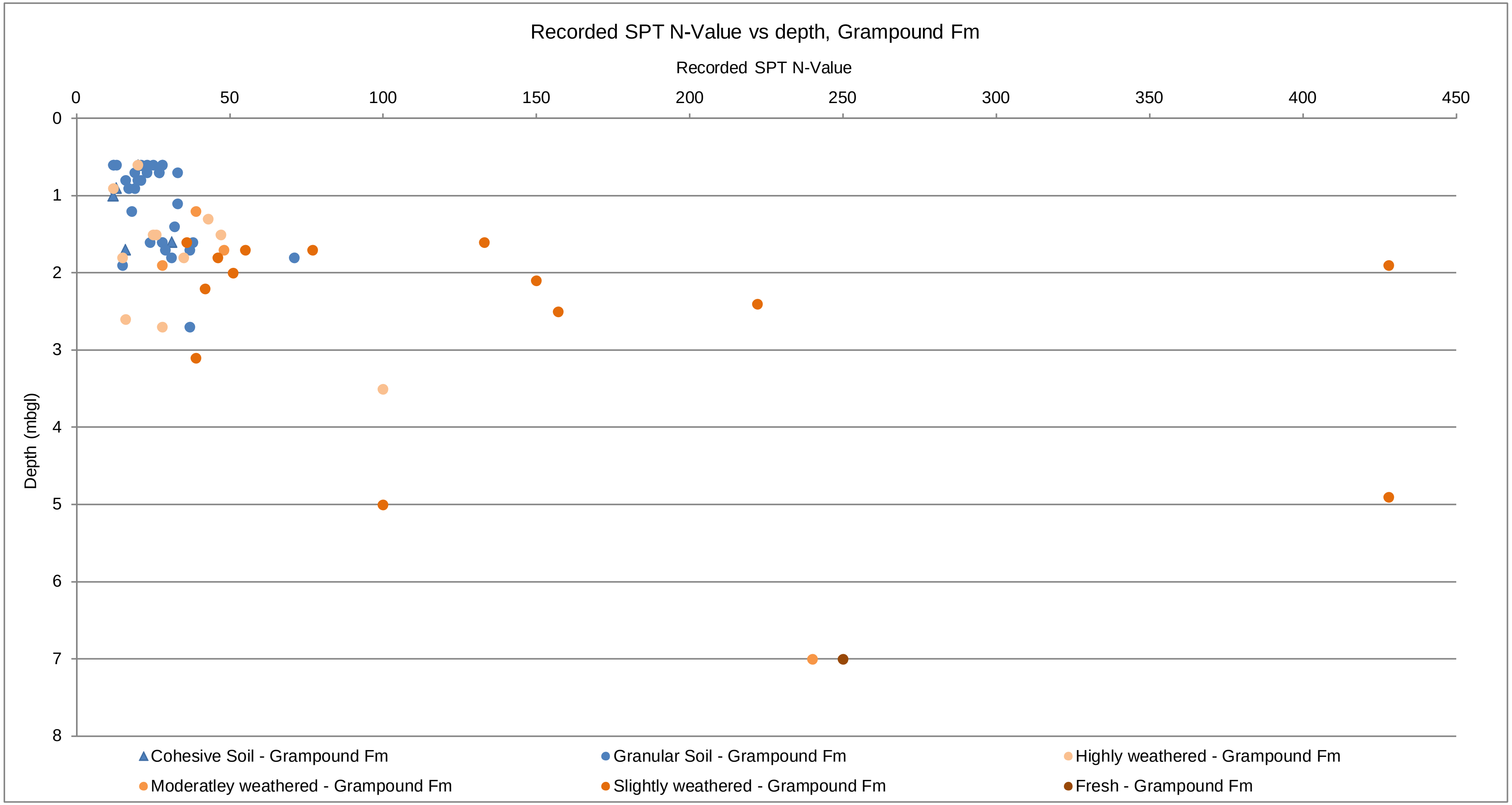


Figure 6-29 Hand Shear Vane Readings – Grampound Formation

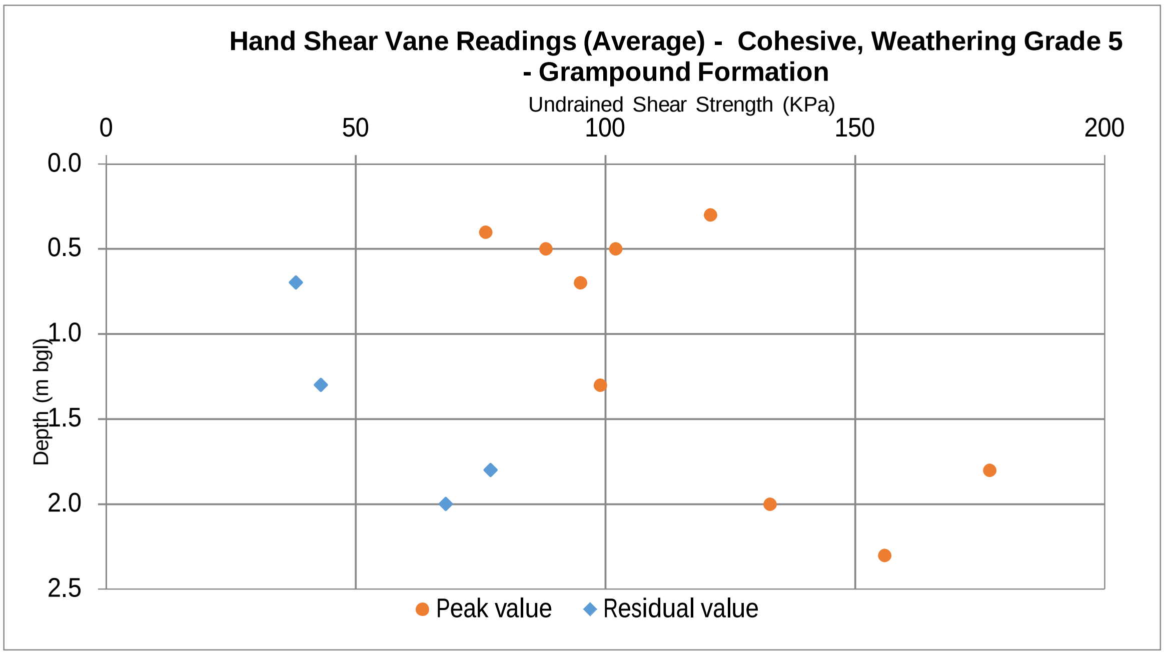


Figure 6-30 Particle Size Distribution Grading Curve – Grampound Formation – Coarse

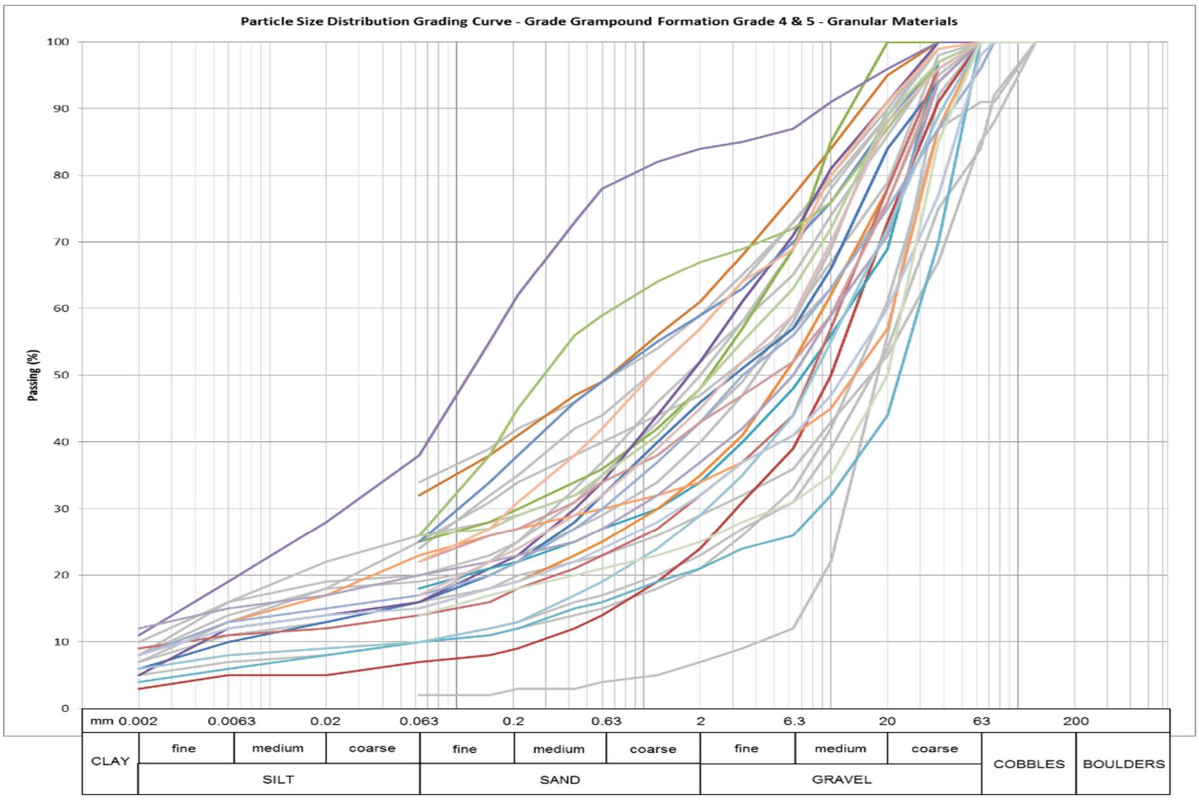


Figure 6-31 Particle Size Distribution Grading Curve – Grampound Formation - Fine

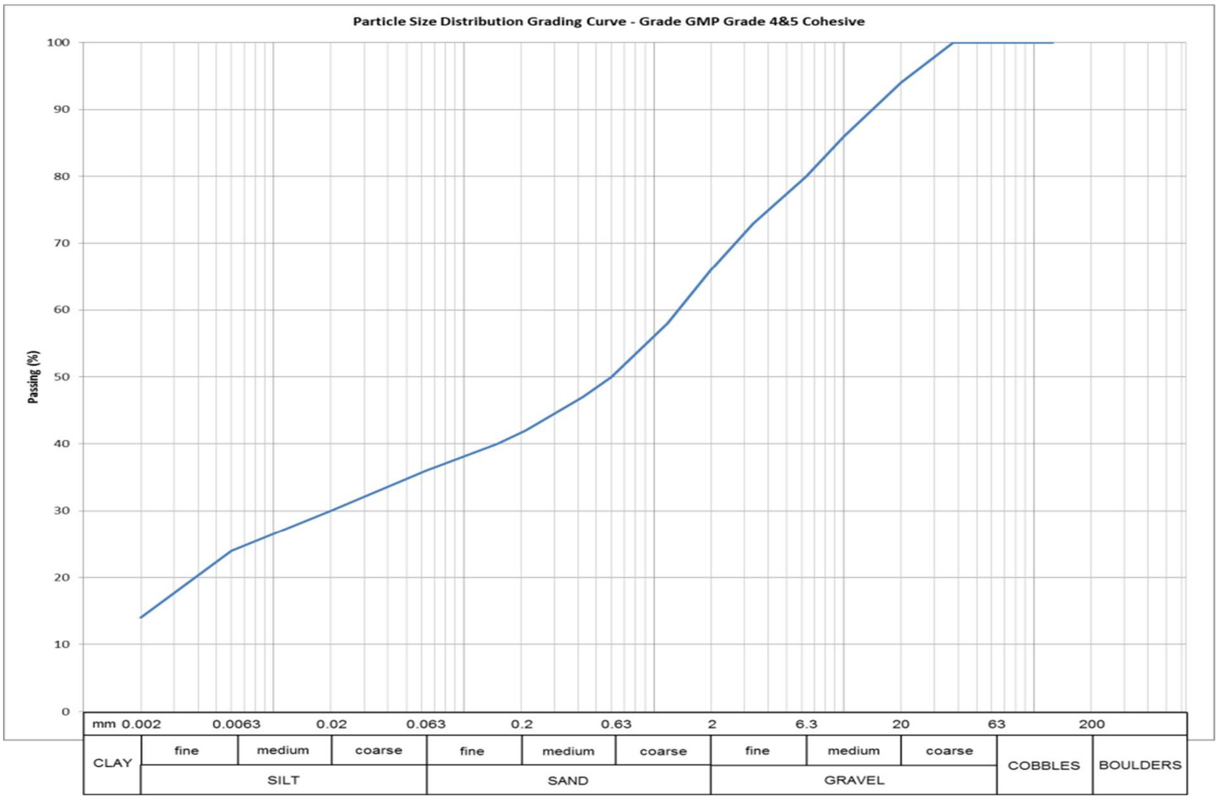


Figure 6-32 Casagrande Chart – Grampound Formation Grade 4&5

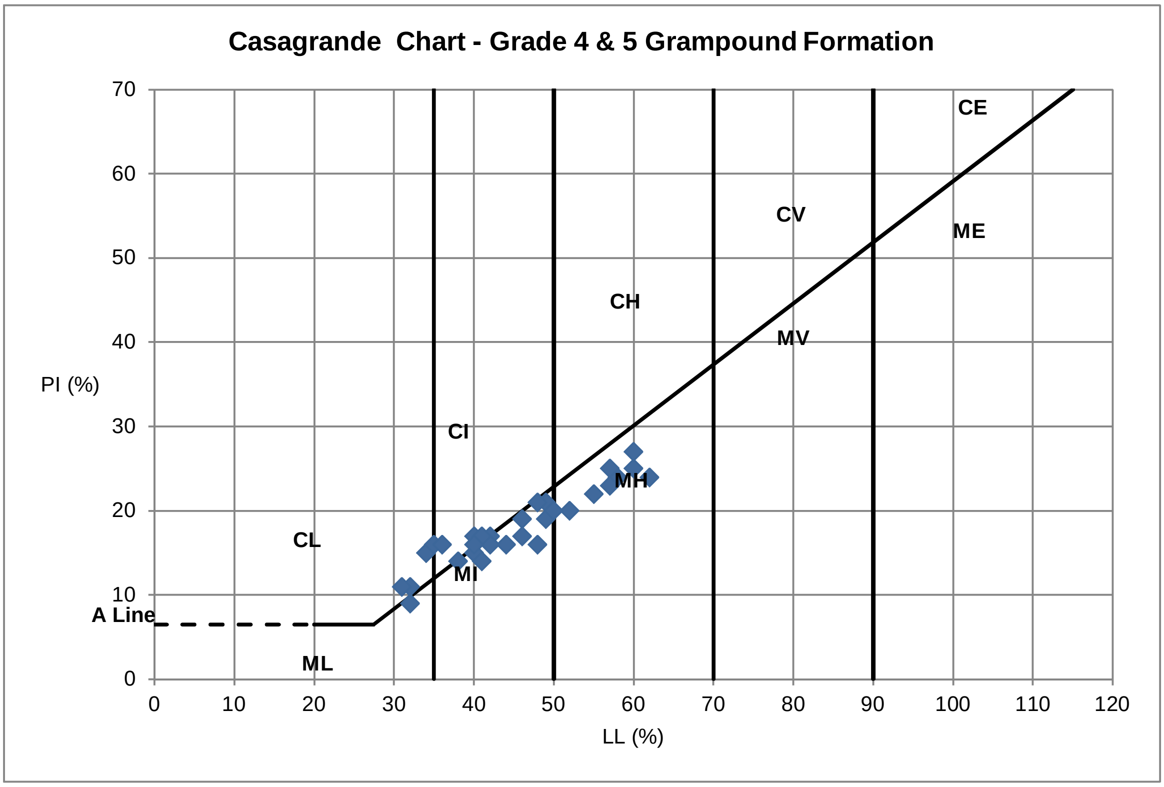


Figure 6-33 Summary of Shear Box Test Results Peak angle of Shear Resistance– Grampound Formation

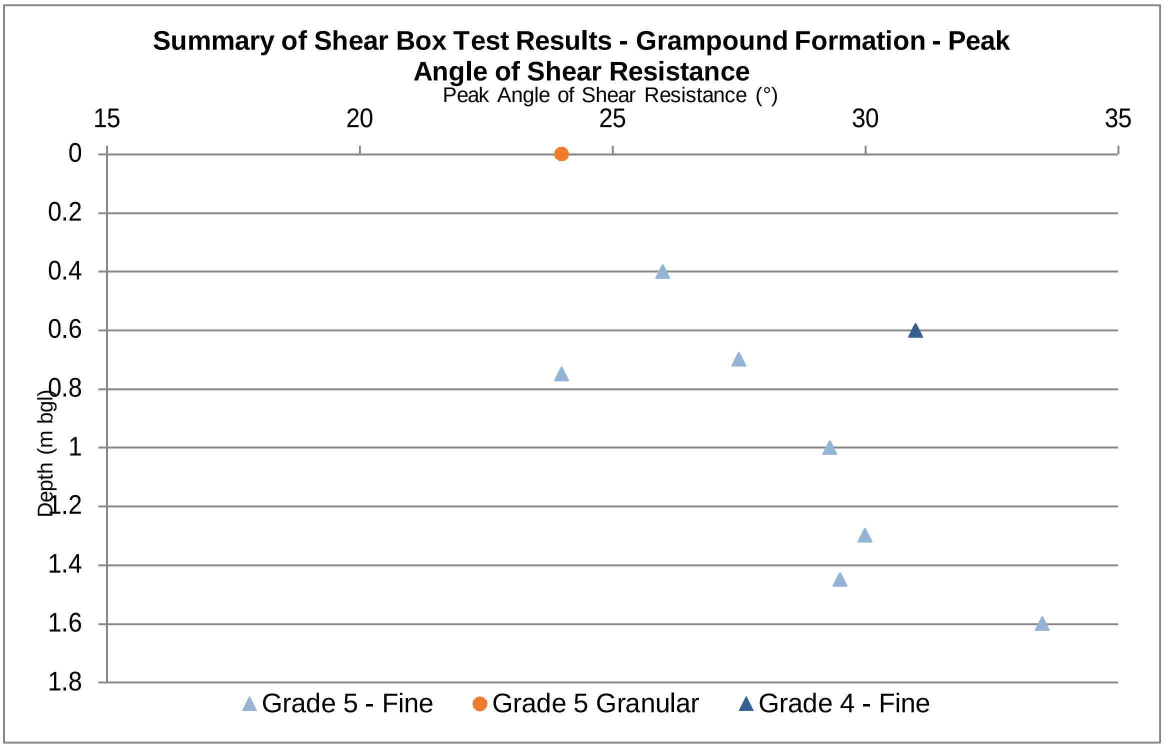


Figure 6-34 Summary of Shear Box Test Results Peak effective Cohesion Intercept – Grampound Formation

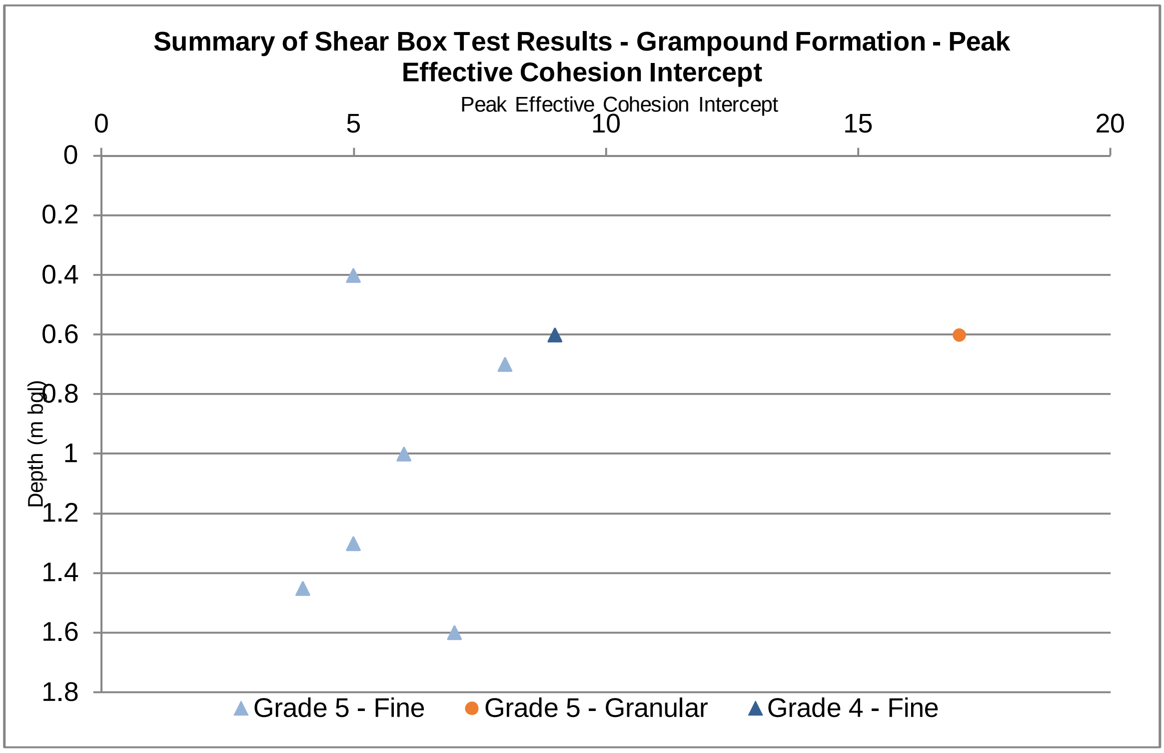


Figure 6-35 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 0 – All Strata

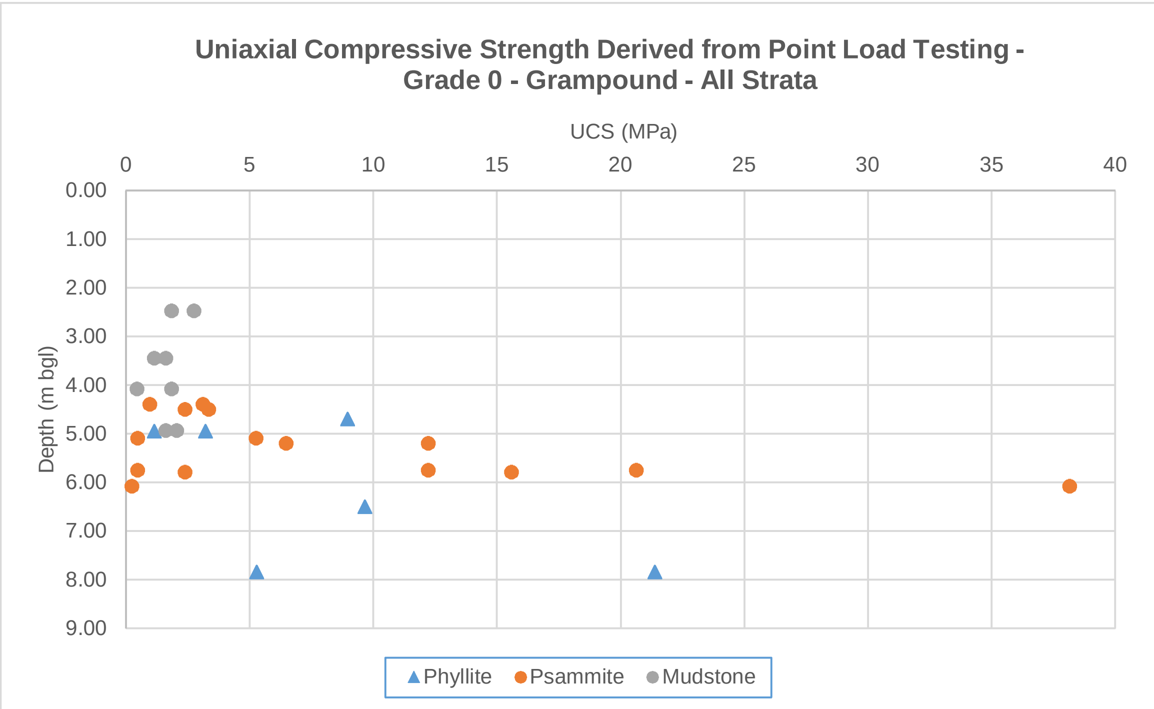


Figure 6-36 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 0 – Phyllite

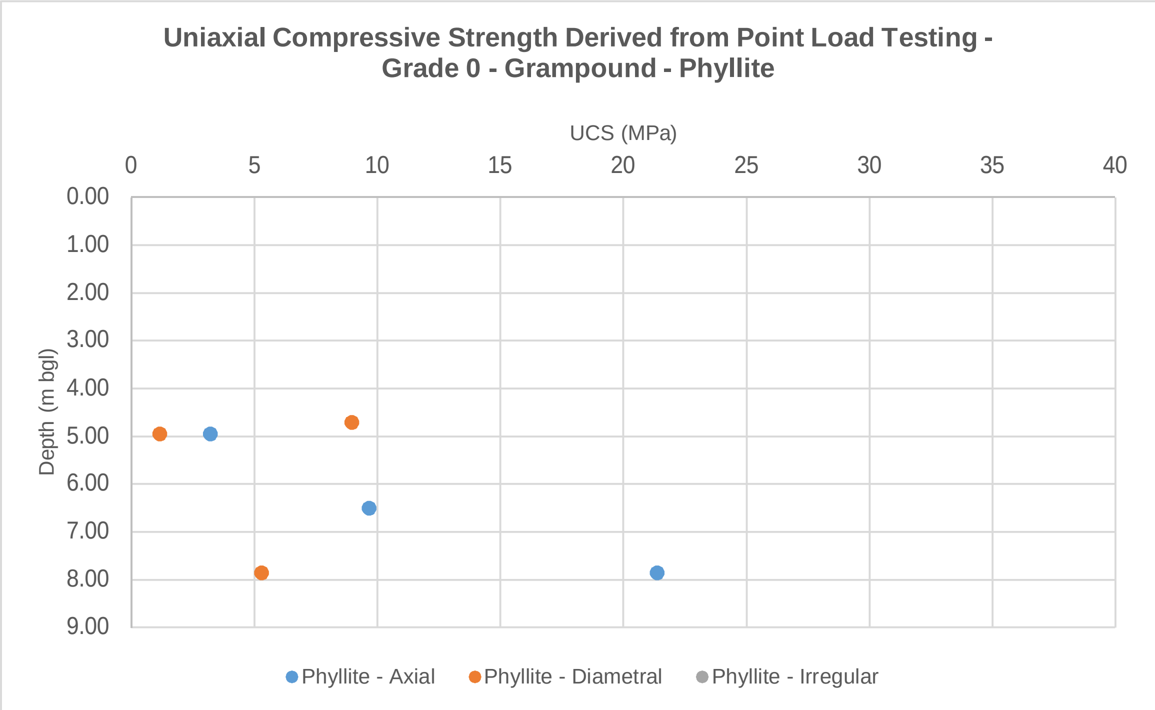


Figure 6-37 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 0 – Psammite

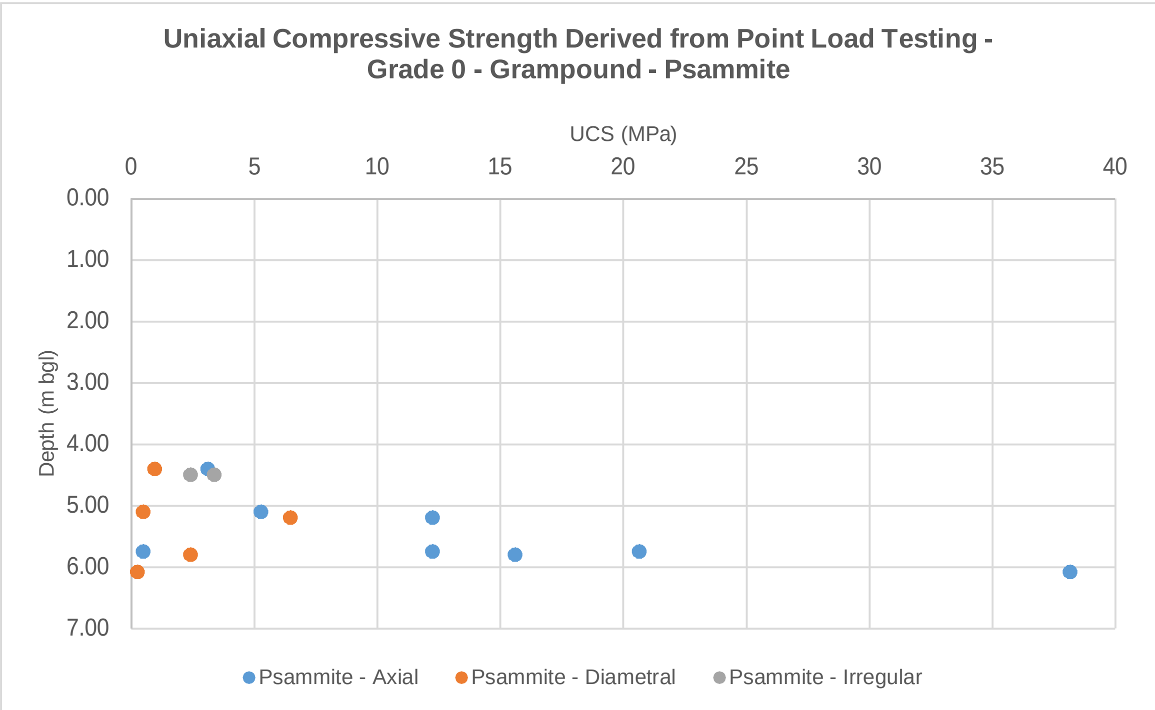


Figure 6-38 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 1 – All Strata

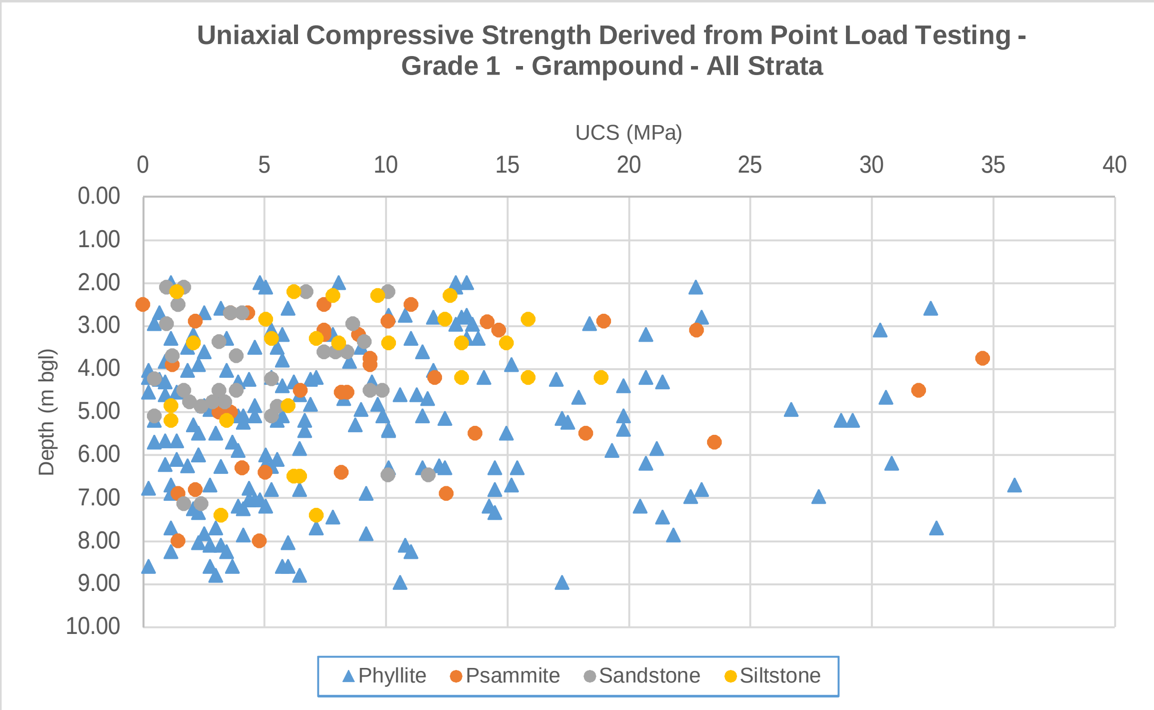


Figure 6-39 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 1 – Phyllite

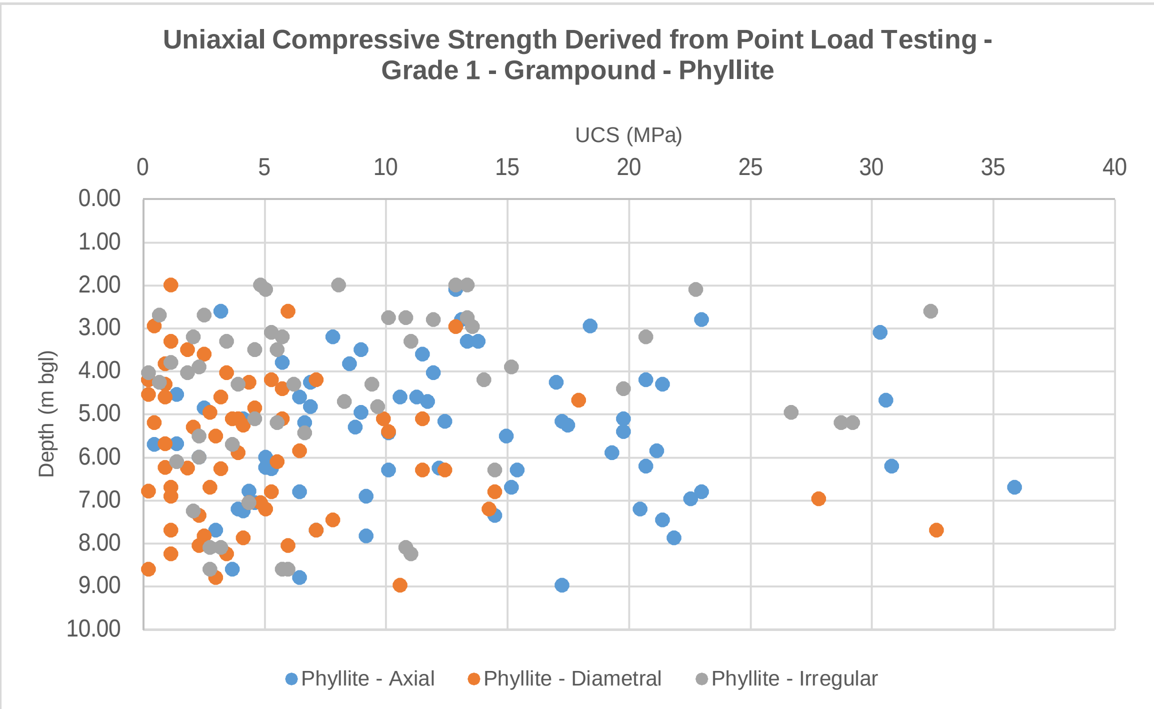


Figure 6-40 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 1 – Psammite

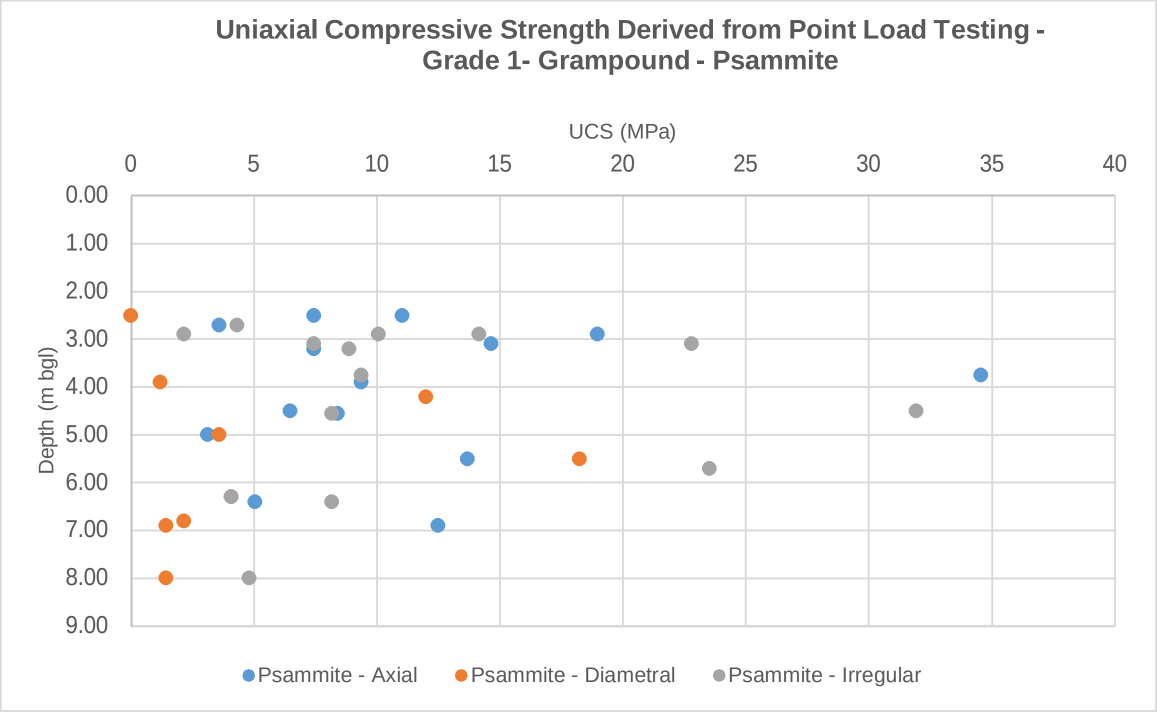


Figure 6-41 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 1 – Sandstone

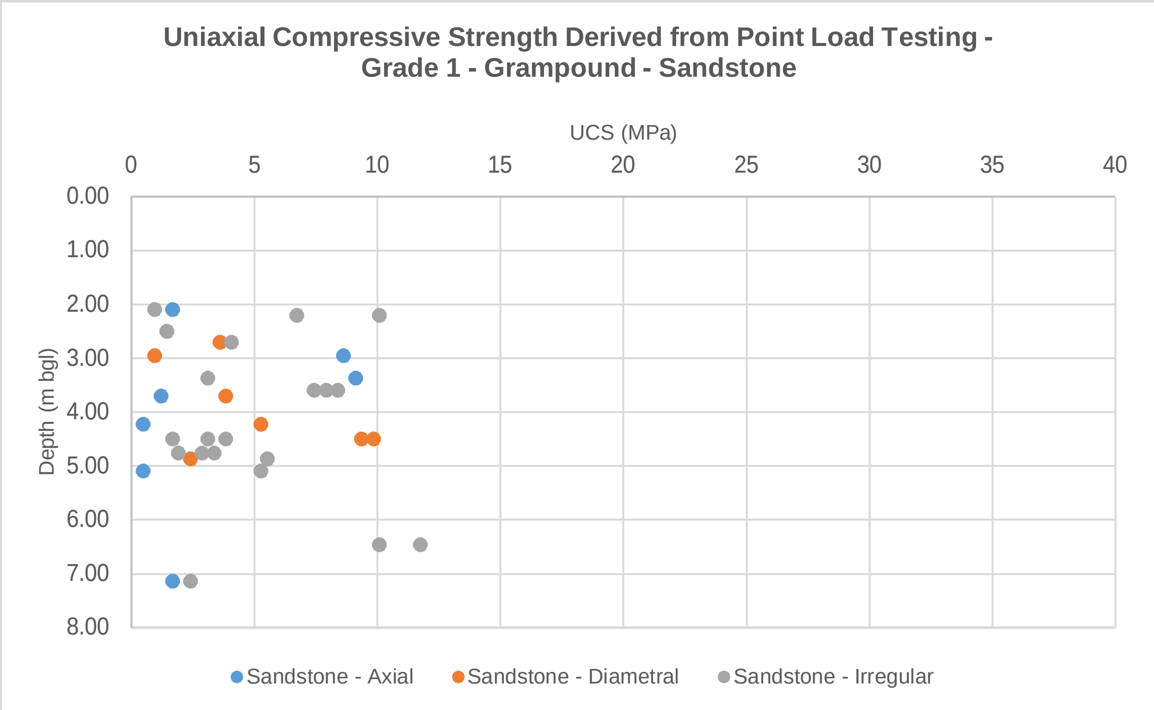


Figure 6-42 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 1 – Siltstone

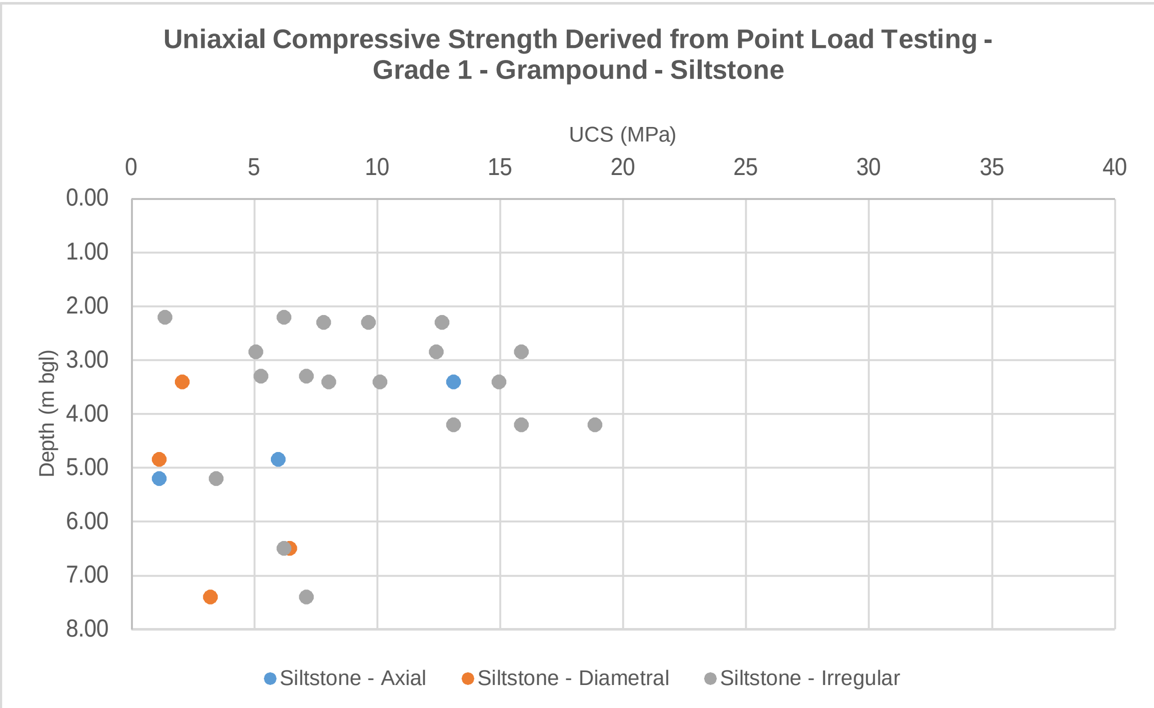


Figure 6-43 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 2 – All Strata

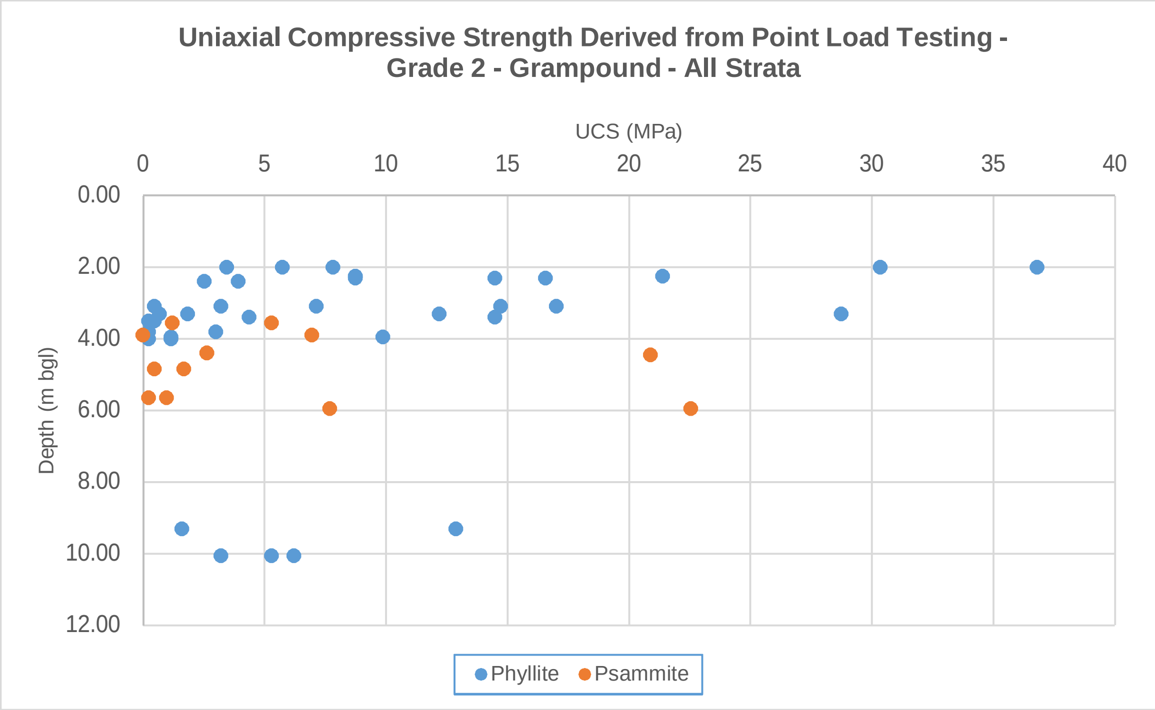


Figure 6-44 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 2 – Phyllite

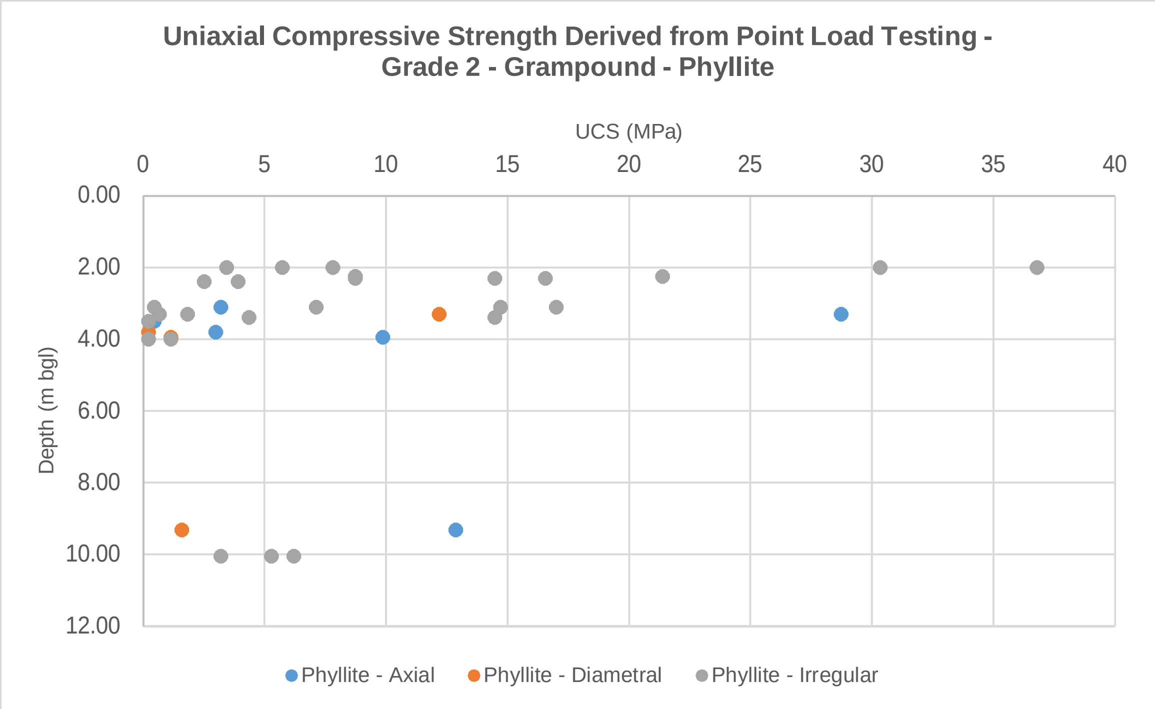


Figure 6-45 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 2 – Psammite

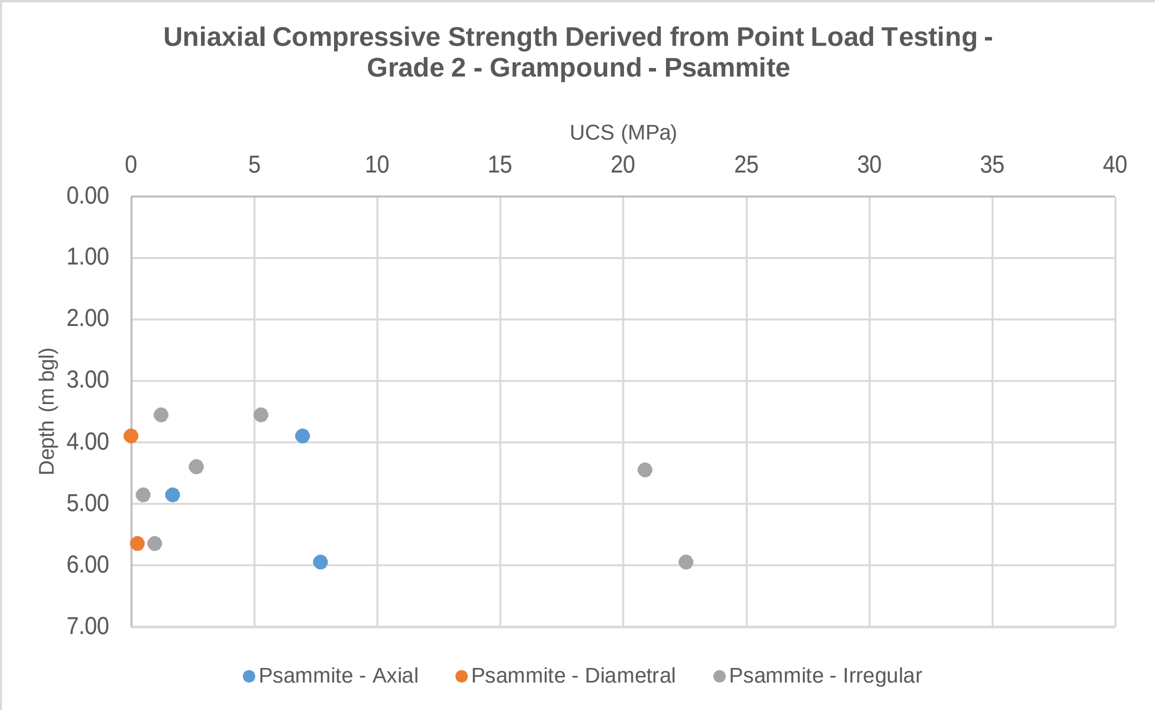


Figure 6-46 Uniaxial Compressive Strength Derived from Point Load Testing – Grampound Formation – Grade 3 – Phyllite

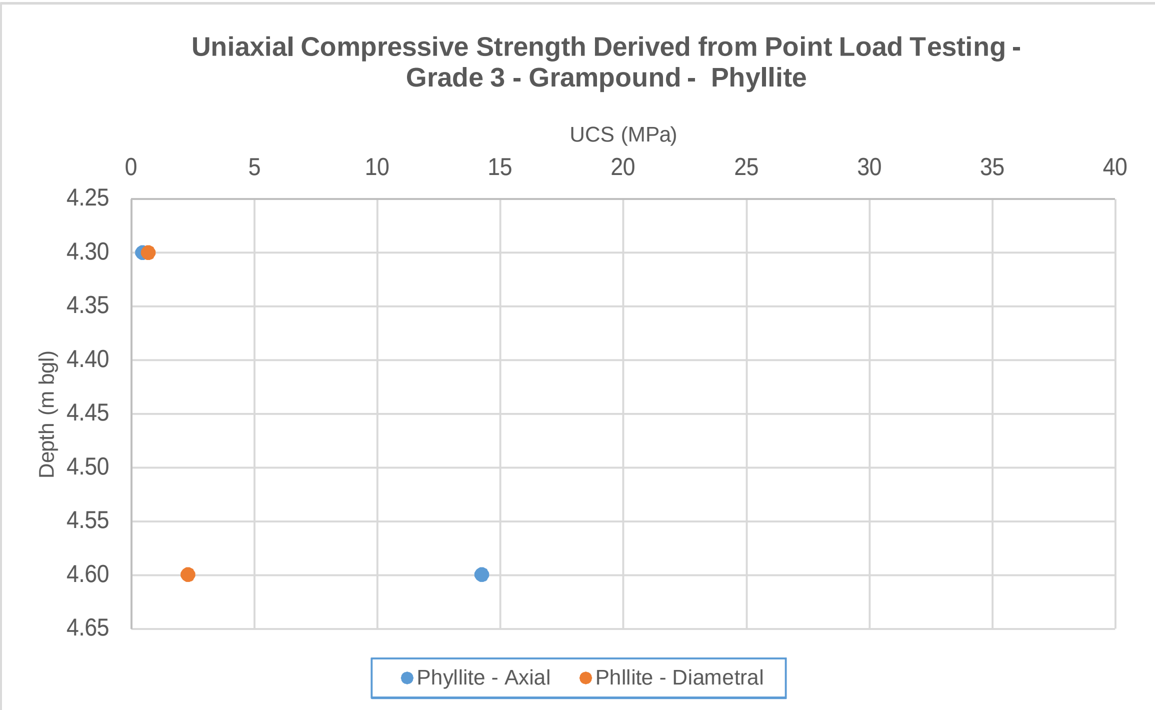


Figure 6-47 Slake Durability – Grampound Formation

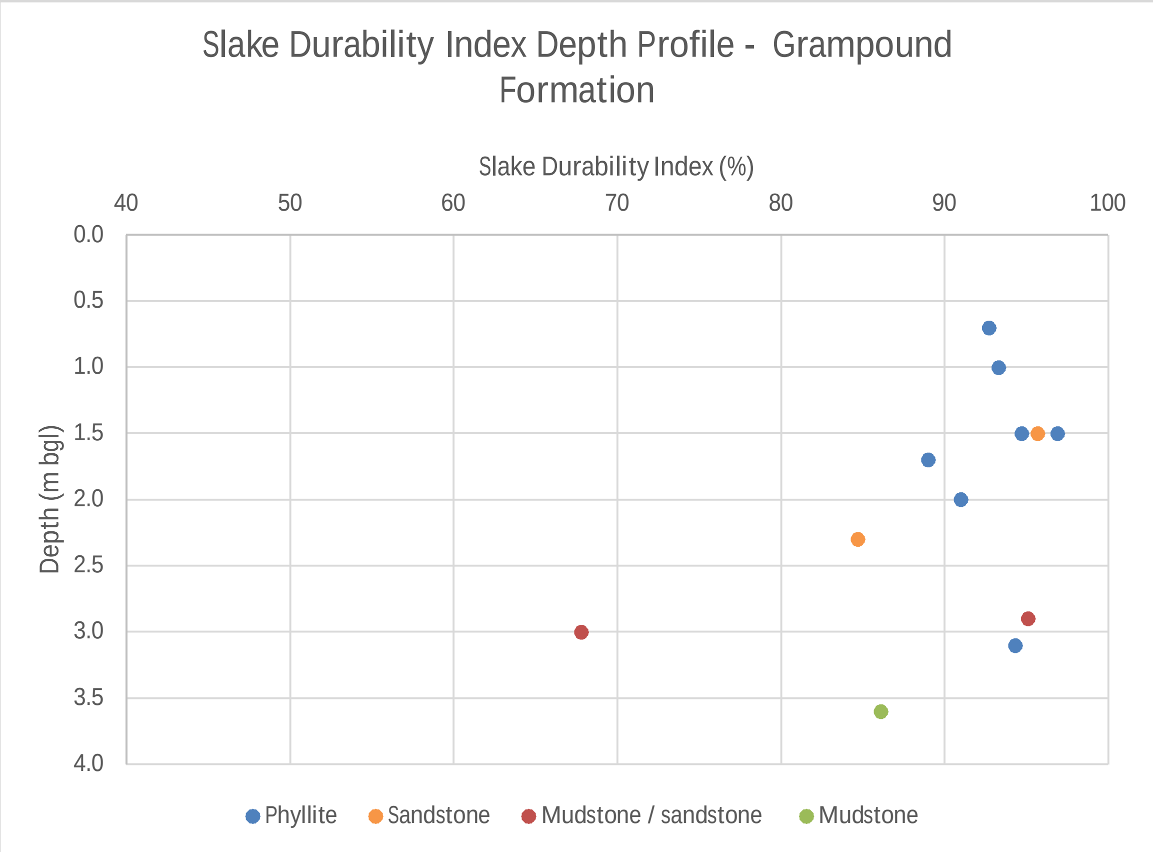


Figure 6-48 Recorded SPT N-Values versus Depth - Trendrean Mudstone Formation

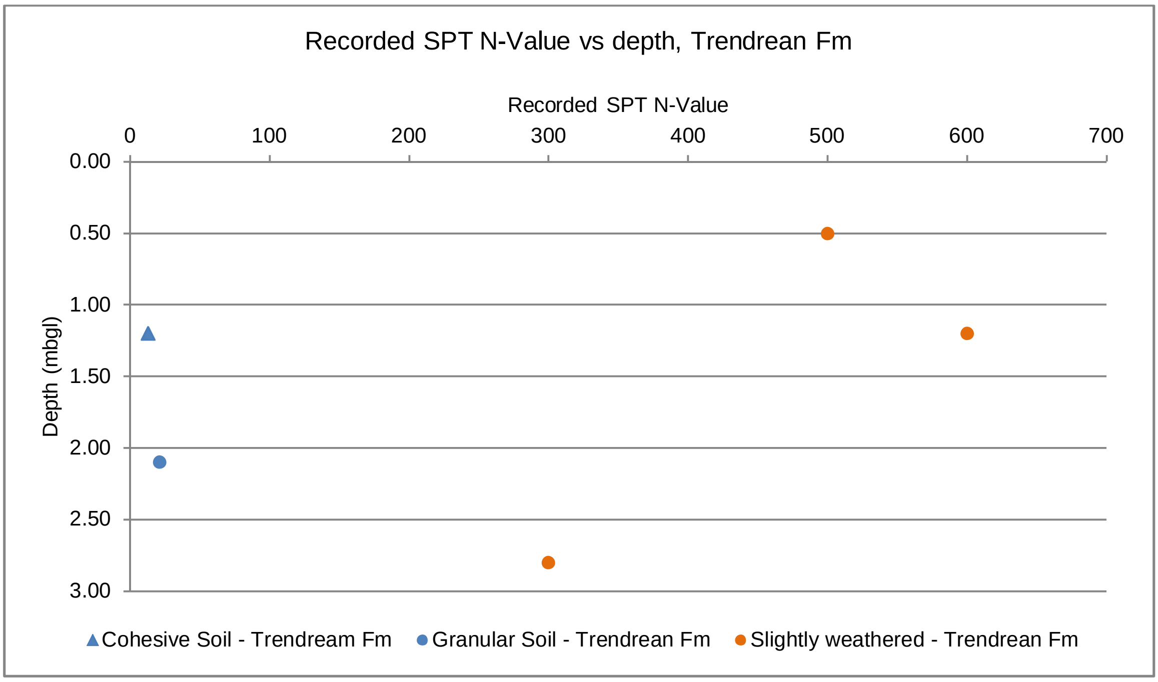


Figure 6-49 Particle Size Distribution Grading Curve – Trendrean Mudstone Formation

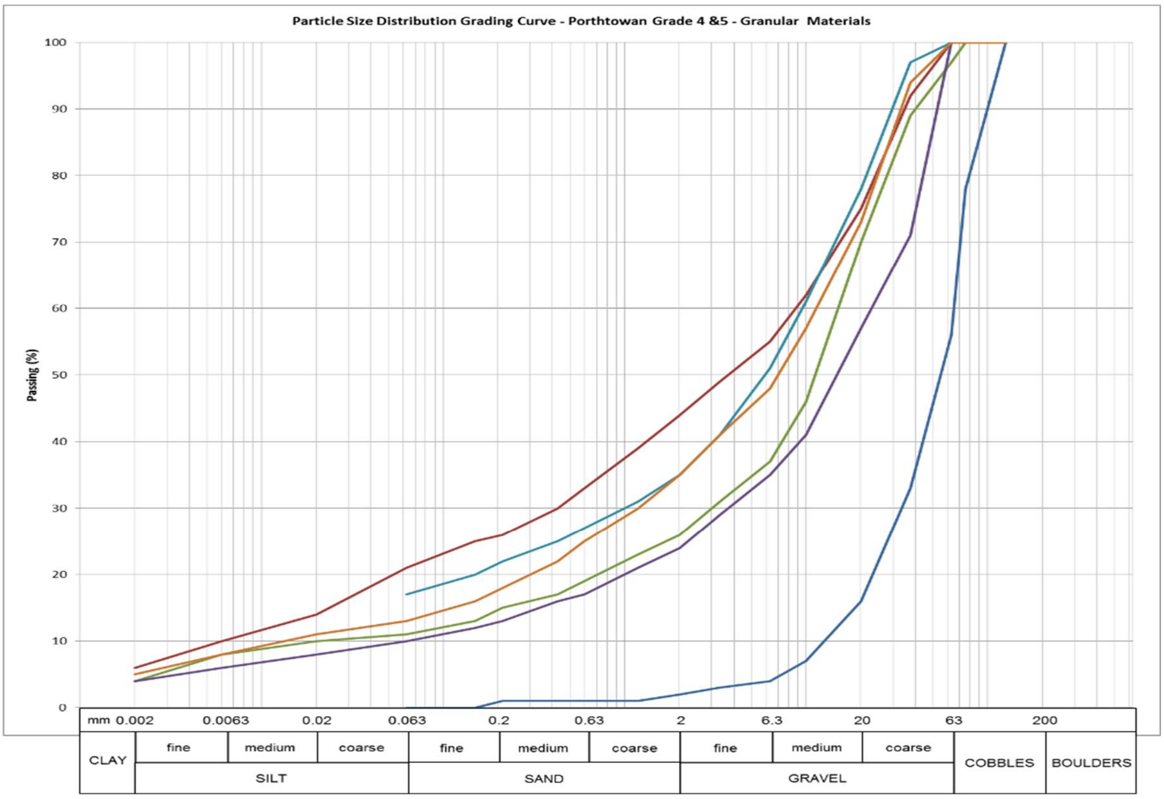


Figure 6-50 Casagrande Chart – Trendrean Mudstone Formation

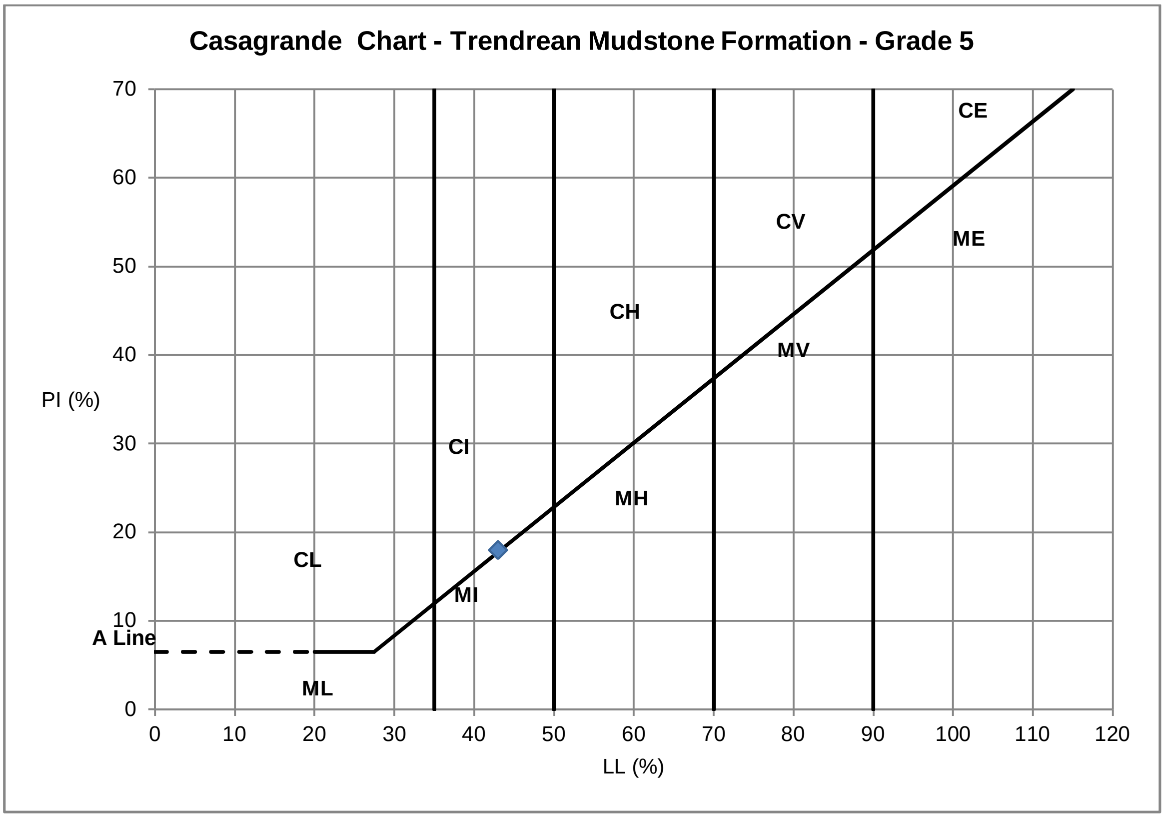


Figure 6-51 Uniaxial Compressive Strength Derived from Point Load Testing - Grade 0 - Trendrean Mudstone Formation - Phyllite

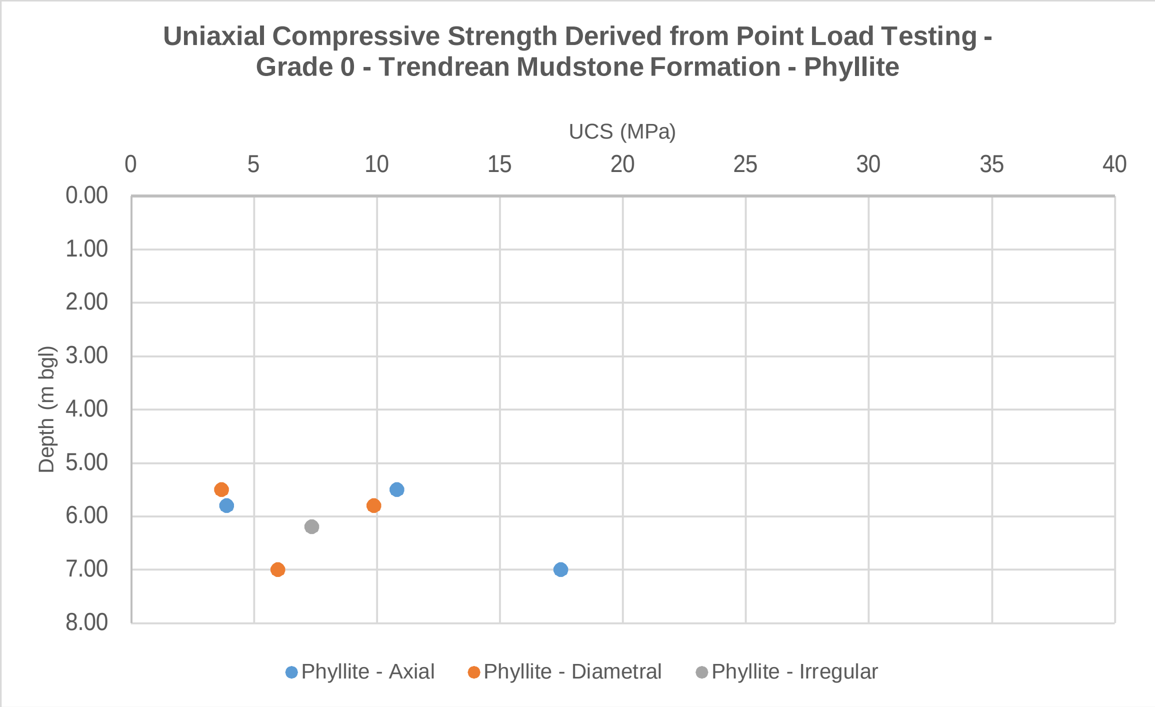
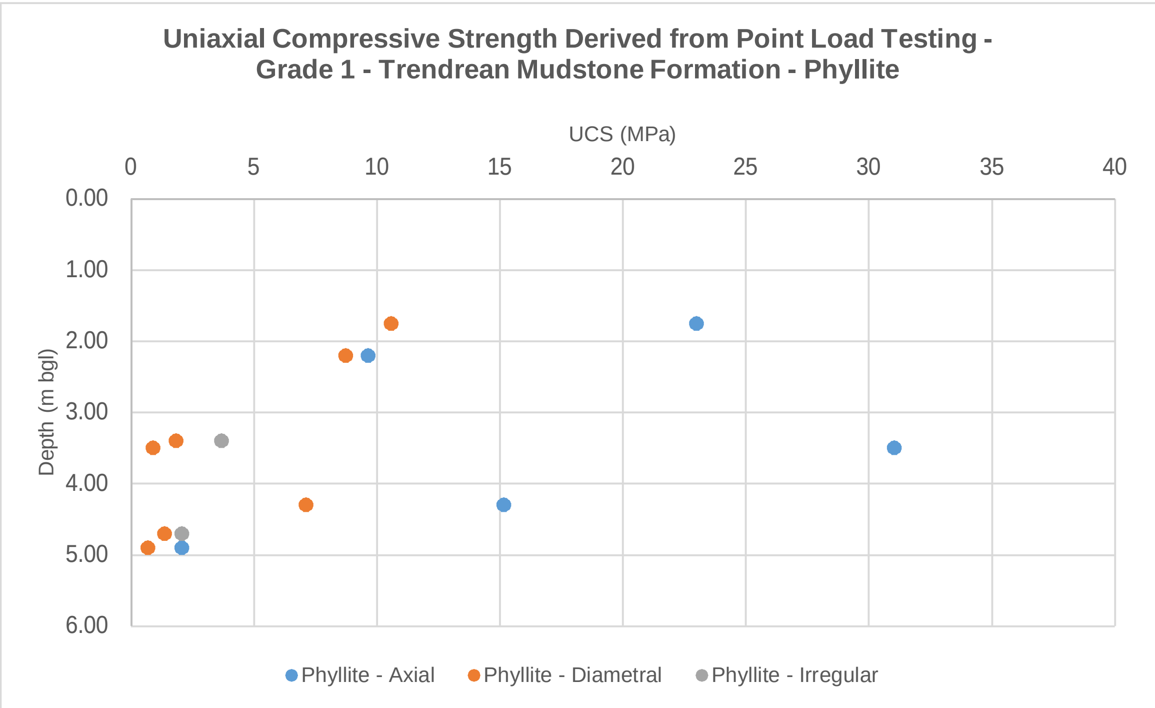


Figure 6-52 Uniaxial Compressive Strength Derived from Point Load Testing - Grade 0 - Trendrean Mudstone Formation - Phyllite



7. Human Health and Controlled Waters Generic Risk Assessment

7.1 Introduction

This section presents generic human health and controlled waters risk assessments carried out using the ground investigation data obtained between 23 January 2017 and 31 March 2017. The objective of the assessments was to evaluate potential risks posed by impacted soil or groundwater to human health or controlled waters receptors due to the construction or operation of the scheme.

7.2 Site Investigation

The strategy for the ground investigation, which was designed to characterise ground conditions, included formation of 72 rotary cored boreholes and mechanical excavation of 103 trial pits (full details of the ground investigation are presented in Section 4).

A total of 21 soil samples were obtained from nine borehole and 11 trial pit locations at depths ranging from 0.10 m bgl to 0.82 m bgl and analysed for a range of determinands including metals, total polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), ammoniacal nitrogen, total cyanide, total phenols, and asbestos (six select soil samples were additionally analysed for pesticides, US EPA 16 PAHs, and TPH CWG).

Sixteen of the 21 soil samples, obtained from nine borehole and seven trial pit locations at depths ranging from 0.10 m bgl to 0.82 m bgl, underwent soil leachate analysis comprising testing for pH, ammoniacal nitrogen, metals, US EPA 16 PAHs, and TPH CWG.

7.3 Site Investigation Results

Visual and olfactory evidence of contamination

No visual or olfactory evidence was encountered in soils during the ground investigation.

Soil analysis results

The pH of soil samples ranged from 5.76 to 8.13. There were detections of metals (including arsenic, cadmium, copper, chromium, hexavalent chromium, lead, mercury, nickel, phosphorous, selenium, and zinc) at all locations. Phenols were detected at BH-R-07 (0.28 m bgl) and TP-R-086 (0.2 m bgl) at respective concentrations of 0.4 mg/kg and 0.3 mg/kg.

There were no detections of pesticides, US EPA 16 PAHs, or TPH CWG; and there were no detections of asbestos in the 21 soil samples analysed for asbestos in soil.

Soil Leachate analysis results

While the majority of determinands analysed were reported below the laboratory LOD, detections occurred in ammoniacal nitrogen, metals, PAHs, and petroleum hydrocarbons, and MTBE.

There were four detections of ammoniacal nitrogen, which was detected to maximum concentration of 0.12 mg/l at TP-R-095 (0.3 m bgl). These detections are not considered abnormal.

There were various detections of metals (arsenic, boron, copper, lead, nickel, and zinc). The most widespread metals, detected at the majority of locations, were copper, lead, and zinc, detected to maximum concentrations of 22 µg/l (TP-P-09, 0.3 m bgl), 26 µg/l (BH-R-040c, 0.3 m bgl), and 158 µg/l (TP-R-009, 0.1 m bgl) respectively.

There were detections in the majority of US EPA 16 PAHs. These were most prevalent at BH-R-041 (0.45 m bgl). Benzo(a)pyrene was detected at this location only at a concentration of 0.11 µg/l. Naphthalene was detected at 15 locations to a maximum concentration of 1.7 µg/l at BH-R-028 (0.2 m bgl). Anthracene was detected at two locations to a maximum concentration of 0.15 µg/l at TP-R-086 (0.2 m bgl). Fluoranthene was detected at eight locations to a maximum concentration of 0.27 µg/l at BH-R-015 (0.5 m bgl).

TPH was detected at BH-R-032 (0.7 m bgl) and TP-R-OO4A (0.2 m bgl) at concentrations of 1,180 µg/l and 51 µg/l respectively. At BH-R-032 the TPH comprised mid to long chain aliphatics (>C12-C35). At TP-R-OO4A the TPH comprised mid to long chain aliphatics (>C12-C21) and aromatics (>C10-C16). There was a single detection of short chain aliphatics (>C5-C6) at TP-P-09 (0.3 m bgl).

There were no detections of BTEX compounds. Methyl tert-butyl ether (MTBE) was detected at three locations to maximum concentrations of 2 µg/l at BH-R-028 (0.2 m bgl) and 2 µg/l at TP-P-09 (0.3 m bgl).

7.4 Conceptual Site Model

A conceptual site model (CSM) was developed based on a qualitative basis in accordance with the methodology set out in CIRIA C552 ('Contaminated Land Risk Assessment – A Guide to Good Practice'). Details of the CSM are included in the Environmental Study Report, December 2016. The CSM is presented in Table 7-1.

Table 7-1 Conceptual Site Model

Source	Pathway	Receptor	Consequence	Probability	Risk
Made Ground associated with the existing A30 alignment.	Ingestion, inhalation and dermal contact with contaminated soil. Inhalation of windblown dust and asbestos fibres.	End users	Mild	Unlikely	Very Low
	Lateral migration of aqueous and dissolved contaminants via groundwater flow or preferential pathways.	Surface waters (headwaters of the River Kenwyn, River Allen, and Tresillian River)	Mild	Unlikely	Very Low
	Vertical migration of aqueous and dissolved contaminants through shallow strata or preferential pathways.	Groundwater (Secondary A aquifers: Porthtowan and Grampound formations; Head deposits).	Mild	Unlikely	Very Low
	Chemical attack	Buildings (buried concrete structures)	Mild	Unlikely	Very Low
Historical mineral workings for lead, zinc, copper and silver sulphide ores.	Ingestion, inhalation and dermal contact with contaminated soil. Inhalation of windblown dust.	End users	Mild	Unlikely	Very Low
	Lateral migration of aqueous and dissolved contaminants via groundwater flow or preferential pathways.	Surface waters (headwaters of the River Kenwyn, River Allen, and Tresillian River)	Mild	Unlikely	Very Low
	Vertical migration of aqueous and dissolved contaminants through shallow strata or preferential pathways.	Groundwater (Secondary A aquifers: Porthtowan and Grampound formations; Head deposits).	Mild	Unlikely	Very Low
	Chemical attack.	Buildings (buried concrete structures)	Mild	Low Likelihood	Low

7.5 Human Health Generic Quantitative Risk Assessment

Introduction

The human health generic quantitative risk assessment (GQRA) comprised screening of the soils data against generic assessment criteria (GAC) derived for a commercial end use and based on a soil organic matter (SOM) content of 2.5% (the average SOM measured was 3.6%).

Full details of the derivation of the GAC are presented in Appendix A. The samples have also been screened for the presence or absence of asbestos in soil.

GQRA Results

All the available soils data was screened. The full results of the screening are presented in Table A in Appendix A. There were no exceedances of GAC in soil samples and there were no detections of asbestos in soil. There is therefore no evidence that soil concentrations pose risks to human health receptors.

7.6 Controlled Waters Generic Quantitative Risk Assessment

Introduction

The controlled waters generic quantitative risk assessment (GQRA) was undertaken in general accordance with the Remedial Targets Methodology (Environment Agency, 2006) and comprised screening of soil leachate data against a range of GAC selected as appropriate for the protection of the controlled waters receptors identified in the Phase 1 PRA and preliminary CSM.

An exceedance of GAC confirms the substance as a potential contaminant of concern but does not mean controlled waters receptors are necessarily at risk or that remedial works are required, though further evaluation and quantitative assessment would normally be required. The assessment is considered conservative as an exceedance of GAC in soil leachate does not indicate that the substance will be present in exceedance of the GAC at the controlled waters receptor itself.

Selection of GAC

As per the approach in the Remedial Targets Methodology and on the basis of the controlled waters receptors identified in the Phase 1 PRA and preliminary CSM, the soil leachate data have been screened against UK Environmental Quality Standards (EQS) for the protection of aquatic life in freshwater environments and against UK drinking water standards (DWS).

For petroleum hydrocarbons substances for which UK DWS are not available, screening has been carried out against the laboratory limit of detection (LOD) or, where available, World Health Organisation (WHO) guidelines for drinking water quality (2011).

These GAC represent target concentrations relevant to the surface water receptors (headwaters of the River Kenwyn, River Allen, and Tresillian River) and groundwater receptors (the underlying aquifers of the Porthtowan Formation, Grampound Formation, and, where present, Head deposits, all of which are designated Secondary A aquifers).

GQRA Results

All the available soil leachate data was screened. The full results of the screening are presented in Table B in Appendix A. Exceedances of GAC are summarised in Table 7-2 and Table 7-3. The numbers of exceedances shown in Tables 7-2 and 7-3 refer to detectable concentrations only.

Table 7-2 Summary of Controlled Waters Screening (Inland Surface Water Protection)

Determinand	Max Concentration µg/l	GAC µg/l	Number of exceedances
Lead	26	1.2 (EQS 2015)	**14** (BH-R-040c, BH-R-041, BH-R-028, BHR030, BH-R-011, BH-R-015, BH R 032, BH-R-07, TP-R-086, TP-P-09, TP-R-063, TP R OO4A, TP-R-009, and TP-R-003).
Zinc	158	10.9 (EQS 2015)	**9** (BH-R-040c, BH-R-041, BH-R-028, BH-R-011, BH-R-07, TP-R-095, TP-P-09, TP-R-009, and TP-R-003).
Anthracene	0.15	0.1 (EQS 2015)	**1** (TP-R-086).
Benzo(a)pyrene	0.11	0.00017 (EQS 2015)	**1** (BH-R-041)
Fluoranthene	0.27	0.0063 (EQS 2015)	**8** (BH-R-040c, BH-R-041, BH-R-028, BHR030, BH-R-015, BH-R-07, TP-R-086, TP-R-003).
Aro >C10-C12	10	1 (EQS 2015)	**1** (TP-R-OO4A)

Table 7-3 Summary of Controlled Waters Screening (Aquifer Protection)

Determinand	Max Concentration µg/l	GAC µg/l	Number of exceedances
Lead	26	10 (UK DWS)	**3** (BH-R-040c, BH-R-041, and BH-R-028)
Benzo(a)pyrene	0.11	0.01 (UK DWS)	**1** (BH-R-041)
PAH sum of 4 (calculated)	0.31	0.1 (UK DWS)	**1** (BH-R-041)
Ali >C5-C6	4	<1 (LOD)	**1** (TP-P-09)
Aro >C10-C12	10	<10 (LOD)	**1** (TP-R-OO4A)
Aro >C12-C16	18	<10 (LOD)	**1** (TP-R-OO4A)

Further to the exceedances summarised in Table 7-2 and Table 7-3, it is noted that the pH of soil leachate samples ranged from 5.87 to 7.82. The pH of soil leachate samples was beneath the UK DWS minimum threshold for groundwater (6.5) at BH-R-07, TP-R-086, TP-R-095, and TP-P-09; and beneath the UK DWS minimum threshold for groundwater and surface water (6.0) at TP-R-063 and TP-R-003.

Metals

The EQS for lead was exceeded at all locations except BH-S-30 and TP-R-095. The UK DWS for lead was also exceeded at BH-R-040c, BH-R-041, and BH-R-028. The EQS for zinc was exceeded at the majority of locations. There were no exceedances of the UK DWS for zinc.

These exceedances are likely to be associated with the known historical mineral working at Cargoll Mine (located < 500 m to the northwest on Newlyn Downs), which is known to have worked lead, zinc copper and silver, present as sulphide ore. The three locations at which the UK DWS for lead was exceeded are located in the northeast of the study area in the vicinity of Newlyn Down.

It should be noted that lead and zinc environmental standards assume 100% bioavailability and represent a tier 1 assessment criteria. The conservatism of the criteria can be reduced by calculating the actual bioavailability within the surface water receptor. For this reason it is recommended that surface water sampling of the headwaters of the River Kenwyn, River Allen, and Tresillian River, is undertaken.

It is also recommended to test for the presence of metals at the controlled waters receptors; as well as to undertake further soil sampling in the apparent area of impact in the northeast of the site in the vicinity of Newlyn Downs. Should further exceedances of the assessment criteria occur a detailed quantitative risk assessment (DQRA) is advised.

Polycyclic Aromatic Hydrocarbons

The EQS for anthracene was exceeded at TP-R-086. The EQS and the UK DWS for benzo(a)pyrene were exceeded at BH-R-041. The EQS for fluoranthene was exceeded at eight locations (BH-R-040c, BH-R-041, BH-R-028, BHR030, BH-R-015, BH-R-07, TP-R-086, and TP-R-003). The UK DWS for PAHs (sum of four, calculated) was exceeded at BH-R-041.

As the potential source of the PAHs is unclear, it is recommended that further sampling and DQRA is undertaken for PAHs. The sampling should be targeted at the apparent areas of impact, including at BH-R-041 in the southwest of the study area, where PAH detections were most prevalent.

Total Petroleum Hydrocarbons

There was a detection of aliphatics (>C5-C6) at TP-P-09, located in the central part of the study area near Great South Chiverton Mine; and there were detection of aromatics (>C10-C16) at TP-R-OO4A, located in the southwest of the study area.

As the potential source of the petroleum hydrocarbons is unclear, it is recommended that further sampling and DQRA is undertaken for TPH. The sampling should be targeted at the apparent areas of impact, including at BH-R-032, TP-P-09, and TP-R-OO4A (the detections of mid and long chain aliphatics (>C12-C35) at BH-R-032 are considered an unlikely potential risk to controlled waters as this range is typically immobile in soils; however the detections may be indicative of wider impact).

7.7 GQRA Conclusions

Based on the results of the human health GQRA, ground conditions are not considered likely to pose a risk to human health receptors.

The controlled waters GQRA identified widespread exceedances of the GAC for lead and zinc, which is considered likely to be associated with the known historical mineral working at Cargoll Mine, located < 500 m to the northwest on Newlyn Downs. It is recommended that further sampling (of soils and surface water) and risk assessment is undertaken for these substances.

The exceedances of GAC for various leachable PAHs including anthracene, benzo(a)pyrene, and fluoranthene, occurring at eight locations (most prevalently at BH-R-041); and the detections of various petroleum hydrocarbon fractions (particularly at BH-R-032, TP-P-09, and TP-R-OO4A); are similarly considered to require further targeted soil sampling and risk assessment.

Although risks to controlled waters within the study are considered to be low, the further sampling and risk assessment is recommended to provide a more comprehensive evidential basis for the low and very low risks identified in the preliminary CSM.

8. Geotechnical Risk Register

A geotechnical risk register has been prepared, as shown in Table 8-2 below. A geotechnical risk register is considered a live document, and as such has been updated as the project progresses. It should continue to be updated and guidance should be sought from all parties involved in the design and implementation of the works.

The scoring system used in this register can be seen in Table 8-1 below.

Table 8-1: Likelihood classification and risk evaluation

Probability (P)	
Very Likely	5
Probable	4
Likely	3
Unlikely	2
Negligible	1

Impact/Consequence (I)	
Very High	5
High	4
Medium	3
Low	2
Very Low	1

Risk PxI=R		Impact/Consequence				
		1	2	3	4	5
Probability	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Table 8-2: Geotechnical Risk Register

Hazard	Before Control			Risk Control Measure (RCM)	After Control		
	P	I	R		P	I	R
Geotechnical Risks							
Proximity of High Pressure Gas pipeline between approximate chainages 5100 – 6300 and 12920m - 13450m.	2	5	10	Pipeline to be protected by appropriate measures during constructions works	1	5	5
Subsidence due mine workings – potential disused mine shaft located at approximate chainage 12100m.	5	5	25	Additional GI required to establish and delineate any below ground features.	1	5	5
Ground collapse - extremely low strength ground depicted by SPT N value of 0 in BH101 at approximate chainage 1150m	2	4	8	Further ground investigation by Trial pitting.	1	4	4
Unknown Ground Conditions – No ground investigation has been completed in Marazanvose section (between approximate chainage 7150m and 8500m), Chiverton Roundabout (between approximate chainage 0m and 600m), and Quarry section (between approximate chainage 12700m and 12900m).	3	3	9	If encountered during construction, any local variations to the geology may require further investigation and assessment.	1	3	3

Hazard	Before Control			Risk Control Measure (RCM)	After Control		
	P	I	R		P	I	R
Material suitability - proposed re-use of site won material.	2	4	8	Further analysis required to develop and inform Earthwork specification for the use of site won material.	1	4	4
High groundwater table in areas of proposed cut.	4	4	16	Further monitoring is required to capture seasonal groundwater fluctuations.	1	4	4
Buried obstruction – abandoned oil pipeline crossing at approximate chainages 11700m & 12200m.	4	4	16	Obstruction to be removed or protected by appropriate measures, during constructions works.	1	4	4
Excessive total or differential settlement of foundations, including identified areas of alluvium/soft ground conditions at approximate chainages 3500-4000m, 6000, 7000, 9250, 10380-10550m.	4	4	16	Suitable design to be adopted in accordance with findings of the ground investigation.	1	4	4
Excessive settlement due to unknown depth of soft alluvium at TP-R-060.	3	4	12	Further ground investigation is required to prove base of alluvial deposits and therefore develop the ground model at this location.	1	4	4
Proximity of historic quarry feature to proposed road aligment between approximate chainages 12700m and 12900m.	4	4	16	Further ground investigation is required to inform detailed design	1	4	4
Proximity of buried services associated Carland Cross Windfarm	3	5	15	Buried services to be protected by appropriate measures during constructions works	1	5	5
Poor ground conditions at proposed structures locations.	4	4	16	Foundation to be inspected during construction by a competent Engineering Geologist or Geotechnical Engineer.	1	4	4
Buried obstructions causing delay.	3	3	9	Early identification during works by trial pitting if suspected and for items of critical path.	2	3	6
Aggressive ground conditions and sulphate attack on concrete, steel and other buried structures.	2	3	6	Implement all recommendations of BRE Special Digest 1 during	1	3	3

Hazard	Before Control			Risk Control Measure (RCM)	After Control		
	P	I	R		P	I	R
				detailed design of buried structures.			
Instability of excavation side slopes during construction.	4	4	16	Carry out full design of temporary works, use of trench boxes and supports if appropriate, groundwater control measures.	1	4	4
Instability of embankments due to underlying soft and compressible materials, and materials with low shear strengths.	2	5	10	Following identification of areas of disturbance and soft, compressible ground appropriate design measures and ground treatment of the alignment corridor should be implemented where identified.	1	5	5
Failure of ground beneath plant.	3	5	15	Working platforms to be prepared for operations. All working platforms to be designed to current best practice.	1	5	5
Plant working on high/side long ground.	2	5	10	Full temporary works design to take into account slopes and working platforms. Establish safe working stand-off for slopes.	1	5	5
Environmental/Ecological Risks							
Protected species legislation - badger sett at approximate chainage 11050m.	5	5	25	Further ecological planning and assessment to ensure compliance with habitat migitation	1	5	5
Potable surface water spring abstraction point at approximate chainage 11025m.	3	3	9	At detailed design replace spring abstraction point with a borehole abstraction.	1	3	3
Disruption of groundwater abstraction point at West Nancemere Farm located between approximate chainage 13575 – 13700m.	3	3	9	Design and/or mitigation to be developed at detailed design to ensure potable water supply is maintained.	1	3	3

9. References

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Appendix A. Screened Contamination Data: Table A and Table B

Envirolab Job Number: 17/01083
Client: Structural Soils Limited (Bristol)
Client Project Name: A30 Carland Cross to Chiverton
Client Project Ref: 732088

Client Sample ID	Units	Number of Results	Number of Detections	Maximum Concentration	Screening criteria	Number of Exceedances	BH-R-040c	BH-R-041	BH-R-028	BHR030	BH-R-011	BH-S-30	BH-R-015	BH-R-032	BH-R-07	TP-R-086	TP-R-088A	TP-R-095	TP-P-005	TP-P-09	TP-P-09	TP-R-014	TP-R-55	TP-R-063	TP-R-OO4A	TP-R-009	TP-R-003
Depth to Top							0.30	0.45	0.20	0.65	0.38	0.82	0.50	0.70	0.28	0.20	0.35	0.30	0.10	0.30	0.60	0.20	0.30	0.40	0.20	0.10	0.10
Date Sampled							01-Feb-17	02-Feb-17	03-Feb-17	08-Feb-17	14-Feb-17	14-Feb-17	09-Feb-17	13-Feb-17	15-Feb-17	16-Feb-17	15-Feb-17	15-Feb-17	01-Mar-17	24-Feb-17	24-Feb-17	03-Mar-17	02-Mar-17	21-Mar-17	08-Mar-17	09-Mar-17	16-Mar-17
Sample Type							Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil	Soil	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES	Soil - ES
% Stones >10mm	% w/w	21	19	34.3			27.3	34.3	7.6	14.5	11	28.7	4.1	18.5	17.8	28.4	<0.1	29.5	6	6.9	<0.1	14.2	2.9	2.1	2.2	12.6	10.6
pH	pH	21	21	8.13			6.09	7.74	6.78	8.13	6.64	7.2	6.4	6.47	6.18	6.09	7.73	6.26	6.29	5.87	6.38	6.51	6.24	6.26	7.45	6.67	5.76
Metals																											
Arsenic	mg/kg	21	21	96	635	0	22	19	26	21	11	6	13	21	16	41	10	22	39	96	27	27	7	9	30	24	32
Antimony	mg/kg	1	0	5	7750	0											<5										
Boron (water soluble)	mg/kg	15	0	1	207000	0	<1	<1	<1	<1		<1		<1	<1	<1		<1	<1	<1	<1	<1	<1			<1	
Cadmium	mg/kg	21	20	2.3	223	0	1.2	0.9	1.6	2.3	1.6	1.4	1.5	1.8	1.2	0.8	<0.5	1.1	1.9	1.9	2.1	1.8	1.7	1	0.9	0.7	0.9
Copper	mg/kg	21	21	112	69800	0	32	20	14	37	20	19	25	30	12	35	6	16	19	112	40	18	11	19	18	15	18
Chromium	mg/kg	21	21	55	9550	0	17	14	13	17	23	36	33	17	21	12	5	15	19	20	21	17	46	55	20	14	23
Chromium (hexavalent)	mg/kg	6	0	1	24	0					<1		<1				<1							<1	<1		<1
Lead	mg/kg	21	21	236	1390	0	61	64	41	236	19	11	25	23	41	28	4	23	39	93	67	33	16	24	32	49	30
Mercury	mg/kg	21	2	3.89	32	0	<0.17	<0.17	<0.17	0.42	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	3.89	<0.17	<0.17	<0.17	<0.17	<0.17
Nickel	mg/kg	21	21	41	1710	0	22	25	17	21	27	35	31	29	15	12	4	13	10	21	41	10	29	37	9	10	15
Phosphorus	mg/kg	6	6	1160							98		324				1160							535	596		334
Selenium	mg/kg	21	9	3	12300	0	1	<1	2	<1	2	1	<1	<1	<1	1	<1	2	<1	2	3	2	<1	<1	<1	<1	<1
Zinc	mg/kg	21	21	342	1050000	0	59	53	72	90	53	54	66	66	39	29	9	34	53	152	342	65	57	75	57	49	59
Other																											
PAH (total 16)	mg/kg	21	3	5.91			<0.08	5.91	0.33	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	1.5	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
TPH total (>C6-C40) with CLEANUP	mg/kg	15	3	87	28600	0	15	87	34	<10		<10		<10	<10	<10		<10	<10	<10	<10	<10	<10			<10	
Nitrate (water sol 2:1)	mg/kg	6	5	41							9		2				2							4	41		<1
Sulphate (water sol 2:1)	g/l	6	0	0.01							<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Sulphur (total)	mg/kg	6	5	389							51		164				<50							366	389		247
Loss on ignition (550degC)	% w/w	6	6	7.4							2.7		3.8				1.5							5.2	7.4		6.5
Sulphide	mg/kg	1	0	15													<15										
Sulphate (acid soluble)	mg/kg	1	0	200													<200										
Flash Point (Minimum Value)	degC	1	0	0													>250										
Ammoniacal nitrogen	mg/kg	21	17	7.3			6.6	<0.2	2	<0.2	<0.2	1.2	0.6	0.7	1.2	1.9	1	1.1	3.5	3.5	4.3	2.6	<0.2	0.6	5.1	7.3	2.1
Cyanide (total)	mg/kg	21	0	1	78	0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Phenols - Total by HPLC	mg/kg	21	2	0.4			<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Organic matter	% w/w	21	21	32.3			1.9	2	4.3	1.7	0.3	0.2	1.4	0.6	1.2	1.7	0.1	2.2	5.1	3.9	32.3	2.8	1.8	2.1	3.5	3.1	2.9
Asbestos in Soil (inc. matrix)																											
Asbestos in soil		21	0	0			NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD
Pest-c																											
Mevinphos	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Dichlorvos	µg/kg	6	0	50	151	0					<50		<50				<50							<50	<50		<50
alpha-Hexachlorocyclohexane (HCH)	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Diazinon	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
gamma-Hexachlorocyclohexane (HCH / Lindane)	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Heptachlor	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Aldrin	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
beta-Hexachlorocyclohexane (HCH)	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Methyl Parathion	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Malathion	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Fenitrothion	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Heptachlor Epoxide	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Parathion (Ethyl Parathion)	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
p,p-DDE	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
p,p-DDT	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
p,p-Methoxychlor	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
p,p-TDE (DDD)	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
o,p-DDE	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
o,p-DDT	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
o,p-Methoxychlor	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
o,p-TDE (DDD)	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Endosulphan I	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Endosulphan II	µg/kg	6	0	50	5780	0					<50		<50				<50							<50	<50		<50
Endosulphan Sulphate	µg/kg	6	0	50	5780	0					<50		<50				<50							<50	<50		<50
Endrin	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Ethion	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
Dieldrin	µg/kg	6	0	50	166	0					<50		<50				<50							<50	<50		<50
Azinphos-methyl	µg/kg	6	0	50							<50		<50				<50							<50	<50		<50
PAH 16																											
Acenaphthene	mg/kg	6	0	0.01							<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Acenaphthylene	mg/kg	6	0	0.01							<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Anthracene	mg/kg	6	0	0.02							<0.02		<0.02				<0.02							<0.02	<0.02		<0.02
Benzo(a)anthracene	mg/kg	6	0	0.04							<0.04		<0.04				<0.04							<0.04	<0.04		<0.04
Benzo(a)pyrene	mg/kg	6	0	0.04	38	0					<0.04		<0.04				<0.04							<0.04	<0.04		<0.04
Benzo(b)fluoranthene	mg/kg	6	0	0.05							<0.05		<0.05				<0.05							<0.05	<0.05		<0.05
Benzo(ghi)perylene	mg/kg	6	0	0.05							<0.05		<0.05				<0.05							<0.05	<0.05		<0.05
Benzo(k)fluoranthene	mg/kg	6	0	0.07							<0.07		<0.07				<0.07							<0.07	<0.07		<0.07
Chrysene	mg/kg	6	0	0.06							<0.06		<0.06				<0.06							<0.06	<0.06		<0.06
Dibenzo(ah)anthracene	mg/kg	6	0	0.04							<0.04		<0.04				<0.04							<0.04	<0.04		<0.04
Fluoranthene	mg/kg	6	0	0.08							<0.08		<0.08				<0.08							<0.08	<0.08		<0.08
Fluorene	mg/kg	6	0	0.01							<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Indeno(123-cd)pyrene	mg/kg	6	0	0.03							<0.03		<0.03				<0.03							<0.03	<0.03		<0.03
Naphthalene	mg/kg	6	0	0.03	462	0					<0.03		<0.03				<0.03							<0.03	<0.03		<0.03
Phenanthrene	mg/kg	6	0	0.03							<0.03		<0.03				<0.03							<0.03	<0.03		<0.03
Pyrene	mg/kg	6	0	0.07							<0.07		<0.07				<0.07							<0.07	<0.07		<0.07
TPH CWG																											
Ali >C5-C6	mg/kg	6	0	0.01	5860	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Ali >C6-C8	mg/kg	6	0	0.01	17400	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Ali >C8-C10	mg/kg	6	0	0.01	4850	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Ali >C10-C12	mg/kg	6	0	0.1	22900	0					<0.10		<0.10				<0.10							<0.10	<0.10		<0.10
Ali >C12-C16	mg/kg	6	0	0.1	81700	0					<0.10		<0.10				<0.10							<0.10	<0.10		<0.10
Ali >C16-C21	mg/kg	6	0	0.1	1910000	0					<0.10		<0.10				<0.10							<0.10	<0.10		<0.10
Ali >C21-C35	mg/kg	6	0	0.1	1910000	0					<0.10		<0.10				<0.10							<0.10	<0.10		<0.10
Total Aliphatics	mg/kg	6	0	0.1							<0.10		<0.10				<0.10							<0.10	<0.10		<0.10
Aro >C5-C7	mg/kg	6	0	0.01	46200	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Aro >C7-C8	mg/kg	6	0	0.01	106000	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Aro >C8-C9	mg/kg	6	0	0.01	8110	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Aro >C9-C10	mg/kg	6	0	0.01	8110	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
Aro >C10-C12	mg/kg	6	0	0.1	27900	0					<0.1		<0.1				<0.1							<0.1	<0.1		<0.1
Aro >C12-C16	mg/kg	6	0	0.1	37300	0					<0.1		<0.1				<0.1							<0.1	<0.1		<0.1
Aro >C16-C21	mg/kg	6	0	0.1	28600	0					<0.1		<0.1				<0.1							<0.1	<0.1		<0.1
Aro >C21-C35	mg/kg	6	0	0.1	28600	0					<0.1		<0.1				<0.1							<0.1	<0.1		<0.1
Total Aromatics	mg/kg	6	0	0.1							<0.1		<0.1				<0.1							<0.1	<0.1		<0.1
TPH (Ali & Aro)	mg/kg	6	0	0.1	28600	0					<0.1		<0.1				<0.1							<0.1	<0.1		<0.1
BTEX - Benzene	mg/kg	6	0	0.01	47	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
BTEX - Toluene	mg/kg	6	0	0.01	107000	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
BTEX - Ethyl Benzene	mg/kg	6	0	0.01	12800	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
BTEX - m & p Xylene	mg/kg	6	0	0.01	13600	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
BTEX - o Xylene	mg/kg	6	0	0.01	13600	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01
MTBE	mg/kg	6	0	0.01	12100	0					<0.01		<0.01				<0.01							<0.01	<0.01		<0.01

NAD No asbestos detected

Screened against commercial generic assessment criteria based on a soil organic matter content of 2.5%

Envirolab Job Number: 17/01083
Client: Structural Soils Limited (Bristol)
Client Project Name: A30 Carland Cross to Chiverton
Client Project Ref: 732088

Client Sample ID	Unit	Method	Number of Results	Number of Detections	Maximum Concentration	Surface water inland protection	Reference	Number of Exceedances	Aquifer protection	Reference	Number of Exceedances	BH-R-040c	BH-R-041	BH-R-028	BHR030	BH-R-011	BH-S-30	BH-R-015	BH-R-032	BH-R-07
Depth to Top												0.30	0.45	0.20	0.65	0.38	0.82	0.50	0.70	0.28
Date Sampled												01-Feb-17	02-Feb-17	03-Feb-17	08-Feb-17	14-Feb-17	14-Feb-17	09-Feb-17	13-Feb-17	15-Feb-17
pH (leachable)	pH	A-T-031w	16	16	7.82							6.82	7.23	7.14	7.82	6.75	6.63	6.94	6.62	6.3
Ammoniacal nitrogen (leachable)	mg/l	A-T-033w	16	4	0.12	0.2	EQS 2015	0	0.5	UK DWS		<0.02	0.09	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Metals (leachable)																				
Arsenic (leachable)	µg/l	A-T-025w	16	6	3	50	EQS 2015	0	10	UK DWS	0	1	3	3	<1	<1	<1	<1	<1	<1
Boron (leachable)	µg/l	A-T-025w	16	10	31				1000	UK DWS	0	31	21	20	<10	<10	<10	<10	<10	16
Cadmium (leachable)	µg/l	A-T-025w	16	0	1	0.08	EQS 2015	0	5	UK DWS	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Copper (leachable)	µg/l	A-T-025w	16	15	22				2000	UK DWS	0	11	5	5	2	1	<1	4	5	3
Chromium (leachable)	µg/l	A-T-025w	16	0	1	4.7	EQS 2015	0	50	UK DWS	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium (hexavalent) (leachable)	mg/l	A-T-040w	16	0	0.05	0.0034	EQS 2015	0		UK DWS		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead (leachable)	µg/l	A-T-025w	16	14	26	1.2	EQS 2015	14	10	UK DWS	3	26	16	14	6	2	<1	2	3	5
Mercury (leachable)	µg/l	A-T-025w	16	0	0.1	0.07	EQS 2015	0	1	UK DWS	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel (leachable)	µg/l	A-T-025w	16	5	2	4	EQS 2015	0	20	UK DWS	0	2	1	1	<1	<1	<1	<1	<1	<1
Selenium (leachable)	µg/l	A-T-025w	16	0	1				10	UK DWS	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Zinc (leachable)	µg/l	A-T-025w	16	16	158	10.9	EQS 2015	9				13	21	11	3	11	4	9	10	34
PAH 16MS (leachable)																				
Acenaphthene (leachable)	µg/l	A-T-019w	16	7	0.23							<0.02	0.23	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02
Acenaphthylene (leachable)	µg/l	A-T-019w	16	2	0.04							<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Anthracene (leachable)	µg/l	A-T-019w	16	2	0.15	0.1	EQS 2015	1				<0.02	0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Benzo(a)anthracene (leachable)	µg/l	A-T-019w	16	3	0.08							<0.02	0.05	<0.02	0.02	<0.02	<0.02	0.08	<0.02	<0.02
Benzo(a)pyrene (leachable)	µg/l	A-T-019w	16	1	0.11	0.00017	EQS 2015	1	0.01	UK DWS	1	<0.02	0.11	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Benzo(b)fluoranthene (leachable)	µg/l	A-T-019w	16	2	0.05							<0.02	0.05	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02
Benzo(ghi)perylene (leachable)	µg/l	A-T-019w	16	1	0.11							<0.02	0.11	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Benzo(k)fluoranthene (leachable)	µg/l	A-T-019w	16	1	0.04							<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Chrysene (leachable)	µg/l	A-T-019w	16	3	0.08							<0.02	0.05	<0.02	0.03	<0.02	<0.02	0.08	<0.02	<0.02
Dibenzo(ah)anthracene (leachable)	µg/l	A-T-019w	16	0	0.02							<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fluoranthene (leachable)	µg/l	A-T-019w	16	8	0.27	0.0063	EQS 2015	8				0.02	0.15	0.03	0.03	<0.02	<0.02	0.27	<0.02	0.06
Fluorene (leachable)	µg/l	A-T-019w	16	3	0.12							<0.02	0.12	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02
Indeno(123-cd)pyrene (leachable)	µg/l	A-T-019w	16	1	0.11							<0.02	0.11	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Naphthalene (leachable)	µg/l	A-T-019w	16	15	1.7	2	EQS 2015	0				0.18	0.27	1.7	<0.02	0.16	0.12	0.09	0.45	0.16
Phenanthrene (leachable)	µg/l	A-T-019w	16	3	0.74							<0.02	0.41	0.14	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pyrene (leachable)	µg/l	A-T-019w	16	9	0.24							0.02	0.15	0.03	0.03	<0.02	<0.02	0.24	0.02	0.05
PAH sum of 4 (calculated)	µg/l	-	16	1	0.31				0.1	UK DWS	1	<0.08	0.31	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
PAH (total 16) (leachable)	µg/l	A-T-019w	16	16	2.84							0.22	1.95	1.9	0.11	0.16	0.12	0.78	0.54	0.27
TPH CWG Leachable																				
Ali >C5-C6 (leachable)	µg/l	A-T-022w	16	1	4				<1	LOD	1	<2	<2	<2	<2	<1	<1	<1	<1	<1
Ali >C6-C8 (leachable)	µg/l	A-T-022w	16	0	1				<1	LOD	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ali >C8-C10 (leachable)	µg/l	A-T-022w	16	0	1				<1	LOD	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ali >C10-C12 (leachable)	µg/l	A-T-023w	16	0	10				<10	LOD	0	<10	<10	<10	<10	<10	<10	<10	<10	<10
Ali >C12-C16 (leachable)	µg/l	A-T-023w	16	2	70							<10	<10	<10	<10	<10	<10	<10	70	<10
Ali >C16-C21 (leachable)	µg/l	A-T-023w	16	2	518							<10	<10	<10	<10	<10	<10	<10	518	<10
Ali >C21-C35 (leachable)	µg/l	A-T-023w	16	1	592							<10	<10	<10	<10	<10	<10	<10	592	<10
Total Aliphatics (leachable)	µg/l	A-T-023w	16	2	1180							<10	<10	<10	<10	<10	<10	<10	1180	<10
Aro >C5-C7 (leachable)	µg/l	A-T-022w	16	0	1				<1	LOD	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aro >C7-C8 (leachable)	µg/l	A-T-022w	16	0	1	74	EQS 2015	0	<1	LOD	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aro >C8-C9 (leachable)	µg/l	A-T-022w	16	0	1				<1	LOD	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aro >C9-C10 (leachable)	µg/l	A-T-022w	16	0	1				<1	LOD	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aro >C10-C12 (leachable)	µg/l	A-T-023w	16	1	10	2	EQS 2015	1	<10	LOD	1	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aro >C12-C16 (leachable)	µg/l	A-T-023w	16	1	18				<10	LOD	1	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aro >C16-C21 (leachable)	µg/l	A-T-023w	16	0	10	0.1	EQS 2015	0	<10	LOD	0	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aro >C21-C35 (leachable)	µg/l	A-T-023w	16	0	10	0.00017	EQS 2015	0	<10	LOD	0	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total Aromatics (leachable)	µg/l	A-T-023w	16	1	28							<10	<10	<10	<10	<10	<10	<10	<10	<10
TPH (Ali & Aro) (leachable)	µg/l	A-T-023w	16	2	1180							<10	<10	<10	<10	<10	<10	<10	1180	<10
BTEX - Benzene (leachable)	µg/l	A-T-022w	16	0	1	10	EQS 2015	0	1	UK DWS	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
BTEX - Toluene (leachable)	µg/l	A-T-022w	16	0	1	74	EQS 2015	0	700	WHO 2011	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
BTEX - Ethyl Benzene (leachable)	µg/l	A-T-022w	16	0	1	20	EQS 2015	0	300	WHO 2011	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
BTEX - o Xylene (leachable)	µg/l	A-T-022w	16	0	1							<1	<1	<1	<1	<1	<1	<1	<1	<1
BTEX - m & p Xylene (leachable)	µg/l	A-T-022w	16	0	1							<1	<1	<1	<1	<1	<1	<1	<1	<1
BTEX - Total Xylenes (calculated)	µg/l	-	16	0		30	Former DSD	0	500	WHO 2011	0	<2	<2	<2	<2	<2	<2	<2	<2	<2
MTBE (leachable)	µg/l	A-T-022w	16	3	2				15	WHO 2011	0	1	<1	2	<2	<1	<1	<1	<1	<1

Surface water screening criteria exceedances
Ground water screening criteria exceedances
Surface water and groundwater screening criteria exceedances
PH below UK DWS lower threshold for groundwater (6.5)
PH below UK DWS lower threshold for groundwater and surface water (6.0)

Surface water exceedance - used Hardness 0 - 50 CaCO3 (most conservative value)

EQS 2015	The WFD (Standards and Classification) Directions 2015
UK DWS	UK Drinking Water Standards
WHO 2011	WHO Drinking Water Guidelines 2011

TP-R-086	TP-R-095	TP-P-09	TP-R-063	TP-R-OO4A	TP-R-009	TP-R-003
0.20	0.30	0.30	0.40	0.20	0.10	0.10
16-Feb-17	15-Feb-17	24-Feb-17	21-Mar-17	08-Mar-17	09-Mar-17	16-Mar-17
6.2	6.33	6.37	5.87	6.72	6.62	5.88
<0.02	0.12	0.02	0.02	<0.02	<0.02	<0.02
<1	<1	2	<1	1	2	<1
12	11	12	13	18	16	<10
<1	<1	<1	<1	<1	<1	<1
3	1	22	3	4	8	5
<1	<1	<1	<1	<1	<1	<1
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
2	<1	10	2	4	9	4
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<1	<1	1	<1	<1	2	<1
<1	<1	<1	<1	<1	<1	<1
6	13	13	3	5	158	38
0.03	<0.02	<0.02	0.09	0.05	0.03	0.08
<0.02	<0.02	<0.02	<0.02	0.03	0.04	<0.02
0.15	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.17	<0.02	<0.02	<0.02	<0.02	<0.02	0.03
0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
1.55	0.21	0.4	0.56	0.16	0.24	0.29
0.74	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.15	<0.02	<0.02	<0.02	<0.02	<0.02	0.03
<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
2.84	0.21	0.4	0.65	0.24	0.31	0.43
<1	<1	4	<1	<1	<1	<1
<1	<1	<1	<1	<1	<1	<1
<1	<1	<1	<1	<1	<1	<1
<10	<10	<10	<10	<10	<10	<10
<10	<10	<10	<10	12	<10	<10
<10	<10	<10	<10	11	<10	<10
<10	<10	<10	<10	<10	<10	<10
<10	<10	<10	<10	23	<10	<10
<1	<1	<1	<1	<1	<1	<1
<1	<1	<1	<1	<1	<1	<1
<1	<1	<1	<1	<1	<1	<1
<1	<1	<1	<1	<1	<1	<1
<10	<10	<10	<10	10	<10	<10
<10	<10	<10	<10	18	<10	<10
<10	<10	<10	<10	<10	<10	<10
<10	<10	<10	<10	<10	<10	<10
<10	<10	<10	<10	28	<10	<10
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Appendix B. Factual Report

A30 – Chiverton to Carland Cross

Factual Report on Ground Investigation

Project No: 732088

Client: Highways England

Available on request from Highways England. Highways England can be contacted:

By Email: A30ChivertontoCarlandCross@Highwaysengland.co.uk

In Writing: Highways England
Temple Quay House
2 The Square
Temple Quay
Bristol, BS1 6HA

By Telephone: 0300 123 5000

JULY 2017

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If you need help accessing this or any other Highways England information, please call **0300 123 5000** and we will help you.

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