Cardiff Parkway Developments Ltd

Cardiff Parkway

Ground Investigation Report

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Contents

Page

1 Introduction 1

1.1 Background 1
1.2 Scope of Report 2

2 The site 3

2.1 Site Location 3
2.2 Current Land Use 3
2.3 Topography 4
2.4 Geology 4
2.5 Hydrology and Hydrogeology 5
2.6 History and Previous Land Use 5
2.7 Buried Utilities 6
2.8 Contamination 6
2.9 Unexploded Ordnance (UXO) 8

3 Ground Investigations 9

3.1 Summary of Completed Ground Investigations 9
3.2 Scope of Investigation 9
3.3 Laboratory Testing 10
3.4 Reporting 10

4 Ground Condition and Geotechnical Parameters 11

4.1 General 11
4.2 Summary of Stratigraphy 11
4.3 Made Ground 13
4.4 Tidal Flat Deposit - Clay 14
4.5 Tidal Flat Deposits – Peat 24
4.6 Glacial Till 28
4.7 Undifferentiated Bedrock of St Maughan’s Formation and Mercia Mudstone Group 31
4.8 Groundwater 34
4.9 Encountered Contamination 36
4.10 Concrete Aggressivity 36
4.11 Summary of Geotechnical Parameters 37

5 Contamination Assessments 39

5.1 Conceptual site model 39
5.2 Human health risk assessment 40
5.3 Controlled Waters Risk Assessment 41
5.4 Ground gas monitoring 45

5.5 Contamination Recommendations 56

6 Geotechnical Risk and Opportunities Register 58

6.1 Introduction 58
6.2 Project Geotechnical Risk and Opportunity Register 58

7 Further Investigation 63

References

Figures

Figure 1 - Site Location
Figure 2 – Site Topography
Figure 3 – Superficial Geology
Figure 4 – Bedrock Geology
Figure 5 – Desiccated Crust Thickness
Figure 6 – Bedrock Surface Elevation
Figure 7 – Soft Clay and Peat Thickness
Figure 8 – Section (1)
Figure 9 – Section (2)
Figure 10 – Section (3)
Figure 11 – Section (4)
Figure 12 – Section (5)
Figure 13 – Section (6)
Figure 14 – Section (7)
Figure 15 – Section (8)
Figure 16 – Section (9)
Figure 17 – Section (9) with CPT

Appendices

Appendix A
Project Proposal

Appendix B
Parameter Plots

Appendix C
Groundwater

Appendix D

Surface Water

Appendix E

Gas

1 Introduction

Cardiff Parkway Development Limited intends to develop the land to the south of the existing St Mellons Business Park, located approximately 7km east of Cardiff. The proposed development includes:-

Cardiff Parkway Train Station, comprising:

- A new Station Building
- Slewing of the relief lines for the Great Western Mainline to accommodate a new island platform between mainline and relief lines, and construction of new platforms to the north and south of the Main lines and Relief lines.
- Access footbridges for new platforms.
- Widening of existing rail embankments to accommodate the slewed lines and new platforms and access footbridges.
- Modifications to the existing Overhead line Electrification system, including new foundations.

A new business park. The current masterplan for which comprises:

- Two to three-storey buildings,
- Associated roads
- Car parking
- Open spaces including parks and Sustainable Drainage Systems (SuDS)

Raising of the site area with imported fill to achieve necessary flood protection levels. Existing reens will need to be diverted and additional reens may need to be constructed to provide appropriate mitigation.

1.1 Background

Separate desk studies were produced for the proposed business park development to the north of the train station [1] and for the proposed train station [2].

This report presents the findings of the initial ground investigations undertaken in June 2019, which were proposed to inform the design of the railway station elements and early phases of the business park development, and also to provide information to support the planning application for the overall development proposals at the site.

In addition, the findings of the Ground Investigation Report for the design of OLE structures in the Great Western Route Modernisation project [3] and Factual Report [4], the Ground Investigation Factual Report for Green Lane Overbridge [5] and historical boreholes recorded on the BGS Online Viewer [6] have been considered. The data from these reports has been incorporated into the main data set.

1.2 Scope of Report

The GIR summarises the findings of recent and historical ground investigations, and information available through the British Geological Survey (BGS) [6] to provide an interpretation of the ground and groundwater conditions for the site.

A summary of the site, the site's history, derived geotechnical parameters for design, groundwater conditions, environmental assessment for risk to human health and controlled waters and key ground hazards and risks are presented.

The aim of the report is to provide information to support planning application, inform GRIP 4 rail design development and to allow design of initial elements of the scheme proposals.

2 The site

Using the desk study issued for Cardiff Parkway a summary for the site is given below.

2.1 Site Location

The site is located approximately 7km east of Cardiff, near St Mellons. The Great Western railway, comprising two main lines and two relief lines supported on low height embankments crosses the site, dividing the site into northern and southern area.

The site is currently occupied by fields with a network of drainage channels or 'reens'. The northern area is bounded by Faendre Reen to the west, and to the north by St Mellons Business Park. Heol Las defines the eastern site boundary. The southern area of the site is bounded to the south and west by fields.

2.2 Current Land Use

A network of drainage reens covers the site, which are managed manually, with water levels varying seasonally. The reens vary in size and depth. The smaller reens are typically in the region of 2m in width and major reens up to 7m in width, measured at the base of the reen. The reens are typically steep sided, with side slopes approaching 1:1 for the smaller reens, and slightly slacker for the major reens. Whilst some of the deeper reens are permanently water filled the shallower reens are seasonally dry. The reens separate the land area into smaller field parcels.

The fields within both the northern and southern areas of the site are occupied predominantly by agricultural grazing land, with some fields set aside for growing crops. The fields are parcelled by the adjacent reens acting as a network of drainage channels. These reens possess small bridge crossings allowing access across the sites footprint. Unhindered access is available to reach all undertaken exploratory hole positions from the north at two locations, and to the east. The three access points are:

- St Mellons Business Park to the north of the proposed site appears to have been constructed at or close to the original ground level. Fill has been locally placed in the south-western corner of the business park to provide ramped access for the southern building.
- The northern area of the site is bounded by Faendre Reen. Beyond the river there is an area of rough grassland and trees before a residential area.
- Green Lane Overbridge, situated along Heol Las road and to the immediate east of the site area, has recently been reconstructed as part of the gauge clearance works for the Great Western rail electrification works. Further details of this are included with the desk study assessment [1].

Access tracks are present in the northern area of the site spanning east to west, following the alignment of the gas main, and approximately 180m north of the

Great Western railway line. The tractor track is accessible from Heol Las road running along the eastern boundary of the site. A track further north is also present, too accessible from Heol Las road.

Electricity pylons were constructed in 1970-73 across the site area. A gas governor is located in the south-eastern part of the northern area of the site's location, and gas pipelines associated with this also cross the site area.

A culvert is present spanning below the railway corridor towards the east of the site. It is of concrete construction with wing walls protruding to the adjacent fields. The watercourse appears to be a medium sized drainage ditch [2].

2.3 Topography

A topographic survey for the site was undertaken in January 2018. The survey covered the majority of the site excluding the railway corridor, a topographic plan has been produced, shown in Figure 2. The existing ground level across the site is shown to be relatively flat, ranging from 5 to 6mAOD.

It is noted from the GRIP 2 Desk Study [1], the railway is positioned on an embankment, typically 1 to 2m above the sites ground level, approximately 7mAOD along the railway.

2.4 Geology

The site is overlain by a variable thickness of Tidal Flat Deposits, comprising soft clay and silt with beds of peat overlying a discontinuous layer of Glacial Till deposits over the predominantly mudstone bedrock of the St Maughan's Formation and Mercia Mudstone.

The Tidal Flat Deposits are associated with the deposition of the Severn Estuary, typically comprising clay and silt with beds of peat overlying sand and gravel. The desk study refers to the early postglacial rivers that flowed along channels deeper than those today, with the sea level 30m lower then it is today. The gradual eustatic rise in sea level resulted in the infill of valleys with fluvial deposits, typically consisting of alluvial mud, silts and sands with gravel. The buried river channels mean that the depth of the bedrock and thickness of the superficial deposits is therefore anticipated to vary across the site.
The bedrock in the northern site is predominately of the St Maughan's Formation. The southern site is typically underlain by bedrock of the Mercia Mudstone Group. Both bedrocks share similar descriptions and characteristics, it is understood that the Mercia Mudstone overlies the St Maughan's Formation, which dips 40º to the north east [1].

2.5 Hydrology and Hydrogeology

The Tidal Flat Deposits aquifer designation classifies the deposit as unproductive. The St Maughan's Formation is classified as a secondary (A) aquifer. Whilst the Mercia Mudstone Group underlaying the southern area of the site and part of the northern area is classified as a secondary (B) aquifer.

Given the low-lying location of the site, groundwater is anticipated to be present at shallow depths. The Tidal Flat Deposits are generally low permeability materials but higher permeabilities can be encountered at the interface between solid geology formations and the overlying superficial deposits and where more granular or organic layers are present within the deposits.

Many drainage channels are located within the site area. The Faendre Reen drainage channels runs along the western boundary, flowing south, which many of the other reens and ditches connecting into. The general drainage direction of surface water flow is anticipated to be towards the Severn Channel which his some 1.5km to the south.

2.6 History and Previous Land Use

The site is located to the east of the Faendre Reen, within an area of land which was reclaimed for agricultural use from the Severn Estuary intertidal zone during Roman times.

The site is currently used as agricultural land, predominantly grazing, and has a flat topography with ground elevations varying across the site between 4.5mAOD and 5.5mAOD. The fields are drained by a network of reens which typically maintain groundwater levels across the site to a metre or so below the ground surface.

The Great Western railway line, which crosses the site on low height embankment approximately 2m in height, was constructed in the mid-19th Century.

Industrial buildings associated with a gas governor facility were constructed in the late 1990s in the south eastern corner of the northern area of the site. Four gas pipelines are known to cross the site from the gas governors. Overhead electricity cables were constructed crossing the sites area in the 1960s.

No historical landfill sites within the site boundary have been identified.

2.7 Buried Utilities

There are several utilities known to be present within the site.

A high pressure gas main runs across the site from north west to south east and connects into gas governors that are present on small areas in the north and east of the site.

Two intermediate pressure gas mains cross the site from east to west from the eastern gas governor.

A foul rising main crosses the north of the site in an east to west alignment.

A water main is located to the west of the site, running along the eastern site of Cypress Drive.

In addition to the buried services, 275kV high voltage overhead power cables cross the site from north west to south east.

2.8 Contamination

A contamination review was undertaken and presented in the desk study [1] and a preliminary conceptual site model was developed, based on available information. This formed the basis of the Preliminary Risk Assessment and underpinned the scope of the ground investigations. The preliminary risk assessment has been undertaken in accordance with CIRIA 552 [7].

The conceptual site model identified potential sources, pathways and receptors of contamination that may be present within the site. A summary is shown in Error! Not a valid bookmark self-reference. below, from which identification and justification of the source-pathway-receptor linkages as well as the associated risk classifications are presented. The conceptual model has been updated to reflect the latest development proposals.

Table 1 - Source-Pathway-Receptor Linkages and their Associated Risk Classification

Potential Source	Potential Receptor	Possible Pathway	Likelihood	Severity	Risk	Comment
Onsite Made Ground Fly tipped waste Infilled land Imported materials Ground gas from peat Pollution incidents **Offsite** Landfills	**End site users:** Public using the business park (P) & Maintenance Workers (general maintenance) (M)	Direct dermal	Unlikely (P)	Medium (P)	Low	Buildings and hardstanding are anticipated to occupy the majority of the site, but there will be some areas of landscaping. Should the level of the site be raised using imported fill (e.g. to achieve design flood levels), site end users would be even more unlikely to be exposed to any potential contaminants. Potential pathways for the migration of ground gas could be created during the installation of piles and/or band drains, which could lead to the build-up of gases and create a risk of asphyxiation and explosion.
			Unlikely (M)	Medium (R)	Low	
		Ingestion	Unlikely (P)	Medium (P)	Low	
			Unlikely (M)	Medium (R)	Low	
		Inhalation of gas or vapours	Likely (P)	Severe (P)	High	
			Unlikely (M)	Medium (R)	Low	
	Construction Workers and Maintenance Works (Intrusive works)	Direct dermal	Likely	Medium	Moderate	Given the limited excavation likely to be required and the limited sources of contamination identified, construction workers are unlikely to be exposed to significant levels of contamination. Potential pathways for the migration of ground gas could be created during the installation of piles, which could lead to the build-up of gases and create a risk of asphyxiation and explosion.
		Ingestion	Likely	Medium	Moderate	
		Inhalation of gas or vapours	Likely	Medium	Moderate	
	Surface waters; Faendre Reen and reen along eastern boundary; Hendre lake	Leaching, lateral migration within groundwater contaminated surface water run off; Inflow of impacted reen water	Unlikely	Mild	Very low	Due to the cohesive nature of the soils anticipated at the site, the migration of groundwater through these layers is likely to be limited. Depending on the grading of the materials used, water could however migrate through the imported materials and enter controlled surface waters. For this reason, the risk to surface waters needs to be considered when selecting materials for import.

2.9 Unexploded Ordnance (UXO)

A detailed UXO risk assessment report [8] for the site, concludes that the UXO risk is low. It concludes the most probable UXO threat is posed by WWII German High Explosive (HE) bombs, with a residual threat present from Incendiary Bombs (IBs) and British Anti-Aircraft Ammunition (AAA). Whilst there is a residual UXO risk present within the site, it is not believed to be a significant risk pathway to warrant on site pro-active mitigation measures.

The report recommends mitigation measures for all ground works. This includes:

- An operational UXO emergency response plan to be held on site.
- UXO safety and awareness briefings for all personnel working on site.

Undertaking these mitigation measures is recommended to reduce the UXO risk to as low of reasonably practicable (ALARP).

3 Ground Investigations

3.1 Summary of Completed Ground Investigations

The following ground investigations have been undertaken in the vicinity of the site:

- Green Lane Overbridge 2015 [5].Undertaken within site proximity, along Heol Las road. Ground investigation comprised of 7no. boreholes monitored for ground water ingress and 3no. trial pits.
- GWRM – Section M 2016 [4]. In the proximity of the site the ground investigation comprised of 4no. boreholes monitored for groundwater ingress, 8no. inspection pits and 8no. Cone Penetration Tests (CPT)
- BGS online viewer boreholes [6]. Within and surrounding the site footprint previous ground investigations comprising of 6no. boreholes, of which borehole ST28SE11 is not available to view.
- Initial phase of ground investigation conducted for Cardiff Parkway Developments Ltd in 2019 [9]. This ground investigation is discussed in detail below.

3.2 Scope of Investigation

The scope of the initial phase of ground investigation as set out in the ground investigation specification [10] was completed and included:

- 6 No. Cable percussive boreholes;
- 5 No. Cable percussive boreholes with rotary cored follow on;
- 7 No. Trial pits
- 6 No. Cone Penetration Testing with shear wave velocity testing
- 7 No. In-Situ shear vane test
- 5 No. Piston sampling
- 10 No. Borehole SPT profiles
- 8 No. Ground water monitoring
- 10 No. Standpipes
- 10 No. Dissipation tests
- Laboratory geotechnical and chemical testing
- Groundwater and surface water monitoring and sampling

Ground investigations are required to inform the planning application and the design of proposed earthworks, infrastructure and buildings for initial phases of the development.

Note that all ground investigation was undertaken in the agricultural areas across the site. The existing railway embankments were not investigated as part of the initial phase of ground investigation.

3.3 Laboratory Testing

Geotechnical classification testing was undertaken on selected samples taken during the investigation. The details of these laboratory testing are given below:

The natural water content was determined on thirty-nine selected samples. Atterberg Limits tests were carried out on thirty-eight selected samples to determine the liquid limit, plastic limit and plasticity index.

Particle size distributions were determined for thirty-three samples by wet sieving.

Unconsolidated undrained triaxial compression tests were carried on twelve specimens prepared from full diameter UT100 and piston samples to determine the undrained strength of the soft soils.

One dimensional consolidation tests were carried out on twelve specimens prepared from full diameter UT100 and piston samples to determine consolidation parameters. Four sample of the rock core were tested for unconfined compressive strength, with point load index testing undertaken on thirty selected representative samples of the core to assess the rock strength.

Samples were despatched to Chemtest limited from which nineteen had organic matter determined and four had loss on ignition determined. The BRE SD1 (2005) suite of tests was carried on twenty-nine samples by Chemtest limited.

No chemical testing was undertaken on samples of soil, as no potentially contaminated materials were encountered during the ground investigation.

Selected groundwater (Appendix C) and surface water (Appendix D) samples were dispatched to i2 Analytical, where chemical analyses were carried out for a suite of contaminants including general inorganics, phenols, hydrocarbons and metals.

In addition to the laboratory testing above six round of fortnightly gas monitoring was undertaken from standpipes installed into the boreholes across the site (Appendix E).

3.4 Reporting

A factual ground investigation report for the Cardiff Parkway initial ground investigation was produced in August 2019 by Geotechnical Engineering Ltd [9]. Digital AGS data was also prepared and issued with the factual report.

4 Ground Condition and Geotechnical Parameters

4.1 General

The ground and groundwater conditions and the geotechnical testing referred to in the following sections include those encountered in the exploratory holes undertaken in the investigation **Error! Reference source not found.**. In addition, relevant information from the two historical ground investigations undertaken in the site's proximity **Error! Reference source not found.**[5], as discussed in Section 3.1, have been considered in the assessment along with the boreholes surrounding the site from the BGS online viewer [6]. Limited geotechnical testing data was available from the BGS online viewer boreholes, the SPT N values with depth have been recorded. The nature of these values is unknown as to whether they have been corrected. These values have not been implemented in the interpretation of geotechnical parameters.

4.2 Summary of Stratigraphy

The ground conditions encountered during the current ground investigation and the two prior investigations are summarised in **Table 2.**

Table 2 – Summary of encountered stratigraphy

Material Name	Typical Description	Depth (mbgl)	Thickness (m)
Made Ground			
Made Ground	Generally no Made Ground was encountered across the site by exploratory holes, excluding Green Lane Overbridge. The Made Ground of the railway embankment was encountered during the 2016 investigations undertaken for the electrification works of the mainline [4]) and found to comprise grass over silty sandy clay, with gavel subangular to sub rounded brick and mudstone. (The Made Ground of the railway embankment was not investigated as part of the 2019 initial investigation) **Tarmacadam with silty sandy clays and gravels, including coarse brick, siltstone, limestone, sandstone, coal, slag and glass.	GL	Railway – 0.1 to 0.4 **GL - 0.4 to 7.9**

Material Name	Typical Description	Depth (mbgl)	Thickness (m)
Drift Geology			
Tidal Flat Deposit – Clay	Soft to firm slightly sandy gravelly clay with abundant wood fragments and frequent rootlets. Infrequent gravel of sandstone and mudstone. (Increasing thickness towards the East) [Desiccated Crust present across the majority of the site; locally mottled clay with frequent rootlets]	GL to 7.9	0.8 to 7.5 [Desiccated Crust: 0.3 – 1.6]
*Tidal Flat Deposit – Peat	Firm clayey fibrous peat becoming slightly sandy organic silty clay. Frequent fragments of plant material and wood fragments. (Frequently occurring towards the east of the sites footprint) **Described as spongy oxidising fibrous peat within Green Lane Overbridge.	0.4 to 11.1	0.2 to 2.0
Glacial Till Deposit	Firm slightly gravelly sandy silty clay. Gravel of coarse sandstone, mudstone and siltstone. Frequent pockets of fine sands. (Increasing thickness towards the west of the site) [Glaciofluvial Deposits are suggested to be present in infrequent bands towards the north of the site; typically sand or gravels]	GL to 7.5	0.4 to 5.4
Solid Geology			
Undifferentiated Bedrock of St Maughan's and Mercia Mudstone	Extremely weak to very weak mudstone and sandstone tending to very stiff clay. Sub horizontal fractures. (Increasing thickness towards the south of the sites footprint)	6.0 to 15.0	0.2 to 24.8 [Undefined thickness]

***** Intersects, Tidal Flat Deposit – Clay
****** In Localised Areas (Green Lane Overbridge): (GL101 to GL107, GL121 to GL123 & M-BH13)

The ground conditions encountered throughout the site were generally consistent with the geology predicted from the BGS online viewer [6]. Published superficial geological mapping indicates the presence of Glacial Till and Tidal Flat Deposits across the site; as presented in Figure 3. The Published geological mapping indicates the bedrock geology to comprise Mercia Mudstone Group overlying the St Maughan's Formation, both of which are red brown mudstones, locally weathered to a firm to stiff clay with subordinate siltstone and sandstone bands. The boundary between bedrock formations, based on the published mapping, are shown on Figure 4. It was very difficult for GEL to distinguish between the two strata on the basis of descriptions when logging the boreholes, and the test data did not indicate any significant difference between the two strata in terms of their engineering properties. For the purposes of this report these bedrock strata have been considered as undifferentiated bedrock, and combined parameter plots have been presented.

A number of geological long/cross sections have been prepared for the site, including all relevant exploratory holes (Figure 8 to Figure 17), with section locations, presented on Figure 3 to Figure 7.

The following sections provide more detail on each of the strata's identified on the site, **Table 2**. Derived geotechnical parameters are assessed additionally.

4.3 Made Ground

Across the majority of the site, Made Ground is absent. Isolated areas of Made Ground are present associated with the Green lane overbridge approach embankments the railway embankments crossing the site area and farm track running through the site.

The Made Ground at the location of Green Lane Overbridge was recorded on exploratory holes associated with the gauge clearance works for the Great Western Rail Electrification works [5] (GL101 to GL107, GL121 to GL123 and M-BH13), this area possesses the majority of the encountered Made Ground.

It is assumed that Made Ground is present along the railway corridor The cone resistance results for CPT undertaken during the GWRM ground investigation [4], indicate the presence of Made Ground above the sites typical ground level. CPT results can be seen the cross section presented on Figure 17.

Made Ground materials were encountered in CPT01/VS01, CPT05/VS05, TP05. These exploratory holes are located close to the railway embankment. The observations of the three exploratory hole locations are discussed in Section 0.

Parameter plots related to Made Ground are shown in Appendix B1.

4.3.1 Typical Description

The localised area of Made Ground associated with the approach embankments to the Green Lane Overbridge was described as Made Ground comprising black tarmacdam with silty sandy gravels. Gravel that has a low content of angular to sub-rounded coarse cobbles composed of brick, siltstone, limestone, sandstone and concrete. The material is described as having frequent fragments of coal, slag, tyres, metal, glass and plastic bags. Made Ground encountered in CPT01/VS01 and CPT05/VS05 appears to be natural reworked materials with fragments of brick. The Made Ground encountered in TP5 comprises sandy gravels of sandstone and mudstone and appears to be material placed for a temporary platform, potentially associated with works on the railway.

The nature of the Made Ground materials associated with the railway embankment have not been investigated during the recent investigations, but it is considered likely that the embankments will be constructed of predominantly granular material.

4.3.2 Classification

A limit amount of classification testing was undertaken on Made Ground. All available tests were undertaken in the location of Green Lane Overbridge. The classification testing undertaken is summarised in the **Table 3**.

Table 3 - Classification testing within Made Ground

Test	Number of Tests	Min	Max	Mean
Moisture Content	10	6	48	18
Plastic Limit	1	28		
Liquid Limit	1	65		
Plasticity Index	1	37		

In addition, four PSD tests were undertaken. The locations of these four tests were Green Lane Overbridge. As shown in Plot E.1.3.

The Made Ground can be characterised as a sandy gravel, with a 60% gravel content, and less than 10% fines.

4.3.3 Strength and Stiffness

Standard Penetration Tests

Twenty-one SPTs were undertaken in the Made Ground. Values ranged from 4 to 21, with no obvious correlation between the number of blows and the depth of the material tested. An estimated mean value for the SPT tests can be derived as 10. These results were obtained from Green Lane Overbridge, of which the embankment has now been replaced by an engineering embankment as part of the bridge renewal.

No strength tests were undertaken within made ground encountered elsewhere in the site, and the ground conditions may not be the same as at the Green Lane Overbridge, therefore the derived SPT N value of 10 may not be applicable elsewhere on the site.

4.4 Tidal Flat Deposit - Clay

The Tidal Flat Deposit were typically described as soft to very soft clay with components of gravel and fine sand, wood fragments (up to 50mm) and frequent rootlets (up to 20mm diameter). It is typically bluish grey to brown or grey in colour. When the spare samples were split and described the material was consistent with this description and showed no evidence of laminations or persistent granular layers.

The clay was encountered from ground surface, beneath a 0.1 to 0.2m thick layer of topsoil to a maximum recorded depth of 7.9mbgl (GL102). The thickness of the Tidal Flat Deposits increases towards the south eastern corner of the site, is absent at the north-western margins of the site and has its greatest recorded thickness in the vicinity of the Green Lane Overbridge. The thickness of the soft clay and peat across the site is presented in Figure 7. Parameter plots related to Tidal Flat Deposit are shown in Appendix B2.

Desiccated Crust

The surface of the Tidal Flat Deposit clays was observed to have a ‘desiccated crust’ with a significantly higher strength to that typically recorded. This is generally described as firm (in some instances stiff) clay. It is typically a locally mottled clay with frequent rootlets. The curst is generally light to orangish brown and grey in colour. The presence of the crust is believed to be due to the fluctuations of groundwater levels over the site’s history. The thickness of the crust varies but is generally 1.2m thick, ranging from 0.2 to 1.6m in thickness. The variation in crust thickness across the site is shown in Figure 5.

A desiccated crust has not been encountered in all exploratory holes, in particular some of the exploratory holes undertaken at Green Lane Overbridge. As shown with Figure 14, it can be suggested the exclusion of the desiccated crust is due to the excavation of the ground; shown by the depth of Made Ground present below the sites typical ground level.

4.4.1 Classification

Natural Moisture Content

Natural moisture content with elevation is presented in the Plot B2.1, the plot is bounded by a moisture content value of 100. The natural moisture content for the TFD clay varies from 17% to 133% with forty-five tests conducted. Derived upper and lower bound values are 70% and 30% respectively. A derived mean natural moisture content was suggested as 50%.

A correlation can be observed with the natural moisture content increasing with depth, see Plot B2.1.

Atterberg Limits

Test	Number of Tests	Min to Max (Derived Lower and Upper bound value)	Mean Value
Plastic Limit	44	14 to 35 (23 to 35)	26
Liquid Limit	44	25 to 79 (55 to 70)	58
Plasticity Index	44	11 to 44 (15 to 40)	32

The Atterberg Limits have been plotted against elevation with the natural moisture content, shown in Plot B2.2, the following can be observed:

- The natural moisture content can be seen to increase with depth, whilst the liquid limit and plastic limit remain generally consistent in their values.
- It is noted that as the elevation of the tests decreases the natural moisture content tends towards the liquid limit, this can be seen from roughly 3mAOD and below. The inclination towards the plastic limit at higher elevations suggest the clay is not normally consolidated over this elevation range, which is consistent with the presence of a desiccated crust and the deposit's descriptions of "firm clay "in the upper 1-2m.

Based on the plasticity chart, shown in Plot B2.3. The Tidal Flat Deposit clay ranges from low to a very high plasticity, but a large portion of test results are clustered within the high plasticity clay range.

Particle Size Distribution

Twenty-four PSD tests were undertaken on samples of TFD clay with the results presented in Plot B2.4. A typical composition for the clay is a high percentage fines content, confirming the materials clayey composition. The PSD data indicates typically over 95% fines than 63μm of which 30-50% is in the clay sized fraction (<2μm). Typically, less than 5% of material coarser than 63μm, generally indicated to be sand.

On the basis of the PSDs and Atterberg Limits data, the material would be described as a slightly sandy silty CLAY.

[Note that a few of the samples tested indicated a greater gravel/sand content. This is present in BH01 and BH02, of which a 20% cobbles content is present in BH02. This may be associated with the close proximity of the former (now backfilled) river channels than have been identified to the north of the site areas].

Organic Content

Total Organic Content was determined for the Tidal Flat Deposits, both for the Clay and Peat strata, and test results are presented in Plot B2.5. The organic content for the Tidal Flat Deposit clay typically ranged from 0.75 – 2.5%, based on sixteen tests. An estimated mean value for the organic content of the clay is suggested as 1.5%. One test result undertaken in BH06 exhibits a value of 14% and could be due to its locally organic nature.

BS5930:2015 [11] indicates the clay can be assumed to be inorganic to slightly organic under its derived upper and lower bound range.

Bulk Unit Weight

Bulk unit weight for the Tidal Flat Deposit Clay can be determined from the relationship with moisture content. The unit weight, γ , and moisture content w, are related by the expression (Craig) [12]:

$$\gamma = (1 + w)\gamma_w/(w + 1/G)$$

Where G is the specific gravity of soil (assumed as 2.65), and γ_w is the unit weight of water, $9.81kN/m^3$.

The mean moisture content for the clay was derived as 55%. Using the above equation, a value for unit weight of the Tidal Flat Deposit clay was calculated to be $16.5kN/m^3$.This supports the graph in Plot B2.6. Based on this approach. upper and lower bound derived values of $18.5kN/m^3$ and $15.5kN/m^3$ are proposed respectively.

4.4.2 Compressibility

Pre-consolidation

Eight recent Oedometer tests were undertaken within the Tidal Flat Deposit clay, with an additional four from Green Lane Overbridge, shown in Plot B2.7.

[Note the plot presents two oedometer tests undertaken in the GTD, located at a depth on the Tidal Flat Deposit and the Glacial Till Deposit boundary]

The development of the Over-Consolidation Ratio has been based on the following assumptions:

- Unit Weight of the Clay: $16.5kN/m^3$
- Depth of groundwater level: $1mbgl$

Using the shape of the plots from the Oedometer tests; void ratio e against log applied effective stress, $\log(p')$, its suggested that the deposit has experienced previous applied stress and is assumed to be over-consolidated.

OCR profiles have also been estimated from CPTs based on correlations with cone resistance and vertical effective stress (Lunne, et. al) [13] and by relating OCRs with undrained shear strengths, as presented below:

$$c_u = 0.22\sigma_V' \, OCR^{0.8} \text{ (adopted from BS8002: 2015 [14])}$$

Plot B2.8 presents the OCR profiles for all CPTs. The following upper and lower bound derived values of OCR are considered reasonable for the site based on this approach:

- Within the upper TFD (between 5mAOD and 4mAOD), OCR ranges from a lower bound of 2 to an upper bound of 20.
- Between 4mAOD and 2.5mAOD, OCRs range from 2 to 11.
- Below 2.5mAOD and within the TFD Clay, OCRs range from 2 to 8.

The sudden increase in OCR at 7-8mbgl is consistent with encountering Glacial Till Deposits and Weathered Bedrock. These have been subject to significantly higher magnitudes of stress prior to the Holocene period.

The variability in OCR profiles for CPT05 and CPT06 pertains to the reduced thickness of the TFD toward the west of the site. This is consistent with geological mapping.

The increase in OCRs at shallow depths is consistent with the desiccated crust, previously identified. The testing has been conducted adjacent to the South Wales Mainline only.

The results obtained from the CPT indicate higher values of OCR in comparison to those derived from the oedometer testing.

4.4.2.1 Compression

Compression Index (C_c) and Compression Ratio (C'_c)

The compressibility of normally consolidated soils can be expressed in terms of either compression index C_c or compression ratio C'_c. Oedometer data from the initial and Green Lane Overbridge ground investigations were used to determine the compression index for the clay deposits. The compression index was determined as follows:

$$C_c = (e_0 - e_1)/\log\left(\frac{\sigma'_1}{\sigma'_0}\right)$$

Where, e_0, e_1, σ'_1, σ'_0 are the void ratio and applied effective stress respectively.

Based on the seventeen oedometer tests undertaken in the clay, calculated C_c values ranged from 0.07 to 0.91, with a typical value ranging between 0.35 - 0.37.

A relationship between the compression index C_c and compression ratio C'_c is as presented below:

$$C'_c = C_c/(1 + e_0)$$

Where in the relationship, e_0 associates with the initial void ratio of the sample.

Calculated C'_c from the derived C_c values, ranging from 0.05 to 0.26.

As proposed by Nath and DeDalal [15], the following correlations with liquid limit, w_L, initial void ratio, e_0, and the plasticity index, I_P, have been used to determine the compression ratio C'_c:

$$C'_c = 0.0021w_L + 0.0587$$

$$C'_c = 0.0888e_0 + 0.0525$$

$$C'_c = 0.0025I_P + 0.0866$$

With the relationships and correlations undertaken, the following can be observed:

- A derived C'_c value is equal to 0.157 across from the available Oedometer tests undertaken in the clay.
- The initial void ratio for the above correlations was found using the Oedometer plots. If no void ratio was available for the deposit, the correlation was not undertaken. The initial void ratio for the clay ranged from 0.415 to 2.482. The derived value for C'_c was equal to 0.221.
- Using the liquid limit, a value of C'_c equal to 0.179 was calculated. Whilst using the plasticity index a derived value of 0.165 was derived.
- The C'_c values obtained from the oedometer plots and the above correlations have been plotted with elevation, in Plot B2.9. An upper and lower bound can be suggested between 0.22 to 0.125 respectively. An estimated derived value for the compression ratio C'_c of 0.18 is inferred.

The modified compression index, λ^*, is derived from interpretation of the oedometer results that show over-consolidation or an unloading loop. The derivation of this parameter is shown on Plot B2.10. An estimated mean value for the modified compression index is equal to 0.062.

The modified index is related to the conventional material parameter with the following correlation [16]:

$$\lambda^* = C_c/(2.3(1+e))$$

A value for the conventional compression index is derived; applying a void ratio, e_0, of 1.4, such that $C_c = 0.35$.

4.4.2.2 Recompression

Recompression Index (C_r) and Recompression Ratio (C'_r)

From the seventeen oedometer tests undertaken in the clay, sixteen included unload stages, with seven of the tests reloaded. No unload-reload tests were undertaken for Green Lane Overbridge.

The recompression index C_r for the clay was calculated to vary between an upper and lower bound of 0.174 and 0.020. A derived recompression index of 0.097 can be inferred.

The derived recompression index can be estimated from the empirical value of the ratio of the recompression index and compression index, C_r/C_c, (Terzaghi) [17]**Error! Reference source not found.**. An estimated value for this empirical ratio is derived as 0.241 and has been used with the derived C_c value (presented above) to calculate C_r equal to 0.108. Confirming the inferred recompression index value presented above.

Similarly, it has been assumed that the compression ratio and recompression ratio are related by similar factors, C'_r/C'_c . Using the derived compression ratio, C'_c (presented above), a value of 0.040 was predicted for the recompression ratio C'_r.

Swelling Index (C_s)

The modified swelling index, κ^*, is derived from the interpretation of each oedometer tests. The derivation of this parameter is shown in Plot B2.11. An estimated mean for the modified swelling index equates to 0.011.

The modified index is related to the conventional material parameter with the following correlation [16]:

$$\kappa^* = (C_s/(1+e))(2/2.3)$$

Applying the above correlation, a value for the conventional swelling index is derived; assuming an initial void ratio, e_0, of 1.4; the estimated mean value for initial void ratio for Tidal Flat Deposit Clay, from which $C_s = 0.03$.

4.4.2.3 Secondary Compression

Similarly, to the parameter interpretation above, a modified creep index, μ^*, in relation to volumetric strain can be derived, see Plot B2.12. A value for μ^* is proposed as 0.003 for the clay. The derivation of the modified index can estimate a value for the conventional parameter, C_α, from a relationship presented below [16]:

$$\mu^* = C_\alpha/2.3(1+e)$$

From the above relationship, a value for the conventional secondary compression index is derived as 0.017; assuming an initial void ratio, e_0, of 1.4, based on the estimated mean for the initial void ratio for Tidal Flat Deposit Clay.

4.4.3 Consolidation

Coefficient of Vertical Consolidation (c_v)

The coefficient of consolidation, c_v, obtained from the laboratory oedometer test data for the clay has been plotted and presented in Plots B2.13 & B2.14.

The plot of c_v with the applied pressure stages, indicates the relationship between the consolidation of the deposit and the applied pressure. Excluding the assumed outliers at low pressure stages it can be inferred that as the applied pressure increases on the sample the coefficient of vertical consolidation increases.

The plot of elevation with the coefficient of vertical consolidation supports the derived range. No clear trend is evident.

Coefficient of Horizontal Consolidation (c_h)

A total of nine dissipation tests were conducted during the CPT investigation. 6 of which were within the TFD. Plot B2.15 presents C_h results from dissipation testing conducted alongside the CPTs. Lower and upper bound C_h of 5 $m^2/year$ and 20 $m^2/year$ for the TFD have been derived.

Coefficient of Secondary Consolidation (C_{sec})

Eight oedometer tests recorded the coefficient of secondary consolidation, C_{sec}, at a pressure stage. These results from the oedometer tests have been plotted against applied pressure stage and presented in the Plots B2.16 & B2.17. The C_{sec} values range between 0.006 to 0.014 $m^2/year$.

The coefficient of secondary consolidation can be derived from a relationship with the moisture content of the sample. The correlation is presented below (Simons and Menzies) [18]:

$$C_{sec} = 0.00018 \times Moisture\ Content$$

The correlated C_{sec} values determined from the above relationship are presented with elevation along with the oedometer determined values. The following can be observed:

- As the elevation of the undertaken tests decreases the coefficient of secondary consolidation increases. The above correlation can be deemed reasonable, agreeing with the trend displayed from the oedometer results. It is noted that the oedometer results obtained are generally greater than the derived value, which is consistent with observations by Simons and Menzies.
- At elevations of 4mAOD and above, a derived lower and upper bound for C_{sec}, can be found as 0.004 and 0.007.
- Below 4mAOD a suggested range for the coefficient of secondary consolidation is between 0.005 to 0.0125.

A plot of the coefficient of secondary consolidation with moisture content is presented in the Plot B2.18. It is noted that the results obtained for laboratory oedometer testing's exhibit a greater moisture content per C_{sec} unit than the derived correlated values.

4.4.4 Strength and Stiffness

Shearing Resistance

In the absence of drained shear strength results, an estimate for the deposits constant volume angle of shearing resistance, $\varphi'_{cv,k}$, can be derived from the following equation (BS 8002:2015) [14]:

$$\varphi'_{cv,k} = (42° - 12.5\log_{10} I_P)$$

The above relationship can only be estimated for deposits with plasticity index between 5 and 100%.

For the clays derived mean plasticity index of 30%, a value for $\varphi'_{cv,k}$ is estimated as 24°. Based on derived upper bound plasticity index of 40%, a value of $\varphi'_{cv,k}$ would be reduced to 22°.

4.4.4.1 Undrained Shear Strength

Standard Penetration Tests

Forty-four tests were undertaken on the Tidal Flat Deposit clay across 15 exploratory holes. The following can be observed (Plot B2.19):

- For the cohesive clay no strong correlation between SPT N values and Elevation is apparent. SPT N values ranged from 0 to 12 with a mean value of $N = 3$.
- Three tests were undertaken at Green Lane Overbridge, in GL101, GL103 and GL105. From 1.5mbgl to 4.5mbgl. SPT N values ranged from 4 to 11. These locations are under a reasonable thickness of the approach embankments for the bridge, it is expected there is some strength gain of the TFD Clays in this area.

The undrained shear strength can be derived for the clays from the corrected “N” values using the empirical relationship detailed in CIRIA R143 [19] and as proposed by Stroud, in the form of:

$$c_u = f_1 N_{60}$$

Where f_1 is based on the plasticity index of the soil. The derived plasticity index of the Tidal Flat Deposit clay was 30%. Using CIRIA R143 [19], a value of f_1 equal to 4.5 has been adopted. For the estimated corrected SPT N value of 3 the corresponding undrained shear strength value will be given as $13.5kN/m^2$. As the elevation of the test undertaken decreases so does the undrained shear strength. It is noted that the N_{60} value applied to the above formula is equal to the N value obtained from the corrected SPT N values obtained through testing.

In-situ Vane Tests

A total of fifty-eight hand shear vane tests were conducted within the Tidal Flat Deposit clay on samples retrieved from exploratory holes; boreholes and trial pits. A further twenty-nine machine vane tests were undertaken in the clay.

Vane tests from all investigations undertaken have had a Bjerrum [20] vane correction factor applied to them. The Bjerrum vane correction factor is an empirical factor that correlates the shear strength measured in vane test with the average strength governing stability. The factor depends on the plasticity index of the clay, the derived plasticity index gives a Bjerrum vane correction factor of roughly 0.9 was calculated. This correction factor was applied to the field readings as follows:

$$c_u = 0.9c_{u(vane)}$$

The following results for undrained shear strength were observed from the hand vane tests:

- Tests conducted between 5.5mAOD to 4mAOD ranged from corrected values of $117.0kN/m^2$ to $58kN/m^2$. An estimated mean value for this elevation range is $70kN/m^2$. It is noted all tests conducted within this elevation range are designated as the desiccated crust.
- The remaining tests undertaken below 4mAOD ranged from $59kN/m^2$ to $8kN/m^2$. With a mean value derived as $24kN/m^2$.

As with the SPT results, as the elevation of the test undertaken decreases so does the undrained shear strength.

The following results for undrained shear strength were observed from the machine vane tests:

- Tests conducted in the clay typically ranged from $49kN/m^2$. to $14kN/m^2$. A mean value for the undrained shear strength was derived as $27kN/m^2$.

Undrained Triaxial Tests

Seven unconsolidated undrained triaxial tests were conducted in the Tidal Flat Deposit Clay. The undrained shear strength, with results ranging from $6kN/m^2$ (2mAOD) to $23kN/m^2$ (-1.3mAOD) with a mean value for the undrained shear strength of $14kN/m^2$. No tests were undertaken in the desiccated crust.

The tests completed by the triaxial tests agree with the findings of the hand shear vane testing described above once below an elevation of 4mAOD. The presence of the desiccated crust is consistent with the higher undrained strengths determined by the triaxial testing of samples from above 4mAOD, see Plot B2.20.

Cone Penetration Testing

The undrained shear strength of the TFD and underlying deposits has been estimated from the cone resistance as presented by Lunne, Robertson and Powell [13]

$$N_{kt} = \frac{q_t - \sigma_{vo}}{c_u}$$

This requires N_{kt} to be determined. Published data suggests this could range between 12 and 18 when the reference undrained shear strength is the average of the triaxial compression, direct simple shear and triaxial extension strength.

Undrained shear strengths have been predicted from the CPT tests with a N_{kt} factor of 14 based on the match with the correct hand shear vanes. Details are presented in Plot B2.20.

The following can be observed from the c_u plots with depth from the CPTS:

- From 5.5mAOD to 4mAOD c_u lower and upper bound ranges from $8kN/m^2$ to $35kN/m^2$ have been derived.
- Below 2mAOD, c_u generally ranges from $8kN/m^2$ to $25kN/m^2$. (Undrained shear strengths higher than this range are anticipated to be where the CPTs are within the glacial deposits or underlying weathered rock.

Correlated Data

In normally consolidated clays the undrained shear strength generally increases with effective vertical stress (Craig) [12]. As proposed by Skempton the following correlation between the ratio, c_u/σ_v', and the plasticity index, I_P, for normally consolidated clays is presented below:

$$c_u/\sigma_v' = 0.11 + 0.0037I_P$$

The mean derived plasticity index for the Tidal Flat Deposit Clay, as presented above, is equal to 30%. Applying the above formula, a c_u/σ_v' of 0.24 is obtained.

The ratio of undrained shear strength with effective vertical stress was plotted with elevation, as seen in the Plot B2.21. A value for the ratio can be estimated from the plot, with a value of 0.24 suggested. The range for the ratio can be estimated to be between an upper bound of 0.26 and a lower bound of 0.2.

The ratio of 0.24 has been used on the data plots of c_u with depth to provide a benchmark on the values reported in the sections above. The in-situ vertical effective stress has been estimated at each CPT location so that the c_u profile could be developed. Individual ground profiles were developed through interpretation of CPT profiles, to assign appropriate unit weights. The ground water level was taken to be 1mbgl as per section 4.8.

[Note the soils are not truly normally consolidated as they exhibit a degree of over-consolidation. Therefore, the strengths suggested above are not as low as the strengths the black lines from Plot B2.20 might suggest]

Summary

A composite plot of the vane tests, undrained triaxial tests, the CPT c_u profile and the CPT specific correlated c_u profiles with elevation is presented in Plot B2.20. The proposed lower and upper bound derived ranges of undrained shear strength profile based on all of the above data is shown. A summary of the anticipated c_u profile is presented below:

- From 5.5mAOD to 4mAOD – c_u of 15kN/m^2 to 70kN/m^2;
- From 4mAOD to 1mAOD – c_u of 15kN/m^2 to 40kN/m^2;
- Below 1mAOD, the varying undrained shear strength can be associated with the introduction of other materials across the site at a range of depths.

4.4.4.2 Stiffness

Youngs Modulus

The stiffness of the clay can be determined from the correlation of SPT N values with Youngs Modulus as set out in CIRIA 143 [19]. The drained (E') and undrained (E_u) Youngs Modulus were derived using the following equations respectively:

$$E'/N = 0.9$$

$$E_u/N = 1.1$$

where N denotes the mean SPT N value, as used in Section 4.4.4.1. The drained and undrained Youngs Modulus values of $2.7kN/m^2$ and $3.3kN/m^2$ are predicted respectively.

Shear Modulus

As part of the SCPTs, shear wave velocity testing was conducted to provide a measurement of small strain shear modulus (G_0) within the TFD deposits. The predicted G_0 with elevation from the SCPTs is presented in Plot B2.22. The following is observed:

- G_0 generally, ranges from 7.5MN/m^2 to 15MN/m^2;
- From 5.5mAOD to 4mAOD G_0 ranges from 3MN/m^2 to 15MN/m^2;
- From 4mAOD to 2mAOD G_0 ranges from 7.5MN/m^2 to 15MN/m$^{2;}$
- Below 2mAOD G_0 increases slightly from 7.5MN/m^2 to 15MN/m^2 (lower bound) and 15MN/m^2 to 40MN/m^2 (upper bound) at -2mAOD.

4.5 Tidal Flat Deposits – Peat

The Tidal Flat Deposit Peat was not encountered in all exploratory holes undertaken on the site's footprint. Peat was shown to intersect bands of clay across the site's footprint, with the most significant thicknesses identified in the south western corner of the site near the Green Lane Overbridge (GL101 to GL107, GL121 to GL123 and M-BH13). This area has a typical peat composition of spongy oxidising to fibrous peat with frequent rootlets. Typically black to brown in colour.

Across the remainder of the site the peat intersecting the clay was typically described as firm clayey fibrous peat becoming slightly sandy organic silty clay, with frequent fragments of plant material (up to 30mm) and wood fragments (up to 20mm). The peat is typically dark brown in colour.

These bands of peat within the clay were encountered from a depth of 0.4mbgl (ST28SW634) to 11.1mbgl (GL102). A typical depth to encounter the peat was 4mbgl. The thickness of the intersecting peat bands ranged from 0.2m to 2m. The intersecting's bands of peat can be seen on Figure 8 to Figure 17. Plots are shown in Appendix B3.

4.5.1 Classification

Natural Moisture Content

The natural moisture content for the TFD peat varies from 32% to 367% with fifteen tests conducted in the material. A mean value for the natural moisture content is derived as 200%. The natural moisture content of the peat varies dramatically. There is potential for low moisture content to be representative of the clay due to the nature of the peat's thin strata thickness. Shown in Plot B3.1.

Atterberg Limits

The natural moisture content of the deposit generally tends towards the liquid limit at varying elevations, shown in Plot B3.2.

BH10 exhibits a moisture content of 367, with a plastic and liquid limit value of 280 and 470 respectively. The test in BH10 was undertaken in what was described as an oxidising clayey fibrous peat, this could be indicative to these high values.

Based on the Plasticity Chart, Plot B3.3, the peat deposit is shown to range from low to extremely high plasticity. No typical cluster can be assumed, it is suggested that the peats variable nature exhibits a large range in plasticity. Due to this, recommended values are not derived. An extended Plasticity Chart; plot of liquid limit against plasticity index is shown in the Plot B3.4.

Particle Size Distribution

Three PSD tests were undertaken in the peat, the content across the tests varies. A typically high fine content can be suggested with a percent ranging from sixty-five to roughly 99% (BH04). See Plot B3.5.

Organic Content

The organic content for the Tidal Flat Deposit Peat ranges from 1.5 – 19%, from three tests. The test result of 1.5% was recorded in BH06 and is described as a very soft clay tending towards a pseudo-fibrous peat becoming organic silty clay. For a peat this value can be deemed as low. This test can be assumed to have been undertaken in TFD Clay. BS5930:2015 [11] indicates the Tidal Flat Deposit Peat can be assumed to be slightly organic to organic under its organic content range. A plot of Total Organic Content for the Peat is shown in the Plot B3.6.

Bulk Unit Weight

Due to the variable nature of the peat, the bulk density ranges from $10.2kN/m^3$ to $18.1kN/m^3$, seen in Plot B3.7. A derived bulk unit weight is calculated as per Craig **Error! Reference source not found.**, a value of $12.4kN/m^3$ is proposed.

It is noted, that a typical occurrence within the plots indicates softer deposits of Tidal Flat Deposits, both clay and peat, present to the east of the site around and underlying Green Lane Overbridge.

4.5.2 Compressibility

Pre-consolidation Pressure

Two recent Oedometer tests was undertaken within the Tidal Flat Deposit Peat, with an additional three from Green Lane Overbridge. Shown in Plot B3.8.

The development of the OCR has been based on the following assumptions:

- Unit Weight of the peat: $12.4kN/m^3$
- Depth of groundwater level: $1mbgl$

With the varying nature of the peat and two oedometer tests undertaken in peat a rough OCR profile is predicted as to vary between 2 and 4.

OCR profiles from CPT data are presented in Section 4.4.2. Distinct peat bands were not readily identified through assessment of the results, other than in SPCT01 and SCPT04. Peat OCRs during this test ranged from 2 to 4 which are in agreement with oedometer testing. However, it is recommended that all the TFD are considered in unison when designing with OCR profiles due to limited data.

Compression Index (C_c) and Compression Ratio (C_c')

The compressibility of normally consolidated soils can be expressed in terms of either compression index C_c or compression ratio C_c'. As per the Tidal Flat Deposit Clay the same relationships and correlations are applied to the Tidal Flat Deposit Peat (See Section 4.4.2).

Based on the two oedometer tests undertaken in the clay, calculated C_c values ranged from 3.15 to 3.17, with an estimated derived value of 3.16. Correlated values for C_c can be derived from a relationship using the liquid limit as proposed by Skempton, presented below (Hobbs) [21]:

$$C_c = 0.009(w_L - 10\%)$$

With the relationships undertaken the following can be observed:

- An estimated C_c' value is equal to 0.4 from the available Oedometer tests undertaken in the peat. A range for C_c' between 0.34 and 0.47 for the oedometer results.
- The C_c' values obtained have been plotted with elevation, in Plot B3.8. No distinct trend is present.
- Correlated values give a derived C_c value of 0.97 far less than the oedometer results. An estimated value for C_c' of 0.12 is derived, less than the oedometer test results.

Recompression Index (C_r) and Recompression Ratio (C_r')

From the two oedometer tests undertaken in the peat only one was unload-reload tested.

An estimated value for the empirical ratio, C_r/C_c, is derived as 0.260 and has been used with the derived C_c value to calculate C_r equal to 0.822 (Terzaghi) [17].

Similarly, it has been assumed that the compression ratio and recompression ratio are related by similar factors, C_r'/C_c' . Using the derived compression ratio, C_c' (presented above), a value of 0.104 was predicted for the recompression ratio C_r'.

4.5.3 Consolidation

Coefficient of Vertical Consolidation (c_v)

The coefficient of consolidation, c_v, obtained from two laboratory oedometer tests for the peat have been plotted and presented in the Plots B3.10 & 3.11.

The plot of c_v with the applied pressure stages, indicates the relationship between the consolidation of the deposit and the applied pressure. The plot suggests that for the peat, with increasing pressure stages the coefficient of vertical consolidation decreases. Due to the varying nature of the peat a large range is present, c_v ranges from an upper bound of 5.0 to a lower bound of 0.1 $m^2/year$.

The plot of elevation with the coefficient of vertical consolidation provides no clear trend. Despite this, between 0 and 100 kPa, a suggested upper and lower bound of 4 $m^2/year$ and 0.5 $m^2/year$, can be inferred. Above a pressure stage of 100kPa, an upper bound of 1.2 $m^2/year$ and lower bound of 0.2 $m^2/year$ can be suggested.

Coefficient of Horizontal Consolidation (c_h)

Of the nine dissipation tests, only one was conducted in peat (SCPT04). A value of 46m^2/year was determined.

Coefficient of Secondary Consolidation (C_{sec})

One oedometer tests recorded the coefficient of secondary consolidation, C_{sec}, at a pressure stage of 200 kPa. The C_{sec} value was equal to 0.028 $m^2/year$.

The coefficient of secondary consolidation can be derived from a relationship, as discussed above, with the moisture content of the sample. The correlated C_{sec} values determined are presented with elevation along with the oedometer determined value. The following can be observed:

- The plot of elevation with C_{sec} arises no clear trend. A cluster of results can be identified between 0.006 to 0.012. an estimated value for C_{sec} can be derived as roughly 0.001. It is noted that there is great variance to this estimated value.

A plot of the coefficient of secondary consolidation with moisture content is presented in Plot B3.12. It is noted that the result obtained from laboratory oedometer testing exhibits a greater moisture content per C_{sec} unit than the derived correlated values.

4.5.4 Strength and Stiffness

4.5.4.1 Undrained Shear Strength

The relationships and correlations undertaken in Tidal Flat Deposit Clay have also been undertaken for the Tidal Flat Deposit Peat.

Standard Penetration Tests

Twenty-one tests were undertaken on the Tidal Flat Deposit Peat across eleven exploratory holes, two of which are from the initial ground investigation. SPT N values ranged from 0 to 10, with a derived N value of 2 as presented on Plot B3.13.

With the mean corrected N value for peat the undrained shear strength can be derived. The derived plasticity index of the Tidal Flat Deposit Peat was 35% and a value of f_1 equal to 4.5 has been adopted. For the mean corrected SPT N value of 2 the corresponding undrained shear strength value is given as $9kN/m^2$. A suggested range for the undrained shear strength obtained for SPT values can be suggested to be between $0kN/m^2$ and $16kN/m^2$. As discussed in Section 4.4.4.1, $N_{60} = N$; SPT correction factor applied.

In-situ Vane Tests

A total of six hand shear vane tests were conducted within the Tidal Flat Deposit Peat. A further three machine vane tests were undertaken.

Vane tests from all investigations undertaken have had a Bjerrum [20] vane correction factor applied to them. The derived plasticity index of 35% a Bjerrum vane correction factor of roughly 0.85 was derived. This correction factor was applied to the field readings as follows:

$$c_u = 0.85c_{u(vane)}$$

The following results for undrained shear strength were observed from the hand vane tests:

- The undrained shear strength ranged from $7kN/m^2$ to $32kN/m^2$, with a mean value of $24kN/m^2$.

The following results for undrained shear strength were observed from the machine vane tests:

- Tests conducted in the peat exhibited higher undrained shear strengths than the hand vane, ranging from $55kN/m^2$ to $63kN/m^2$. Therefore, a mean value for the undrained shear strength was derived as $58kN/m^2$.

Note that strength determinations for the peat have been based on correlations more typically used for clays and are indicative only and reliance should not be placed on them for design.

Undrained Triaxial Tests

Two unconsolidated undrained triaxial tests were conducted in the Tidal Flat Deposit Peat. With values of $10kN/m^2$ (1.1mAOD) to $45kN/m^2$ (-0.5mAOD).

With limited triaxial tests undertaken within the peat, sufficient evidence is not provided to confirm the vane test results.

4.5.4.2 Stiffness

Youngs Modulus

The stiffness of the clay can be determined from the correlation of SPT N values with Youngs Modulus. Using the mean SPT N value for the peat the drained and undrained Youngs Modulus values are predicted as $1.8kN/m^2$ and $2.2kN/m^2$ respectively.

Shear Modulus

Significant bands of peat were not encountered during the CPT investigation. Plot B3.14 presents G_0 with depth for the peat bands encountered. Between 0.5mAOD and -0.5mAOD G_0 for peat ranges from a lower and upper bound of 25MN/m^2 to 40MN/m^2 respectively.

It is recommended that the upper and lower bound ranges for the whole TFD, presented in Section 4.4.5 are adopted in determining characteristic values of G_0 on site.

4.6 Glacial Till

Glacial Till Deposits (GTD) were encountered in the majority of boreholes. Variously comprising very dense coarse to clayey sand and stiff sandy slightly gravelly clay with rare pockets (up to 10mm) of silt and fine sand. Gravel was recorded as subangular to rounded fine to coarse siltstone, sandstone and quartz. The clay is generally reddish brown to greyish brown in colour, with greenish grey silt and light grey sand.

The GTD were encountered from GL to a top depth of 7.5m. In the very north of the site GTD were encountered at shallow depths and encountered beneath the Tidal Flat Deposits to the south and west. Where present, GTD recorded thicknesses were between 0.4m and 5.4m. Parameter plots based on field and laboratory testing are presented in Appendix B4.

[Note the BGS online viewer indicates a Glaciofluvial Deposit located north of the site, hence the presence of Glaciofluvial Deposits is a possibility]

4.6.1 Classification

Natural Moisture Content

Natural moisture content with elevation is presented in the Plot B4.1. The natural moisture content for the GTD varied from 10 to 20% with nine tests conducted in the material. A derived mean value for the natural moisture content is calculated as 16%.

Atterberg Limits

Test	Number of Tests	Min to Max (Derived Lower and Upper bound value)	Mean Value
Plastic Limit	7	14 to 25 (15 to 20)	17
Liquid Limit	7	23 to 38 (23 to 38)	30
Plasticity Index	7	8 to 20 (8 to 20)	13

The Atterberg Limits have been plotted, as shown in Plot B4.2, with elevation and the natural moisture content of the deposit. It is noted that across the elevations the natural moisture content of the deposit tends towards the plastic limit.

Based on GTD Plasticity Chart, presented on Plot B4.3, a range of low to intermediate plasticity range is indicated.

Particle Size Distribution

Twelve PSD tests were undertaken in the GTD. It is suggested that the GTD typical constituents arise a sandy clay silt. A typical percentage fines content can assume to be roughly 50%. It is noted on two instances within BH01, a high gravel content is present, indicative of a Glaciofluvial Deposit. BH02 exhibits strata composed of *"Very loose brown locally clayey fine and medium sand".* This stratum has been characterised as a Glaciofluvial Deposit.

The location of BH01 and BH02 are located to the very north of the site. The closest exploratory holes to the Glaciofluvial Deposit.

Bulk Unit Weight

Due to the difficult of sampling undisturbed granular material, only five bulk densities were derived, as shown on the Plot B4.5. The bulk density ranges from $20.5kN/m^3$ to $22.5kN/m^3$ for the GTD. A derived bulk unit weight is calculated as per Craig **Error! Reference source not found.**, using the mean moisture content value of 16%. Subsequently a proposed value of $21.5kN/m^3$ was derived for the bulk unit weight of the GTD, consistent with the dataset shown on Plot B4.5.

4.6.2 Strength and Stiffness

Shearing Resistance

The peak and constant volume effective angle of shearing resistance for the GTD has been estimated from correlations of BS 8002:2015 [14], presented below:

$$\varphi'_{cv,k} = 30° + \varphi'_{ang} + \varphi'_{PSD}$$

$$\varphi'_{pk,k} = \varphi'_{cv,k} + \varphi'_{dil}$$

Where values of φ'_{ang}, φ'_{PSD}, φ'_{dil} can be obtained from Table 1 of BS 8002:2015 **Error! Reference source not found.**.

The PSD data for the GTD indicate it to be well graded, with a uniformity coefficient, C_U, generally greater than 6. On this basis a value of φ'_{PSD} of 4 is proposed. On the basis of the visual description of the GTD, parameter value for φ'_{ang} of 2 is proposed, due to the general sub-angular to sub-rounded classification (BS EN ISO 14688-2:2018) [23].

The constant volume effective angle of shearing resistance is then derived with the above correlation; $\varphi'_{cv,k} = 36°$.

Following the guidelines of BS EN 1997-2:2007 [24] the parameter, φ'_{dil}, can be derived from the SPT N values obtained for the GTD. As discussed previously, N_{60} values are the same as N. The derived SPT N value of 15 infers a density index, I_D, roughly equal to 50%. Using the above relationship for $\varphi'_{pk,k}$, a peak effective angle of shearing resistance for the deposit of $\varphi'_{pk,k} = 39°$ is proposed.

4.6.2.1 Undrained Shear Strength

Standard Penetration Tests

Twenty-nine tests were undertaken on the GTD across 12 exploratory holes. The following can be observed (Plot B4.6), SPT N values typically ranged from 10 to 75, with an estimated mean N value derived as 15; a derived calculated mean value is equal to 35 but is not representative of the data set. The values are seen to vary with depth with a rough correlation present, as the elevation decreases the SPT N values increase. The mean SPT N values are seen to increase from 8 at 3mAOD to 20 at -2mAOD.

Using CIRIA R143 [19] an estimation of the undrained shear strength parameter can be derived from the relationship presented below:

$$c_u = 5 \times N_{60}$$

Using the derived corrected SPT N value of 15 a mean undrained shear strength value of $75kN/m^2$ is suggested. Similar to Section 4.4.4.1, the corrected SPT N value is equal to the value of N_{60}.

In-situ Vane Tests

Sixteen hand vane tests were undertaken with the GTD. undrained shear strength varies from $22kN/m^2$ to $120kN/m^2$. A mean value of $65kN/m^2$ was derived. These values are uncorrected.

Five Machine tests were undertaken in the GTD. The corrected undrained shear strength ranged from 24 kN/m^2 to $80kN/m^2$. (Note that for the upper value obtained from the machine vane, the recorded value was given as $> 80kN/m^2$).

Quick Undrained Triaxial Tests

Across two boreholes three tests were undertaken in the GTD. Undrained shear strengths were $69kN/m^2$, $78kN/m^2$ and $160kN/m^2$. This broadly corroborates the results obtained from the vane tests

4.6.2.2 Stiffness

Young Modulus

The drained Youngs Modulus, E', for the Glacial Till Deposit was derived, as set out in CIRIA R143 [19], using the empirical relationship between SPT N values and Drained Youngs Modulus presented below:

$$E' = [0.5 - 2] \times N_{60}$$

Based on the above correlation applying a factor of 1.25 and the estimated derived SPT N value, a value for the drained Youngs Modulus is suggested to be 10 MN/m^2 at 3mAOD to 25 MN/m^2 at -2mAOD.

4.7 Undifferentiated Bedrock of St Maughan's Formation and Mercia Mudstone Group

The bedrock is typically described as an extremely weak to very weak mudstone and sandstone or a ver**y** st**i**ff clay, with components of gravel and lithorelicts of extremely weak mudstones. It is typically reddish brown to dark reddish brown in colour.

The bedrock was typically encountered at depths of 6mbgl to a maximum recorded depth of 15.0mbgl (GL101). The thickness of the bedrock is undefined across the sites footprint, the greatest recorded thickness is recorded as 24.7m in the vicinity of Green lane Overbridge, (GL105). The bedrock surface elevation is presented on Figure 6. Plots shown in Appendix B5.

4.7.1 Classification

Natural Moisture Content

The natural moisture content for the bedrock, can be seen to vary from a lower bound of 10% to an upper bound of 20%. Seventeen tests were conducted in the bedrock, an estimated mean natural moisture content was derived as 15. The natural moisture content with elevation is shown in Plot B5.1.

Atterberg Limits

Test	Number of Tests	Min to Max (Derived Lower and Upper bound value)	Mean Value
Plastic Limit	13	14 to 24 (14 to 16)	16
Liquid Limit	13	19 to 46 (23 to 30)	29
Plasticity Index	13	8 to 22 (8 to 15)	12

Atterberg Limits were plotted with elevation, shown in Plot B5.2. The natural moisture content for the bedrocks are shown to typically tend towards their plastic limit, a clear indication of the consolidation undertaken in the material.

Based on the bedrocks Plasticity Chart, Plot B5.3. it is suggested that the bedrock conforms to a lower plasticity range.

Particle Size Distribution

Seven PSD tests were undertaken in the bedrock. It is noted that six of the seven tests were undertaken at Green Lane Overbridge. A general composition for the strata indicates a fine percentage of 60%, with a 15% gravel content. The be classified as a silty gravelly sand. This classification can be indicative of the weathered surface of the bedrock. The PSD tests are shown in Plot B5.4.

Bulk Unit Weight

From laboratory testing, values for the bedrocks bulk unit weight were determined, as shown in Plot B5.5. A clear trend is present with the bulk unit weight values derived within the bedrock, it can be noted that as the elevation decreases the bulk unit weight increases.

It is suggested from Plot B5.5 a weathered band of bedrock is inferred above -5mAOD. In this weathered band, a lower bound of $21kN/m^3$ and an upper bound of $22kN/m^3$ are suggested. Below -5mAOD, the bedrock can be assumed to be moderately weathered, exhibiting a lower and upper bound of $23kN/m^3$ and $26kN/m^3$ respectively. BS 8002:2015 [14] suggests a range of values for the bedrock of $21kN/m^3$ to $24kN/m^3$ below the groundwater table.

4.7.2 Strength and Stiffness

4.7.2.1 Undrained Shear Strength

Standard Penetration Test

One hundred and twenty-eight SPT tests were undertaken on the bedrock. The SPT N values with elevation plot is shown in Plot B5.6. and capped at an SPT N value of 300. The following can be observed:

- As the elevation for the bedrock decrease the SPT N value increases.
- From an elevation of -5mAOD upwards, a derived lower bound for the SPT N values is suggested as $N = 20$.
- Below an elevation of -5mAOD, a derived lower bound for the SPT N values is suggested as $N = 60$.
- Some instances exhibited SPT N values exceeding 300. BH07 exhibited values of N = 6000 at several elevations

The undrained shear strength can be derived for bedrock based on the relationship between corrected SPT N values and the undrained shear strength proposed by Stroud as presented in CIRIA C570 [25]. The relationship is as follows:

$$2c_u = f_1 N_{60}$$

A value of f_1 equal to roughly 7 has been adopted from the bedrock's derived plasticity index of 12%. The undrained shear strength for the formation can be derived:

- The derived lower bound for the undrained shear strength from an elevation of -5mAOD and above is equal to $70kN/m^2$.
- The derived lower bound for elevations below -5mAOD is equal to $210kN/m^2$.
- An N value of 300 corresponds to an undrained shear strength of $1050kN/m^2$. BH07 exhibits an undrained shear strength of $21MN/m^2$ across several elevations

The classification of the bedrock recommendations is presented in BS5930:2015 [11]. The suggested lower bounds are classified as extremely weak to very weak rock with instances of moderately weak tending towards moderately strong bedrock found in BH07 (BS EN ISO 14689:2018)[26]. Based on this, the above correlation is considered reasonable as at higher elevations; (-5mAOD and above) the bedrock exhibits weathered characteristics.

4.7.2.2 Stiffness

Youngs Modulus

As set out in CIRIA C570 [25] 66the relationship of SPT N values with Youngs Modulus has been used to determine the drained stiffness of the Mercia Mudstone, in the form:

$$E'/N_{60} = 1$$

Where E' is the drained Youngs Modulus. For the bedrock of the Mercia Mudstone Group the drained Youngs Modulus equates to the value of the mean SPT N value

The drained Youngs Modulus is therefore calculated for the two lower bounds provided above, the following can be observed.

- The derived lower bound for the drained Young's modulus from an elevation of -5mAOD and above is equal to $70kN/m^2$.
- The derived lower bound of the drained Youngs modulus for elevations below -5mAOD is equal to $210kN/m^2$.

4.8 Groundwater

4.8.1 Groundwater Strikes

Groundwater strikes were recorded during the completed investigations, with the majority recorded in the Cardiff Parkway Initial Ground Investigation 2019 [9] and a single water strike recorded during the GRWM 2016 [4] investigations. The groundwater strikes are summarised in **Table 4**. The groundwater strikes were recorded at relatively shallow depth, between 1 and 2.2mbgl, typically 3-4mAOD.

The low permeability of the Tidal Flat Deposit clays means that it is unlikely that groundwater seepages during drilling would be observed. It is likely that the encountered water strikes are associated with bands/ pockets of more permeable peat or sandy layers.

Table 4 – Summary of Groundwater Observations

BH	Ground Water Observation	Strata
BH01	GW strike at 1.65m depth (3.75mAOD); rose to 1.6m depth (3.80mAOD) after 20 minutes	Tidal Flat Deposit – Clay
BH02	GW strike at 1.2m depth (3.90mAOD); (no rise)	Tidal Flat Deposit – Clay
BH04	GW strike at 1.2 depth (3.90mAOD); rose to 1.1m depth (4mAOD) after 20 minutes	Tidal Flat Deposit – Clay
BH05	GW strike at 1.65m depth (3.85mAOD); rose to 1m depth (4.50mAOD) after 20 minutes	Glacial Till Deposit
BH06	GW strike at 2.2m depth (3.1mAOD); rose to 1.6m depth (3.7mAOD) after 20 minutes	Tidal Flat Deposit – Clay
BH07	GW strike at 2m depth (3.05mAOD); rose to 1.2m depth (3.85mAOD) after 20 minutes	Tidal Flat Deposit – Clay
BH08	GW strike at 1.2m depth (4mAOD); rose to 1m depth (4.2mAOD) after 20 minutes	Tidal Flat Deposit – Clay & Peat
BH09	GW strike at 1.1m depth (4mAOD); (no rise)	Tidal Flat Deposit – Clay
BH11	GW strike at 2m depth (2.75mAOD); rose to 1.2m depth (3.55mAOD) after 20 minutes	Tidal Flat Deposit – Clay & Peat
M-BH15	GW strike at 1m depth (4.3mAOD); rose to 0.5m depth (4.8mAOD) after 20 minutes	Made Ground

4.8.2 Groundwater Monitoring

The results of the groundwater monitoring show groundwater to be present typically approximately 1mbgl (on average at between 4 and 4.4Mod) with a slight hydraulic gradient towards the south east, with the average piezometric head difference of approximately 0.3m between the north of the site (BH01 and BH02) and the south east of the site (BH07 and BH08). No significant difference has been observed in the monitored water levels between the shallow and deep response zones suggesting hydraulic continuity between the monitored strata. It is assumed that the groundwater is in continuity with the water in the reens. Groundwater monitoring is summarised in **Table 5** below.

Table 5 – Summary of Groundwater Monitoring

BH	Response Zone (mbgl)	Strata	Ground Level (Mod)	Average water level (Mod)
BH01	0.3 – 2.0 (19mm)	Tidal Flat Deposit – Clay	5.4	4.4
	6.7 – 8.0 (50mm)	Undifferentiated Bedrock	5.4	4.3
BH02	0.5 – 2.0 (19mm)	Tidal Flat Deposit – Clay	5.1	4.3
	4 – 5 (50mm)	Glaciofluvial Deposit	5.1	4.4
BH03	0.3 – 2.0 (19mm)	Tidal Flat Deposit – Clay/ Glacial Till Deposit	5.5	4.4
	4.7 -6.0 (50mm)	Glacial Till Deposit	5.5	4.0
BH04	0.5 – 6.0 (19mm)	Tidal Flat Deposit – Clay/ Glacial Till Deposit	5.1	4.2
	11 – 12 (50mm)	Undifferentiated Bedrock	5.1	4.2
BH05	0.5 – 1.5 (19mm)	Tidal Flat Deposit – Clay & Peat	5.5	4.6
	2.7 – 4.0 (50mm)	Glacial Till Deposit	5.5	4.3
BH06	0.3 – 2.5 (19mm)	Tidal Flat Deposit – Clay	5.3	4.4
	3.7 – 5.0 (50mm)	Undifferentiated Bedrock	5.3	4.1
BH07	0.5 – 7.0 (19mm)	Tidal Flat Deposit – Clay	5.1	4.0
	10.5 – 11.5 (50mm)	Undifferentiated Bedrock	5.1	4.0
BH08	0.5 – 6.0 (19mm)	Tidal Flat Deposit – Clay & Peat	5.2	4.0
	8.5-9.5 (50mm)	Glacial Till Deposit	5.2	4.0
BH09	0.4 – 2.0 (19mm)	Tidal Flat Deposit – Clay	5.1	4.3
	9.7 – 11.0 (50mm)	Undifferentiated Bedrock	5.1	4.2
BH10	0.5 – 2.5 (50mm)	Tidal Flat Deposit – Clay & Peat	5.4	4.4

4.9 Encountered Contamination

The following **Table 6** lists the observations for contamination that were made during the investigation.

Table 6 – Contamination Observation

Exploratory Hole	Depth (mbgl)	Strata	Observation
GL105 (2015)	GL	Made Ground	Glass encountered at surface.
GL121 (2015)	GL	Made Ground	Frequent fragments of tyres, metal and plastic bags.
M-BH13 (2015)	0.4	Made Ground	Glass, slag and coal encountered.

The locations discussed in the above table, indicate contamination present across and underlaying Green Lane Overbridge, located along a road running adjacent to the eastern boundary. No Made Ground was encountered across the site's footprint, except from Green Lane Overbridge.

No visual evidence of hydrocarbons was made during the 2019 ground investigation [9] as well as the 2016 GWRM [4] and 2015 Green Lane Overbridge ground investigation [5].

Made ground is present at ground level across three ground investigations, CPT01/VS01 , CPT05/VS05 and TP05. Whilst the descriptions do not indicate direct contaminants, it is noted that the material has been categorised as made ground and exhibits the risk of potential contamination. It is suggested that the made ground is a product of maintenance/expansion work on the current railway corridor and embankment.

As noted in Section 2.2, rubble/fill has been used within the site to form a tractor track, following the alignment of the gas main east to west. The composition of the rubble is unknown and may be a potential source of contamination particularly asbestos.

4.9.1 Evidence of Contamination

Whilst not directly linked to contamination, it is noted that in an exploratory hole, a strong organic odour was encountered in the Tidal Flat Deposit Clay. At a depth of 3.8mbgl (TP09) with a thickness of 0.3m albeit undefined.

It is additionally noted that in two exploratory holes, a strong organic odour was encountered in the Tidal Flat Deposit Peat. At depths ranging from 1.5mbgl (TP05) to 5.1mbgl (BH10), with a thickness ranging from 1.5m to 0.2m.

4.10 Concrete Aggressivity

A total of twenty-nine samples were tested based on the guidance, for a greenfield site, given in BRE Special Digest [27] to determine the required concrete classes. The Design Sulphate Class (DS) was determined, which then followed through to give an Aggressive Chemical Environment for Concrete Class (ACEC).

Sixteen samples of cohesive Tidal Flat Deposits (Clay) were assessed as natural ground not containing pyrite (Section C5.1.1 of [27]). The characteristic water-soluble value determined from the average of the highest two values was 753mg/l. This corresponds to a Design Sulphate Class of DC-2.

Three samples of peat were tested and assessed as natural ground not containing pyrite (Section C5.1.1 of [27]). The characteristic water-soluble value was determined from the highest two results was 470mg/l. This corresponds to a Design Sulphate Class of DS-1.

Four samples of Glacial Till Deposits were tested and assessed as natural ground not containing pyrite (Section C5.1.1 of [27]). The characteristic water-soluble value was determined from the highest two results was 110mg/l. This corresponds to a Design Sulphate Class of DS-1.

Six of the weathered Mudstone were assessed as natural ground containing pyrite, given that Mercia Mudstone is reported as being pyrite-bearing (Section C5.1.3 of [27]). The average oxidizable sulphides were <0.3%, hence pyrite is unlikely to be present. The characteristic water-soluble value determined from the highest two results was 40.5mg/l. This corresponds with a Design Sulphate Class of DS-1.

The summary of the concrete class for buried concrete has been determined as follows:

- Tidal Flat Deposits (Clay): DS-2, AC-2;
- Tidal Flat Deposits (Peat): DS-1, AC-1;
- GTD's: DS-1, AC-1;
- Weathered Bedrock: DS-1, A

4.11 Summary of Geotechnical Parameters

Presented in **Table 7**, below, is a summary of the geotechnical parameters identified through Section 4. Lower and Upper bounds are presented when available, and the suggested mean is presented within brackets when available.

Table 7 – Summary of Geotechnical Parameters

Geological Strata		Geotechnical Parameter																
		Classification						Compressibility			Consolidation			Strength and Stiffness				
		Natural Moisture Content	Atterberg Limits			Organic Content	Bulk Unit Weight	Compression Ratio	Recompression Ratio	Swelling	Coefficient of Vertical Consolidation	Coefficient of Horizontal Consolidation	Coefficient of Secondary Consolidation	SPT N value	Undrained Shear Strength	Constant Volume Angle of Shearing Resistance	Youngs Modulus	Shear Modulus
			Plasticity Index	Plastic Limit	Liquid Limit													
		%	%	%	%	%	kN/m²	–	–	–	m²/year	m²/year	m²/year	–	kN/m²	kN/m²	kN/m²	kN/m²
Made Ground (Green Lane Overbridge)		6 - 48 (18)	37	28	65	–	–	–	–	–	–	–	–	4 - 21 (10)	–	–	–	–
Tidal Flat Deposit - Clay	**Desiccated Crust "Firm"**	30 - 70 (50)	15 - 40 (32)	23 - 35 (26)	55 - 70 (58)	0.75 - 2.5 (1.5)	15.5 - 18.5 (16.5)	0.07 - 0.91 (0.35 - 0.37) Oedometer Interpretation: (0.35)	0.020 - 0.174 (0.097)	-0.03	See plot	5 - 20	0.004 - 0.007	4 - 11	58 - 117 (70)	22 - 24	2.7 - 3.3	3 - 15
	"Soft to Very Soft" Clay												0.005 - 0.014	0 - 15 (3)	6 - 59 (20)			7.5 - 40
Tidal Flat Deposit - Peat		32 - 367 (200)	–	–	–	1.5 - 19	10.2 - 18.1 (12.4)	3.15 - 3.17 (3.16)	(0.822)	–	See plot	–	0.006 - 0.012 (0.001)	0 - 10 (2)	0 - 63	–	1.8 - 2.2	25 - 40
Glacial Till Deposit		10 - 20 (16)	8 - 20 (13)	15 - 20 (17)	23 - 38 (30)	–	20.5 - 22.5 (21.5)	–	–	–	–	–	–	10 -75 (15)	65 - 160 (75)	(36)	10 - 25	–
Undifferentiated Bedrock of St Maughan's Formation and Mercia Mudstone Group	**Weathered**	10 - 20 (15)	8 - 15 (12)	14 - 16 (16)	23 - 30 (29)	–	21 - 22	–	–	–	–	–	–	Lower Bound: 20	Lower Bound: 70	–	–	–
	Moderately Weathered						23 - 26							Lower Bound: 60	Lower Bound: 210			

5 Contamination Assessments

The desk study [1] identified that Made Ground (close to the railway and in discrete areas of the site) may be a potential source of contamination and peat, within the tidal flat deposits, may be a potential source of ground gas, particularly methane. A sampling and monitoring strategy was employed to inform on these risks and is assessed in the following sections.

5.1 Conceptual site model

The conceptual site model presented in the Cardiff Parkway Desk Study [1] has been reviewed and revised based on the findings of the ground investigation. It is presented in **Table 8** below.

Table 8 – Pollutant Linkages for the Cardiff Parkway Site

Source	Pathway	Receptor
Made Ground		
A significant thickness of Made Ground (up to 7.9m) was encountered in the area of Green Lane Overbridge (likely to be the embankment for the bridge). (approximately 40m northwest of the site)	There is potential that contaminants in this material become airborne as dust or vapour, or there could be dermal contact with the material should it be excavated	As this material is offsite, it is not anticipated to be excavated as part of this project and therefore identified receptors within the are unlikely to be exposed to potential contamination within this material.
	The contaminants could mobilise in infiltrating water or overland flow.	There is a potential that this material may already be affecting the nearby reen.
Approximately 0.5m of Made Ground was encountered beneath the rest of Green Lane.	This material is not going to be excavated and is beneath the road surface. As this material is beneath the road surface (cutting off infiltration) and above the water table contaminants is unlikely to mobilise.	No receptor identified
Discrete areas of Made Ground from across the site (i.e. access tracks)	If excavated there is potential that contaminants in this material become airborne as dust or vapour, or there is direct contact with a construction worker.	If excavated construction workers may be exposed to potential contamination. As the site is to be raised, site end users will not be exposed.
	The contaminants could become mobilised by rain or groundwater water infiltration or surface run-off.	Groundwater and surface water (reens).

Source	Pathway	Receptor
Peat		
Layers of peat within the tidal flat deposits are a potential source of methane gas.	This gas is expected to be dissolved with the groundwater body. Migration is likely to be due to groundwater movement and the slow diffusion of the dissolved gas through the waterbody. Potential new pathways for gas migration include vertical migration along piled foundations or band drains and/or horizontal migration through service corridors.	Short term: Construction workers when within excavations/confined spaces. Long term: Any person in a confined space i.e. maintenance workers at the railway station or commercial buildings The general public in open spaces are unlikely to be affected due to the gases dispersing into the atmosphere and therefore not forming hazardous concentrations.

5.2 Human health risk assessment

Aside from the "*Reddish brown sandy clayey angular to sub rounded fine to coarse sandstone and rare mudstone gravel"* encountered in TP05 from 0 – 0.3mbgl and the occasional brick being encountered in the topsoil, no Made Ground was encountered. Made Ground is anticipated to underlie the access tracks shown on Figure 2 and Figure 3, and in the vicinity of the underground services. The rest of the site is underlain by natural deposits comprising tidal flat deposits. The railway embankment that bisects the site was not investigated as part of this ground investigation but will comprise made ground and is a potential source of contamination.

The site ground level is to be raised in development areas as part of the flood defence measures. This will require placement of by approximately 1m of materials and therefore there will be no viable pathway between the in-situ materials and the site end user. If excavated, construction workers might be exposed to contamination arising from this material. However, based on the description and constituents of the material, the proposals to raise the site (i.e. not excavate the material), standard health and safety procedures during construction would be considered sufficient. As such, no soil samples were sent for chemical analysis to inform on the risk posed to human health.

During construction should any potentially contaminated material be encountered this material should be sampled and tested at the earliest opportunity to inform on the risk posed to construction workers. Any import of materials or reuse of Made Ground materials during construction will require validation testing.

5.3 Controlled Waters Risk Assessment

5.3.1 Methodology

Potential pollution risks to controlled waters have been assessed using the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 [28] and screened against results for inland surface water environmental quality standards (EQS).

The identified receptors comprise groundwater and surface water. Due to the ground generally comprising materials of low permeability, surface water features such as the reens are considered the primary controlled water receptor. The reens are distributes throughout the site and along the boundaries as shown on Figure 3. In line with the above mentioned guidelines the groundwater and leachate results have been initially screened against the Environmental Quality Standards (EQS) for freshwater and Minimum Reporting Values (MRVs) to identify potential contaminants of concern.

EQS values for cadmium vary based on the hardness (as $CaCO_3$) of the water in question. Hardness concentrations from samples taken from the groundwater ranged between 126mg/l and 429mg/l and typically between 200 and 300 mg/l. Consequently, the EQS values for a hardness of 100 - 200mg/l (class 4) have been used in the screening assessment.

The 2015 EQSs [28] for lead, copper, nickel and zinc pertain to bioavailable concentrations of the substances. The calculation of the bioavailable levels requires the concentration of calcium and Dissolved Organic Carbon (DOC) to be known. The bioavailable concentrations have been calculated using the Metal Bioavailability Assessment Tool (M-BAT) [29]

5.3.2 Soil quality assessment

As discussed in Section 6.2 above, no sources of potential contamination were encountered during the 2019 Cardiff Parkway Initial Ground Investigation. Therefore, soils within the scheme area are unlikely to pose a significant risk to the water environment. In order to ensure that the proposed development does not have a detrimental impact on controlled waters, any importation of materials or reuse of Made Ground materials during construction will require validation testing.

5.3.3 Groundwater quality assessment

Three rounds of groundwater sampling and analyses have been undertaken as part of the 2019 ground investigation. As presented in **Table 5** of Section 4.8, monitoring installations were placed within the superficial and bedrock strata. The monitoring results indicate that the groundwater is in hydraulic continuity between bedrock and superficial deposits and therefore for the purpose of this assessment will be considered as a single water body.

Typically, the samples recorded no evidence of contamination, however six samples did record some elevated concentrations above the applied criteria as summarised in **Table 9**.

Metals: Boreholes BH01, BH02 and BH06 recorded slight exceedances of the EQS for bioavailable copper (BH01) or cadmium (BH02 and BH06). No potential source of cadmium or copper have been identified. Considering the groundwater flow to be generally from north to south, the measured slightly elevated concentrations of copper and cadmium are likely to be representative of groundwater background concentrations.

Petroleum hydrocarbons: Aliphatic TPHs were recorded in significant concentrations in one sample from BH05 in Round 1, which has a response zone in the glacial till deposits at 2.7 – 4.0mbgl. Heavy aliphatic hydrocarbons, primarily comprising of carbon range C21 to C35, where measured on one occasion at 2100 ug/l. This may indicate the presence of lubricating oils. However, no evidence of hydrocarbon contamination was recorded by the Contractor and no source or pathway for fuel to be found in the groundwater of the glacial till deposits has been found. No petroleum hydrocarbons were measured above the laboratory level of detection of 10ug/l in subsequent rounds or in any other monitored well. No petroleum hydrocarbons were detected within any monitored surface water location. Therefore, petroleum hydrocarbons are not considered of concern with respect to controlled waters.

Phenols: Phenols were detected in a concentration substantially above the EQS on one occasion (BH10 in Round 2). Phenols are organic compounds typically associated with gas works but are also found in herbicides. Borehole BH10 is located in a close proximity to the railway line that crosses the site in the southern part. Herbicides may have been used as part of the track maintenance. The elevated concentration may be a result of a herbicide spillage or leakage, which may have migrated to the shallow groundwater. No phenols were measured above the laboratory level of detection in other rounds of sampling and testing or any other well. No phenols were detected in any of the monitored surface water location. Therefore, phenol is not considered to be of concern with respect to controlled waters.

Table 9 – Groundwater Results that are potentially indicative of contamination

			BH01	BH01	BH02	BH05	BH06	BH10
			R1	R2	R3	R1	R1	R2
		Date	01/08/2019	28/08/2019	12/09/2019	30/07/2019	01/08/2019	27/08/2019
		Response zone depth:	6.7 – 8.0	6.7 – 8.0	4.0 – 5.0	2.7 – 4.0	3.7 – 5.0	0.5 – 2.5
	Units	**AA-EQS Inland surface waters**	SMF	SMF	TFD	GTD	GTD/SMF	TFD
Total Phenols (monohydric)	µg/l	7.7	< 10	< 10	< 10	< 10	< 10	48
Cadmium	µg/l	0.15	0.03	< 0.02	0.17	< 0.02	0.16	< 0.02
Bioavailable Copper	µg/l	1	1.60	1.03	0.38	0.06	0.37	0.01
TPH-CWG - Aliphatic >C12 - C16	µg/l	300*	< 10	< 10	< 10	24	< 10	< 10
TPH-CWG - Aliphatic >C16 - C21	µg/l	-	< 10	< 10	< 10	95	< 10	< 10
TPH-CWG - Aliphatic >C21 - C35	µg/l	-	< 10	< 10	< 10	1700	< 10	< 10
TPH-CWG - Aliphatic >C35 - C44	µg/l	-	< 10	< 10	< 10	300	< 10	< 10
TPH-CWG - Aliphatic (C5 - C35)	µg/l	-	< 10	< 10	< 10	1800	< 10	< 10
TPH-CWG - Aliphatic (C5 - C44)	µg/l	-	< 10	< 10	< 10	2100	< 10	< 10

SMF = St Maughan's Formation, TFD = Tidal flat deposits, GTD = Glacial till deposits
* - WHO guide values for TPHCWG fractions in drinking water
= results indicative of potential contamination (shaded cells: Total Phenols BH10; Cadmium BH02, BH06; Bioavailable Copper BH01 R1, BH01 R2; TPH-CWG >C16–C21, >C21–C35, >C35–C44, C5–C35, C5–C44 BH05)

5.3.4 Surface water quality assessment

Eight rounds of surface water sampling and analyses have been undertaken from five locations shown on Figure 3 between 12th June and 124th September 2019.

In general, the analyses of the surface water samples show no evidence of contamination, with exception of isolated exceedances of zinc.

Two samples (SW1 and SW2, refer to Figure 3 for location), both taken on August 15th (Round 5) recorded elevated concentrations of zinc. These results are shown in **Table 10** below. Sampling points SW1 and SW2 are located on or very close to the site boundary and are monitoring water flowing into the site. A potential source for the elevated zinc concentration has not been identified. No other exceedances have been recorded. Therefore, zinc is not considered of concern.

Table 10 – Summary of Exceedances of Applied EQS for Surface Water Samples

	Sample location	**AA-EQS Inland surface waters (mg/l)**	**SW1**	**SW2**
	Date		**15/08/2019**	**15/08/2019**
	Round		**5**	**5**
Zinc (dissolved)	µg/l		56.00	99.00
Bioavailable zinc	µg/l	13.1	19.78	34.26

= results indicative of potential contamination

5.4 Ground gas monitoring

A note on the proposed strategy for ground gas monitoring was issued in July 2018 to Cardiff Council [30]. It presents a conceptual site model that, based on the encountered ground conditions, is still considered accurate and is summarised below.

5.4.1 Sources

Layers of peat or organic clay present within the tidal flat deposits are considered the primary source of ground gas, particularly methane. Due to the shallow groundwater level (~1mbgl), gases originating from sources within the tidal flat deposits are likely to be dissolved in the groundwater. Gaseous forms are only likely above the water table.

5.4.2 Receptors

As shown in **Table 8**, receptors include construction/maintenance workers, particularly if working in confined spaces or excavations, or end site users including workers or members of the public within on-site buildings.

5.4.3 Pathways

As stated above, the original source of ground gas is anticipated to be the tidal flat deposits, but much of this is likely to have dissolved within the groundwater, meaning that the groundwater itself is also a potential source of ground gas. The dissolved gas migrates, through diffusion within the groundwater or due to the movement of the groundwater itself. Both are anticipated to be slow due to the impermeable nature of the tidal flat deposits. In the site current state vertical migration of gas is considered insignificant. This is supported by lack of evidence of vegetation destress at surface at the site, which is a typical indication of methane presence at shallow depth [31].

Exsolution (or degasification) of the dissolved gas from groundwater will occur at the boundary of the saturated and unsaturated zones. Migration within the unsaturated environment, which is the top 1-2m of the surface of the site including 0.5 -1 m of ground comprising a desiccated crust of TFD, and later post development, within the imported fill, including the drainage blanket, would be driven by hydrodynamic flows and gas pressure variations. A pressure gradient would be generated from natural fluctuations in atmospheric pressure or in the elevation of groundwater. No significant variations in groundwater level are expected considering the nature of the Levels and therefore the flows would be primarily driven by changes in atmospheric pressure. However, considering the low permeability of the TFD gas flux at surface from these deposits is likely to be insignificant. The presence of impermeable barriers like tarmac or concrete post development would inhibit upward migration of the gas, if any, and therefore lateral migration within the crust and overlying fill materials to a point or area of emergence would occur e.g. soft landscaped areas, service corridors, infrastructure.

Higher rates of gas migration could occur if more permeable pathways for gas migration are created for example boreholes, band drains or piled foundations. As a result of degradation processes associated with peat, the groundwater may be oversaturated with ground gas relative to the atmospheric conditions, meaning that if suddenly exposed to atmospheric conditions (i.e. by a borehole/pile/band drain etc.) it would result in a sudden release of gas. However, due to the impermeable nature of the ground it is likely that after an initial spike in gas emissions, flow rates will return to low levels.

5.4.4 Gas Monitoring Strategy

Six rounds of fortnightly gas monitoring from each of the standpipes was undertaken between 16th July and 24th September 2019. The results of which are included in Appendix D.

Shallow response zones (up to 2.5mbgl) have been installed to monitor the near ground surface to establish baseline conditions. Other installations have been installed to reflect band drain installation conditions, with the response zone to extend from within 0.5m of ground level to the base of the tidal flat deposits. Deeper short installation were installed primarily for groundwater monitoring, but have been also been monitored for gas. [30]

Atmospheric Pressure

The monitoring has been undertaken during periods of rising and falling atmospheric pressure, as summarised in **Table 11** below.

Table 11 - Monitoring Dates and Recorded Atmospheric Pressure Conditions

Monitoring Date	Monitoring Round	Atmospheric Pressure Trend*
16th July 2019	1	Falling
17th July 2019	1	Falling
18th July 2019	1	Stable
30th July 2019	2	Stable
31st July 2019	2	Rising
01st August 2019	2	Stable
14th August 2019	3	Falling
23rd August 2019	4	Falling
10th September 2019	5	Rising
11th September 2019	5	Stable
23rd September 2019	6	Stable
24th September 2019	6	Stable

Note: * Based on half-hourly atmospheric pressure measurements recorded by Cardiff Airport Weather Station.

Groundwater Levels

As mentioned in Section 4.9, the onsite groundwater level is typically about 1mbgl meaning many of the response zones were completed flooded. In this scenario, the standpipe will provide a pathway for dissolved gases to reach the surface (similar to that described in the pathways section above). Standpipes with response zones across the whole thickness of the tidal flat deposits is to reflect the gas migration pathway of a band drain. Monitoring installations targeting deeper strata like glacial deposits or bedrock, were primarily installed to monitor and sample groundwater and are not reflective of a potential gas migration pathway. Nevertheless, these standpipes were monitored for ground gas as a precaution.

5.4.5 Baseline Gas Monitoring Results

On each monitoring visit to a given standpipe eight gas readings were taken over a two-minute period. The final reading has been taken to represent the stable gas conditions, as there is potential that gases may have accumulated within the capped standpipe.

Shallow Installations

Shallow response zones from seven boreholes have been monitored to establish baseline ground gas conditions. The results of which are summarised in **Error! Reference source not found.**.

Carbon dioxide

Carbon dioxide was typically recorded between 0 and 6.5% v/v but was recorded up to 11.1% (BH05).

Methane

Methane was not detected in any of the standpipes from any of the monitoring rounds, including those where the response zone crosses peat.

Oxygen

Oxygen concentrations recorded in the shallow standpipes of BH01, BH02 and BH05 typically ranged between 20% and 22%, which is typical with atmospheric oxygen concentrations being approximately 21%. The oxygen concentrations recorded in the shallow standpipes of BH03, BH06, BH09 and BH10 were often substantially lower (as low as 0%). The reason for such low levels of oxygen is unclear but seems to correlate with when higher carbon dioxide concentrations were recorded. No evidence of contamination was observed in this location and the measured ground gas concentrations are not considered significantly elevated.

Carbon monoxide

Carbon monoxide was not detected in any of the gas monitoring rounds.

Hydrogen Sulphide

No hydrogen sulphide was detected in any of the monitoring installations.

Volatile Organic Compound

VOC's were typically recorded in concentrations of less than 6ppm but were recorded in concentrations higher than this on six occasions with concentrations up to 105.1ppm.

Flow

Gas flow rates were typically 0l/hr. Four out of the 42no. monitoring visits recorded positive gas flow rates, ranging from 1.5l/h to 3l/h. Two of the elevated readings were taken on 14th August and two on 23rd August. Both of these days were recorded during falling atmospheric pressures.

Table 12 - Summary of Gas Monitoring Results from Shallow Response Zones

	BH01	BH02	BH03	BH06	BH09	BH05	BH10
Response zone depth	0.3 - 2.0 (19mm)	0.5 – 2.0 (19mm)	0.3 – 2.0 (19mm)	0.3 – 2.5 (19mm)	0.4 – 2.0 (19mm)	0.5 – 1.5 (19mm)	0.5 – 2.5 (50mm)
Stratigraphy	TFD	TFD	TFD/GTD	TFD	TFD	TFD with peat	TFD with peat
Water level (mbgl)	0.8 – 1.4	0.5 – 1.2	0.1 – 1.5	0.6 – 1.4	0.5 – 1.2	0.4 – 1.3	0.5 – 1.3
	Typical range	Typical range	Typical range	Typical range	Typical range	Typical range	Typical range
Carbon Dioxide (%)	0 – 0.2	0 – 0.1	3.1 – 5.6	0 – 3.7	0 – 4.8 (two high values of 9.8 and 11.1)	0 – 6.5	0.8 – 5.5
Methane (%)	0	0	0	0	0	0	0
Oxygen (%)	20 – 21.1	20 – 21.5	0 – 8.6	11.4 – 21.7	0.3 – 21.4	20.3 – 21.3 (one value of 3.3)	5.3 – 18.9
LEL (%)	0	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0	0
VOC (ppm)	0 – 0.8	0 – 0.1	0 – 0.9 (two high concentrations of 63 and 51)	0 – 0.8	0 – 4 (one value of 18.4)	0 – 0.3 (one value of 9)	0 – 5.9 (two high concentrations of 105.1 and 52.1)
Gas flow ltr/hr	0	0	0 (one high flow rate of 15.4)	0 (one high flow rate of 3)	0 (one high flow rate of 1.5)	0 (one high flow rate of 1.5)	0

Long Installations - Band Drain Representative Gas Monitoring Results

Three installations have been installed to represent that potential migration pathway created by a band drain (BH07, BH08 and BH04). These response zones extend from 0.5mbgl to the base of the tidal flat deposits. The results are summarised in **Error! Reference source not found.**.

Carbon Dioxide

Carbon dioxide ranged between 0% and 5.1% v/v.

Methane

Methane was not detected in any of the standpipes from any of the monitoring rounds, including in BH08 where the response zone crosses peat.

Oxygen

Values in BH07 and BH08 ranged between 17.2 and 21.3% v/v. Lower concentrations were recorded in BH04, ranging between 10.3 and 20.4% v/v. The reason for depleted levels of oxygen is unclear. No evidence of contamination was observed in this location and the measured ground gas concentrations are not considered significantly elevated.

Hydrogen sulphide

No hydrogen sulphide was detected in any of the monitoring installations.

Carbon Monoxide

No carbon monoxide was detected in any of the monitoring installations.

Volatile organic compounds

VOC's were typically recorded in concentrations of less than 4.3ppm. This concentration was exceeded on one occasion with a concentration of 23.4ppm recorded in the standpipe in BH08 on 16th July 2019.

Flow

Monitored gas flow rates within the long installations ranged between 0 and 0.9l/h.

Table 13 - Summary of Gas Monitoring Results from Response Zones Representative of Band Drains (Long Installations)

	BH07	**BH08**	**BH04**
Response zone depth	0.5 – 7.0 (19mm)	0.5 – 6.0 (19mm)	0.5 – 6.0 (19mm)
Stratigraphy	TFD	TFD with peat	TFD/GTD
Water level (mbgl)	0.8 – 1.35	0.9 – 1.4	0.6 – 1.3
	Typical range	Typical range	Typical range
Carbon Dioxide (%)	0 – 3.8	0 – 2.6	3.1 – 5.1
Methane (%)	0	0	0
Oxygen (%)	17.2 – 21.3	18.3 – 21.2	10.3 – 20.4
LEL (%)	0	0	0

	BH07	BH08	BH04
Hydrogen sulphide (ppm)	0	0	0
Carbon monoxide (ppm)	0	0	0
VOC (ppm)	0 – 0.5	0 – 2.2 (one high value of 23.4)	0 – 4.3
Gas flow ltr/hr	0	0 – 0.9	0

Deep Installations

Nine response zones have been installed into deeper strata, with the primary purpose being for groundwater monitoring and sampling. These standpipes are not considered to be representative of a potential gas migration pathway due to them being fully flooded i.e. response zones are beneath the groundwater table (~1mbgl). Gases within these standpipes are likely to be the result of dissolved gases coming out of solution, which were formerly contained within the groundwater body (before the installation of the standpipe).

These response zones are at various depths within the tidal flat deposits the glacial till deposits or the St Maughans Formation. The results are summarised in **Table 14**.

Carbon Dioxide

The monitored concentrations of carbon dioxide from the deep installations ranged between 0% and 0.6% v/v.

Methane

Methane was detected on two occasions in the monitored deep excavations at 0.1 and 2.4 % v/v, in BH06 and BH03 respectively. No methane was detected in other locations.

Oxygen

The monitored concentrations of oxygen from the deep installations was between 19.6% and 21.5%.

Hydrogen Sulphide

The monitored concentrations of hydrogen sulphide from the deep installations was 0% for all visits.

Carbon Monoxide

The monitored concentrations of carbon monoxide from the deep installations was 0% for all visits.

Volatile Organic Compounds (VOCs)

The monitored concentration of VOCs from the deep installations was typically between 0ppm and 2.4ppm, but higher values were commonly recorded in each hole up to a value of 117.9ppm. These higher concentrations were generally recorded in the first or second round of monitoring.

Flow

Gas flow rates monitored within the standpipes with deep response zones ranged between -9.4 l/h and 3 l/h. The negative flow rates are likely to be the result of the monitored response zones being fully flooded and the monitored air being drown from the enclosed space of a plain section of the standpipe resulting in negative pressure build up. Therefore, the flow rates measured within these installations will not be considered further.

Table 14 - Summary of Gas Monitoring Results from Deep Response Zones

	BH02	BH03	BH05	BH08	BH06	BH01	BH04	BH07	BH09
Response zone depth	4 – 5 (50mm)	4.7 -6.0 (50mm)	2.7 – 4.0 (50mm)	8.5-9.5 (50mm)	3.7 – 5.0 (50mm)	6.7 – 8.0 (50mm)	11 – 12 (50mm)	10.5 – 11.5 (50mm)	9.7 – 11.0 (50mm)
Stratigraphy	TFD	GTD	GTD	GTD	GTD/SMF	SMF	SMF	SMF	SMF
Water level (mbgl)	0.5 – 1.1	1.3 – 1.7	0.9 – 1.4	1.1 – 1.4	0.9 – 1.6	0.9 – 1.4	0.7 – 1.3	1.0 – 1.3	0.5 – 1.4
	Typical range	Typical range	Typical range	Typical range	Typical range	Typical range	Typical range	Typical range	Typical range
Carbon Dioxide (%)	0 – 0.1	0 – 0.6	0	0 - 0.1	0 – 0.6	0 – 0.3	0 – 0.1	0 – 0.5	0 – 0.1
Methane (%)	0	0 - 2.4	0	0	0 – 0.1	0	0	0	0
Oxygen (%)	20.3 – 21.5	19.6 – 21.5	19.9 – 21.4	19.8 – 21.3	19.9 – 21.3	20.2 – 21.4	20 – 21.2	19.3 – 21.2	19.8 – 21.4
LEL (%)	0	0	0	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0	0	0	0
Volatile Organic Compound - VOC (ppm)	0 – 2.2 (one of 11.2)	0 – 0.9 (two higher concentrations of 10.0 and 10.2)	0 – 1.4 (two higher concentrations of 51.1 and 6.2)	0 – 2.4 (one of 8.1)	0.1 – 0.6 (two higher concentrations of 15.7 and 18.8)	0 – 0.8	0 - 0.3 (two higher concentrations of 42.3 and 117.9)	0 – 0.8 (two higher concentrations of 11.9 and 112.3)	0 – 1.3 (one higher concentrations of 113.5)
Gas flow l/h	-0.6 - 0	0	0 – 1.9	-6 - 0	0 - 3	0	0	-9.4 - 0	0 – 1.5

5.4.6 Summary and Discussion

The completed ground gas monitoring regime was designed to validate the conceptual model presented in the technical note issued by Arup [30] and to confirm a level of risk and inform mitigation measures, if required.

The monitoring results indicated that no significant vertical ground gas migration from the peat deposits to the near ground surface and no significant migration of gas from the dissolved phase to gaseous phase is occurring.

The following has been considered further in the ground gas risk assessment:

- **Flow rates:** The maximum gas flow rate of 15.4 l/h was recorded on the 14th August 2019 in BH03. This measured flow rate is significantly higher than the typically monitored range of between 0 and 3 l/hr across the site during all six monitoring rounds. The values within the high end of that range corresponded with the falling atmospheric pressure conditions and therefore are considered representative of a worst-case scenario.

  Except for organic superficial deposits no other sources of ground gas have been identified. The completed monitoring does not indicate an active gassing conditions associated with that source and therefore the one off measured flow rate of 15.4 l/hr is not considered representative worst case scenario. Consequently, a flow rate of 3 l/h will be used to derive the Gas Screening value (GSV).

- **Methane:** Generally, methane was measured at or below detection level within the monitored installations, except for one occasion where methane was measured at 2.4 %v/v in a deep installation in BH03. Considering the presence of methane generating source (peat bands within the alluvial deposits), the measured maximum concentrations has been applied within the assessment.

- **Carbon dioxide:** Carbon dioxide has been detected across the site at concentrations up to 11.1% v/v. The maximum measured concentrations is considered to be a representative maximum for the site and has been applied within the assessment.

Unexpectedly, VOCs of up to 117.9ppm have been recorded in all monitored installations, particularly within the first two rounds of monitoring. Other than for the TPHs recorded in the groundwater sample from BH05, no evidence of hydrocarbon contamination was recorded either during the field works or subsequent monitoring visits and no potential sources of volatile organic compounds were identified as part of the desk study. Therefore, the source of these elevated levels of VOCs is unlikely to be associated with the ground conditions beneath the site and may be a result of either equipment or human influence during the monitoring.

This has been discussed with Geotechnical Engineering Ltd, the ground investigation contractor, who reviewed the method by which the readings were taken and the calibration certificates of the equipment used. They found no evidence the equipment was faulty and followed the monitoring method specified in the Arup ground investigation specification [10].

These results are therefore considered unexplained and a further course of three rounds of fortnightly gas monitoring is recommended.

5.4.7 Gas Screening Value

Gas screening values (GSV) for the site have been calculated for methane and carbon dioxide using the maximum representative encountered concentrations as reported in **Table 15** below.

Table 15 - Gas Screening Values

Ground gas	**Max Concentration (% Vol)**	**Flow Rate (l/hr)**	**Gas Screening Value (GSV) (l/hr)**	**Characteristic Situation (CIRIA 665)**
Methane	2.4	3	0.072	2
Carbon dioxide	11.1		0.3	2

5.4.8 Recommended Protection Measures

The site has been classified for gas protection measures in accordance with both CIRIA 665 guidance and BS8485:2015, using the ground gas monitoring results obtained from six monitoring rounds.

The calculated GSVs for the proposed development area (Situation A development) falls within the threshold for Characteristic Situation 2, which means that there is a low risk from ground gas.

In line with the guidance provided in CIRIA C665 [31], one to two levels of protection would be required from the following typical scope of protective measures:

a) *Reinforced concrete cast in situ floor slab suspended, non-suspended or raft) with at least 1200 g DPM*[2].

b) *Beam and block or pre cast concrete slab and minimum 2000 g DPM/reinforced gas membrane.*

c) *Possibly underfloor venting or pressurisation in combination with a) and b) depending on use.*

All joints and penetrations sealed.

The design of the ground gas protection measures should be undertaken in accordance with British Standard BS8485:2015 [32]. The required protection measures are dependent on the Characteristic Situation (determined above) and on the end use of the building (Types A to D). The proposed development is likely to comprise multioccupancy commercial properties falling into Type B building type – *Private or commercial property with central building management control of* *any alterations to the building or its uses but limited or no central building management control of the maintenance of the building, including the gas protection measures. Examples include managed apartments, multiple occupancy offices, some retail premises and parts of some public buildings (such as schools, hospitals, leisure centres) and parts of hotels.*

Based on the site being Characteristic Scenario 2 and the proposed building being Type B, a minimum gas protection score of 3.5 would have to be achieved. In accordance with BS8485:2015 [32], this would require a combination of two or more of the following methods of gas protection methods:

- *the structural barrier of the floor slab, or of the basement slab and walls if a basement is present;*
- *ventilation measures; and*
- *gas resistant membrane.*

On confirmation of the final development proposals, design of ground gas mitigation measures will need to be undertaken for each individual building, as the level of management control and maintenance would impact the building type score and consequently the required level of protection. Opportunities should be sought to incorporate the imported fill into the ground gas protection measure design e.g. as a passive ventilation layer.

5.5 Contamination Recommendations

In summary, the completed ground investigation works have not encountered evidence of significant contamination, which is as expected based on the desk study review completed for the proposed development area. Isolated instances of elevated concentrations of hydrocarbons were identified within groundwater these however are unlikely to be indicative of a widespread contamination issue requiring remediation. Risk from ground gas has been assessed to be low and requiring implementation of ground gas protection measures. The following recommendations are made.

The materials encountered as part of the 2019 ground investigation are not considered to pose a risk to site end users and therefore the encountered materials are considered suitable for reuse (with regards to contaminations). Should potentially contaminated material be encountered during construction, it should be sampled and tested at the earliest opportunity to inform on the risk posed to construction workers and suitability for reuse. Any import of materials or reuse of Made Ground materials during construction will require validation testing.

An additional phase of ground investigation is required within the land owned by Network Rail to investigate the potential presence of contamination with the railway embankment. As set out in the “Phasing of proposed ground investigations” report [33], it is recommended that this ground investigation is undertaken when possessions are obtained to allow the embankment widening and sluing of the railway lines.

There is potential that new reens will need to be excavated in the land to the south of the railway. Provided that this material is natural with no potential to have become contaminated, in accordance with regulations, it will be suitable for non-hazardous waste disposal (inert/non-hazardous). This material, comprising tidal flat clay deposits, is potentially naturally high in organic content and therefore may be in exceedance of the Waste Acceptance Criterion for Inert Landfill disposal for Total Organic Carbon. Sampling and testing for total organic carbon may be required for it to be disposed of to an inert waste landfill. Peat and peaty clays would only be considered suitable for non-hazardous disposal, which attracts higher disposal rate.

Generally, groundwater sampling indicated no exceedances of the applied assessment criteria. Cadmium and copper showed slight exceedances of the EQSs in samples obtained from installations monitoring groundwater flowing into the site area and it is considered that these results may be reflective of the background water quality. Aliphatic hydrocarbons and phenols were both detected on one occasion (separate locations). These exceedances are likely to be a result of a localised spillage of fuel and herbicides respectively and are unlikely to be reflective of a widespread contamination issues. As a precaution, it is recommended that a watching brief is implemented during the construction works.

Surface water sampling did not identify any contaminants of concern. Elevated concentrations of zinc were detected in two locations where water flows into the site (SW1 and SW2) on August 15^{th} and these are considered to originate from off-site sources.

Monitoring of gas from standpipes installed across the site has indicated that the tidal flat deposits are a potential source of carbon dioxide and methane. As such, the site has been determined to be Characteristic Situation 2 [30] and therefore one to two levels of protection would be required. The design of the protection measures for each individual proposed building should be undertaken in accordance with BS8485:2015. Opportunities should be sought to incorporate the imported fill into the ground gas protection measures design e.g. as a passive ventilation layer.

Ground gas monitoring indicated elevated concentrations of VOCs across the site in the majority of the monitored locations across the monitored strata. As no indication of a widespread significant contamination with hydrocarbons has been identified, the source of the VOCs is unclear. Therefore, as a precaution, three additional rounds of fortnightly gas monitoring are required to further inform on the risk posed by VOC’s at the site.

6 Geotechnical Risk and Opportunities Register

6.1 Introduction

Geotechnical hazards affecting the project have been identified and risks assessed. Opportunities to mitigate risks, provide more certainty to programme and cost estimates. Geotechnical risks will need to be adequately addressed during detailed design, construction and operation.

Geotechnical risks and opportunities may impact on the cost, programme or quality of the finished scheme. As well as issues related to the design, procurement and construction process, this includes some risks for which there may be implications during the operation of the railway which will need to be accounted for when assessing whole life costs for the Scheme.

6.2 Project Geotechnical Risk and Opportunity Register

The main geotechnical risks and opportunities that have been identified for the project are summarised in Table 16 below.

The scope of the ground investigations undertaken to date, specifically related to the Cardiff Parkway development, were designed to inform the GRIP 4 stage of rail design and provide data to inform the planning application for the wider site.

The requirements for further ground investigation works have been highlighted in the register.

The register should be reviewed and updated throughout the detailed design and construction phase to allow the identified risks and opportunities to be most effectively managed and appropriate mitigation to be considered throughout the design and construction process.

Table 16 - Geotechnical Risk and Opportunity Register

Ref.	Risk / Opportunity Description	Risk Mitigation / Action
1.	There is potential for some areas of the site to settle more than anticipated based on the findings of the ground investigation. This is because of the limited area that the ground investigation has covered and the lateral variability of soft soils which includes: • The variable thickness of the desiccated crust (Figure 5); • The variable thickness of peat • Variations in the thickness of soft clay deposits, due to the presence of buried channels. The interpolation between exploratory holes indicates that there may be a buried channel of thicker soft deposits in the east of the site (Figures 6 and 7). • The extent to which the material beneath the existing embankment has already consolidated and the potential for on-going creep settlement	Further ground investigation will improve the understanding of the geological variability of the site. In particular, geophysical surveys (seismic refraction) will improve the understanding of the variable thickness of the superficial deposits and can be used to target areas of potential buried channels. Detailed design will need to consider the lateral variation in terms of lower and upper bound thickness variations and parameter ranges to assess the impact on the design. This can then inform the ground treatment to be adopted.
2.	Embankment settlements exceed design tolerances, due to the presence of compressible soft soils. Track alignment is subjected to tight settlement and differential settlement criteria. TFD-Clay and TFD-Peat thicknesses vary that will lead to variable settlements. The presence of predominantly peat in the TFD will significantly influence the magnitude of potential “creep” settlements post construction.	Baseline monitoring of the existing railway will inform on if there is any ongoing creep settlement. Design will need to consider ground treatment options for the embankment construction to limit total and differential settlements. The derived parameters presented as part of this GIR can be used for preliminary assessments of settlement, which may be used as a baseline to compare against ground improvement options that are developed.
3.	Opportunity to develop a better understanding of settlement parameters and reduce uncertainty in programmed surcharge periods.	Monitoring of settlement will be required to determine when sufficient settlement of the ground has been achieved to minimise future movements. Review of data collected during initial phases would help inform and refine the design of subsequent

Ref.	Risk / Opportunity Description	Risk Mitigation / Action
		phases with potential to optimise the surcharge design and provide greater programme certainty.
4.	The existing ground investigations scoped to inform GRIP 4 stage of rail design and support planning in the wider site area. Given the limited investigations in the wider site there is the potential for unforeseen ground conditions and the opportunity to refine design assumptions.	For the subsequent phases of the development additional ground investigation in recommended to effectively manage ground risks and uncertainties and provide information needed to develop efficient design solutions. At this stage, it is considered that a suitable scope of additional investigation would include additional boreholes and CPTs for the development plots and raised fill platforms, and additional trial pitting for assessment of the potential for reuse of excavated materials within the site and (depending on development levels) the development of designs for the access roads and hard standings.
5.	Changes to the masterplan risk gathered to date no longer being relevant to development areas.	If changes to masterplan are made the ground investigation requirements should be reviewed.
6.	Potential for piles supporting building structures to refuse before achieving the designed embedment. (The ground investigations encountered some bands of sandstone within the bedrock).	Consider refusal risks when selecting appropriate piling techniques once structural loads have been defined. Further ground investigations (including rotary cored boreholes) for locations of proposed structures across the wider site area.
7.	Embankment construction adjacent to reens Risk that embankment instability may occur during construction and operation due to depth and side slopes of existing reens.	Temporary and permanent works design to consider appropriate parameters based on information presented in this GIR to assess stability risk presented by the reen network. Detailed topographical information about the reens, including the geometry and depth to reen invert will be required to develop detailed designs. Consideration of reen diversion and filling of reens adjacent to the scheme to mitigate the risks associated with the potential instability.

Ref.	Risk / Opportunity Description	Risk Mitigation / Action
8.	To date, no ground investigations directly related to the proposed development have been undertaken within the rail corridor. The works within the rail corridor will involve widening of the embankment, and construction of platforms and canopies. The works will involve excavation of existing embankment materials. The composition of these materials is currently unknown. These is a risk that the materials may be contaminated and contain material that may obstruct excavations or foundation construction.	To inform foundation design and obtain information on engineering properties and chemistry of embankment fill it is recommended that ground investigations are undertaken within the rail corridor. This should be considered as part of the GRIP 5 phase of works. The investigation would include chemical testing to inform the suitability for reuse assessment and WAC testing for offsite disposal . It is proposed that window samples and dynamic probes are used to prove base of embankment fill (anticipated depth 3m) and obtain samples for chemical testing at 100m intervals.
9.	There is potential to encounter contaminated material that may require excavation and disposal.	The targeted ground investigation did not encounter significant contaminant concentrations, but ground investigation only covered discrete areas of the site. Therefore, the risk of encountering unidentified contamination remains. In particular there is a risk of encountering contamination in the Made Ground of the railway embankment, which has not been sampled and tested for contamination as of yet. Another phase of ground investigation is recommended to investigate the materials of the existing railway embankment. Samples of the Made Ground should be collected and sent for chemical testing. If unexpected contamination is excavated during the works it will need sampling and testing to inform on reuse or disposal options. Leachable contaminants will need to be considered for foundation design and excavated materials management.
10.	There is a risk that there is a source of VOC gas in the sub-surface and the monitoring results that have been recorded VOCs are not anomalous.	An additional three rounds of ground gas monitoring are recommended to establish if the ground is a potential source of VOCs.
11.	Potential for methane release during construction, particularly during the installation of band drains or piles. This is because the natural materials such as a peat and	Ground gas protection measures are recommended based on the gas concentrations recorded during the period of monitoring after the ground investigation. Gas monitoring to be considered during the works. Should it become apparent that these

Ref.	Risk / Opportunity Description	Risk Mitigation / Action
	organic clay encountered during the ground investigation are known to be a potential source of ground gas.	concentrations are not representative the gas protection measures should be reviewed.
12.	Excavations to are proposed to the south of the railway to create compensatory reens and to lower ground to compensate for the loss of flood capacity. The nature of materials in these areas have not been investigated to inform design of the reen side slopes. The materials excavated will either need to be reused on site or disposed of. No investigation to assess the suitability for reuse or disposal have been undertaken. There is a low risk that contaminated materials may be present.	To develop the understanding of material present in the mitigation areas, ground investigations in the form of window samples or trial pits every one to two hectares (To 3m depth) are recommended. This will allow assessment of suitability for reuse or characterisation for potential disposal and understand the physical properties of the materials for design of reen side slopes.

7 Further Investigation

As described in Table 16 further ground investigation is recommended to mitigate ground risks and realise opportunities to refine the design to potentially provide more programme certainty and cost savings.

A summary of the recommended further ground investigation works are provided in Table 17.

Table 18- Geotechnical Risk and Opportunity Register

Ref.	Objective	Investigation	Timing
1.	Greater understanding of the thickness of soft ground across the site to better understand settlement.	Geophysical surveys (seismic refraction). Additional boreholes and CPTs in wider site area Additional trial pitting to inform the design of access roads and optimising the opportunities for reuse of excavated materials within the site.	Earliest opportunity
2.	Investigation within the rail corridor to inform contamination assessment, waste assessment, and foundation and embankment design.	Window samples and dynamic probes to prove base of embankment fill (anticipated depth 3m) and obtain samples for chemical testing at 100m intervals. Chemical testing to inform the suitability for reuse assessment and WAC testing for offsite disposal.	During rail possessions (During GRIP Stage 5).
3.	Investigate unusual unexplained VOC and ground gas monitoring results.	An additional three rounds of ground gas monitoring to establish if the ground is a potential source of VOCs.	Immediately
4.	Confirm nature of materials in area to south of railway to allow assessment of suitability for reuse or characterisation for potential disposal and understand the physical properties of the materials for design of reen side slopes.	Window samples every one to two hectares (To 3m depth) and laboratory testing.	Prior to design / construction.
5.	Greater understanding of current rail embankment settlements.	Baseline monitoring of the existing railway to inform if there is any ongoing creep settlement.	During GRIP Stage 4.
6	Greater understanding of rail embankment geometry and adjacent site levels	Detailed topographical survey of the rail embankments and adjacent levels, including crest and invert of reen networks. (Note that any GI undertaken within the embankment fill should be defined following review of the topographical survey data)	During GRIP Stage 4.

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Figures

Figure 1 - Site Location

Figure 2 – Site Topography

Figure 3 – Superficial Geology

Figure 4 – Bedrock Geology

Figure 5 – Desiccated Crust Thickness

Figure 6 – Bedrock Surface Elevation

Figure 7 – Soft Clay and Peat Thickness

Long Sections

Figure 8 – Section (1)

Figure 9 – Section (2)

Figure 10 – Section (3)

Figure 11 – Section (4)

Figure 12 – Section (5)

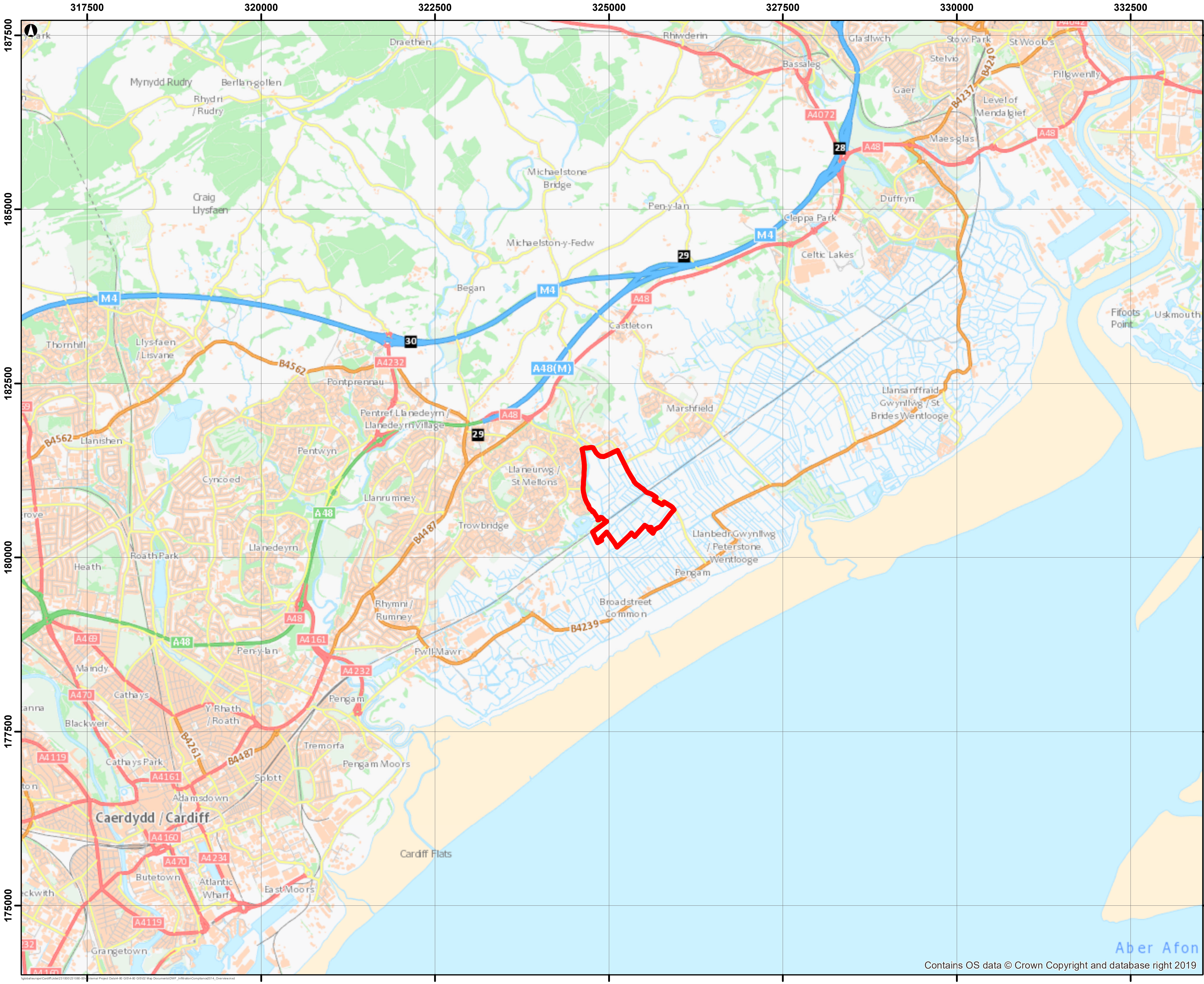
Figure 13 – Section (6)

Figure 14 – Section (7)

Figure 15 – Section (8)

Figure 16 – Section (9)

Figure 17 – Section (9) with CPT



Issue	Date	By	Chkd	Appd

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Job Title

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Job No

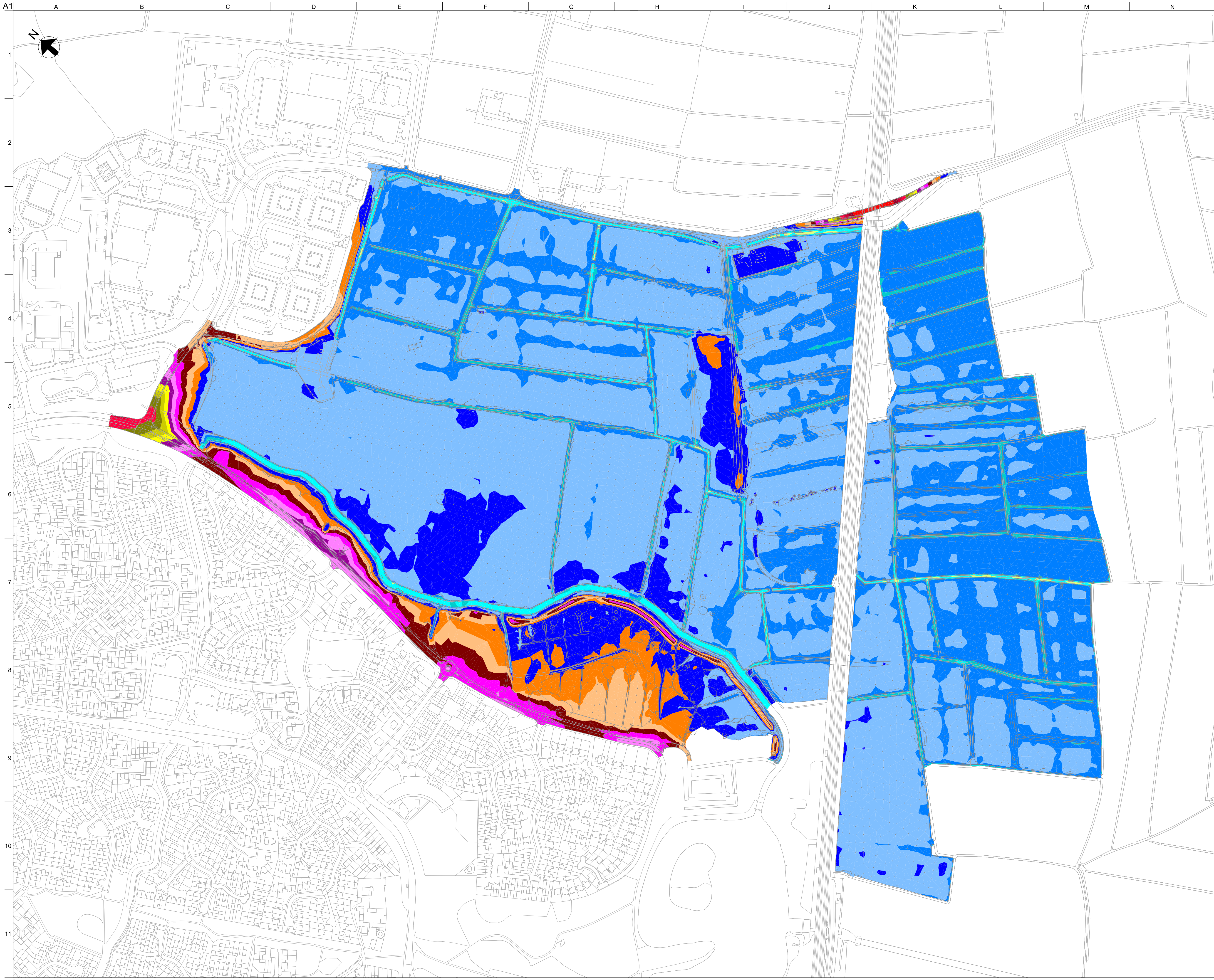
252199

Drawing Status

Figure No

1 - Site Location

Issue



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	11.5m
	11.0m
	10.5m
	10.0m
	9.5m
	9.0m
	8.5m
	8.0m
	7.5m
	7.0m
	6.5m
	6.0m
	5.5m
	5.0m
	4.5m
	4.0m
	3.5m
	3.0m
	2.5m
	2.0m

Note

Figure produced from topographic survey undertaken in January 2018.

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Colour Coded Existing Site Topography

Scale at A1 1:2500

Discipline Civils

Job No **252199-00**

Drawing Status

Drawing No **Figure 02**

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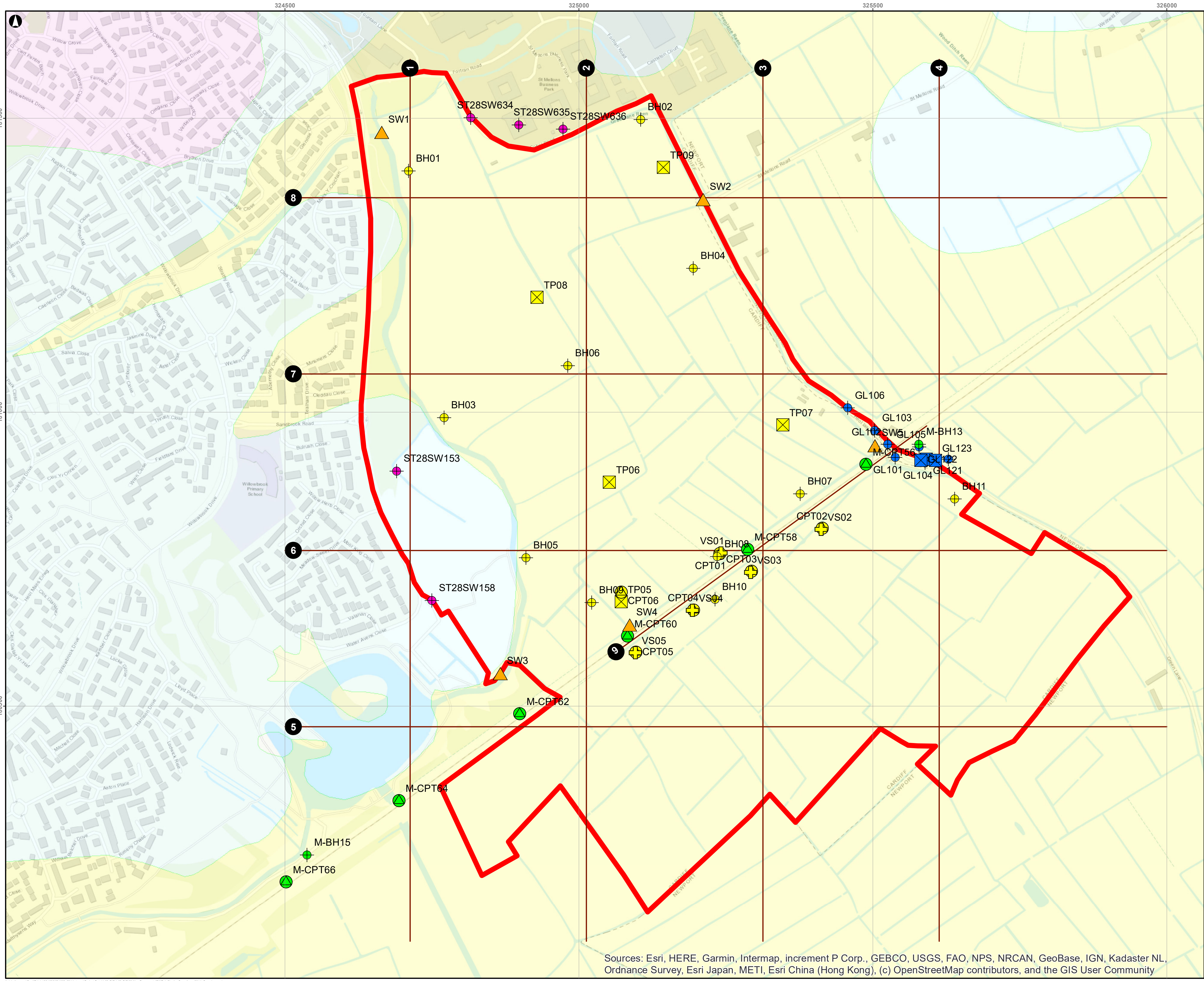

Legend

- SW monitoring
- BGS boreholes

GWRM

Type

- BH
- CPT

Green Lane Overbridge

Type

- BH
- TP

Initial Ground Investigation

Type

- BH
- TP
- VS
- CPT
- Site Boundary
- TIDAL FLAT DEPOSITS - CLAY, SILT AND SAND
- TILL, DEVANSIAN - DIAMICTON
- GLACIOFLUVIAL DEPOSITS, DEVENSIAN - SAND AND GRAVEL

Issue	Date	By	Chkd	Appd
P01	25/10/19	Ed Boss		

Metres: 0 75 150 300

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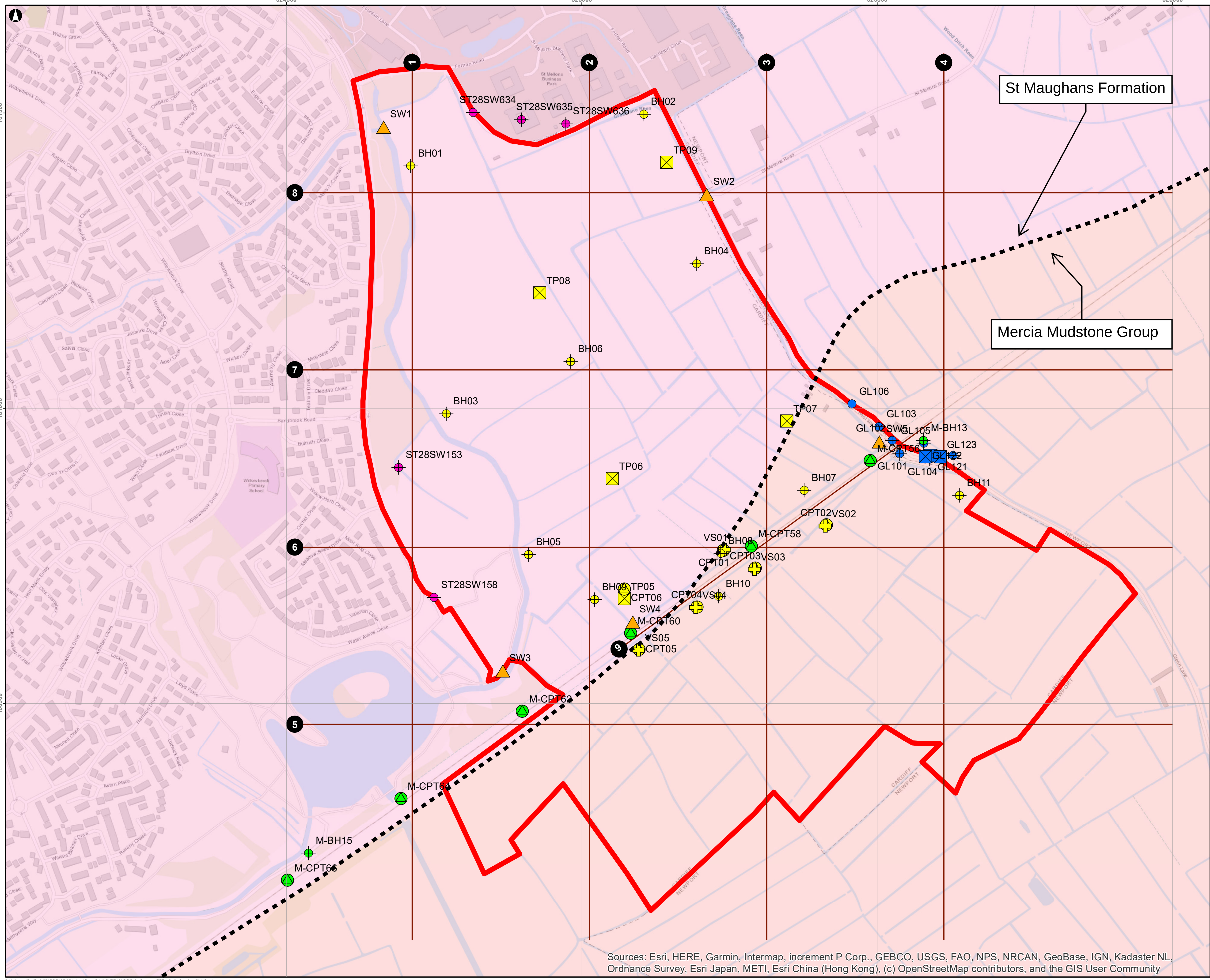
Drawing Status: Issue

Figure No: 3 - Site Plan: Superficial Geology

Issue



Legend

- SW monitoring
- BGS boreholes

GWRM

Type

- BH
- CPT

Green Lane Overbridge

Type

- BH
- TP

Initial Ground Investigation

Type

- BH
- TP
- VS
- CPT

- Site Boundary
- MERCIA MUDSTONE GROUP - MUDSTONE
- ST MAUGHANS FORMATION - ARGILLACEOUS ROCKS AND [SUBEQUAL/SUBORDINATE] SANDSTONE, INTERBEDDED

Issue	Date	By	Chkd	Appd
P01	25/10/19	Ed Boss		

Metres

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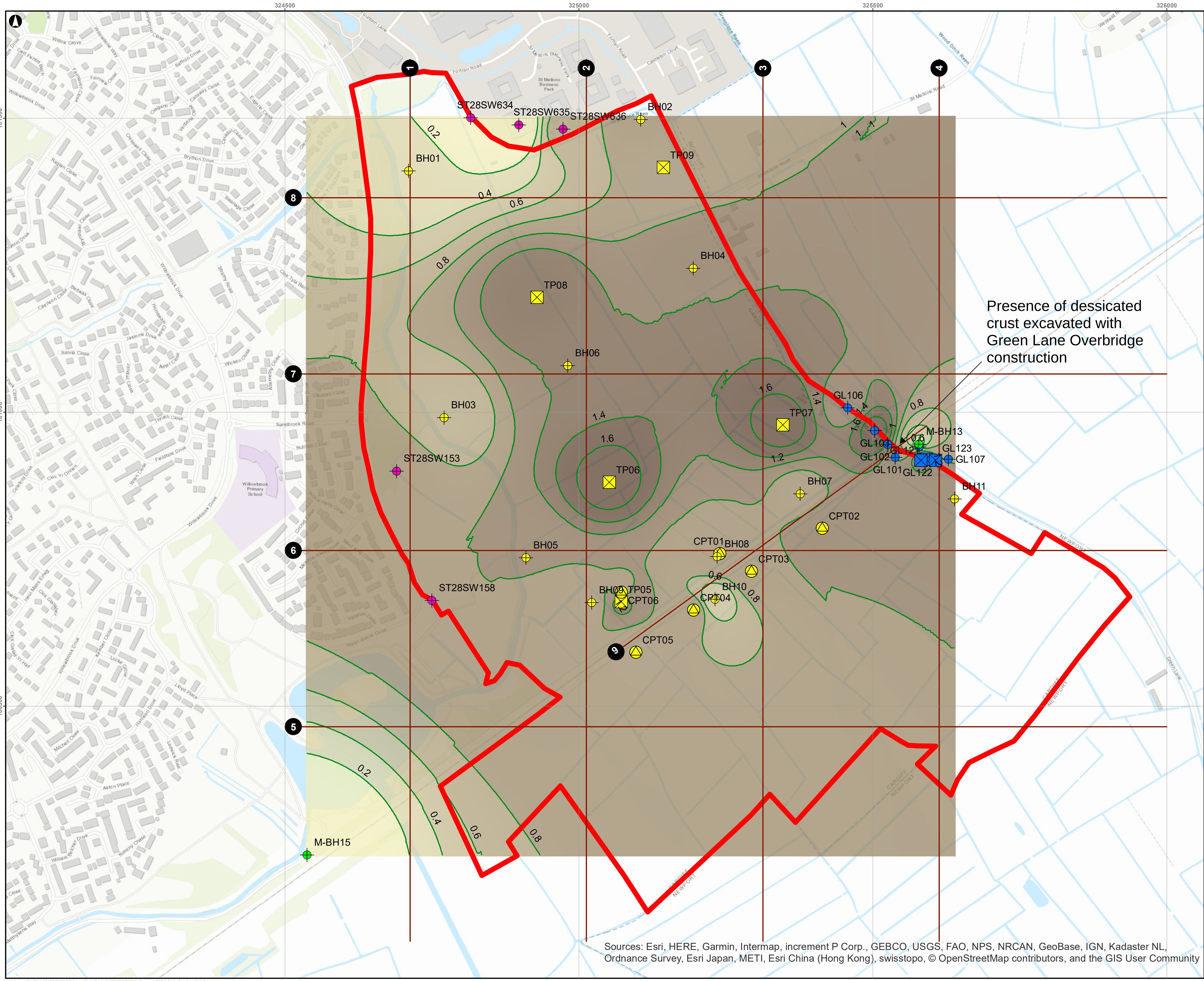
Drawing Status

Issue

Figure No

4 - Site Plan: Bedrock Geology

Issue



Legend

Site Boundary
- Site Boundary

Initial Ground Investigation
- BH
- CPT
- TP

GWRM
- BH

BGS boreholes
- BGS boreholes

Green Lane Overbridge
- BH
- TP

Dessicated Crust Thickness (m)
- 0 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6

[Note dessicated crust identified from log description for Tidal Flat Deposit Clay of "firm"]

Issue	Date	By	Chkd	Appd
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Metres 0 75 150 300

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Changes in soft clay/peat thickness across the site

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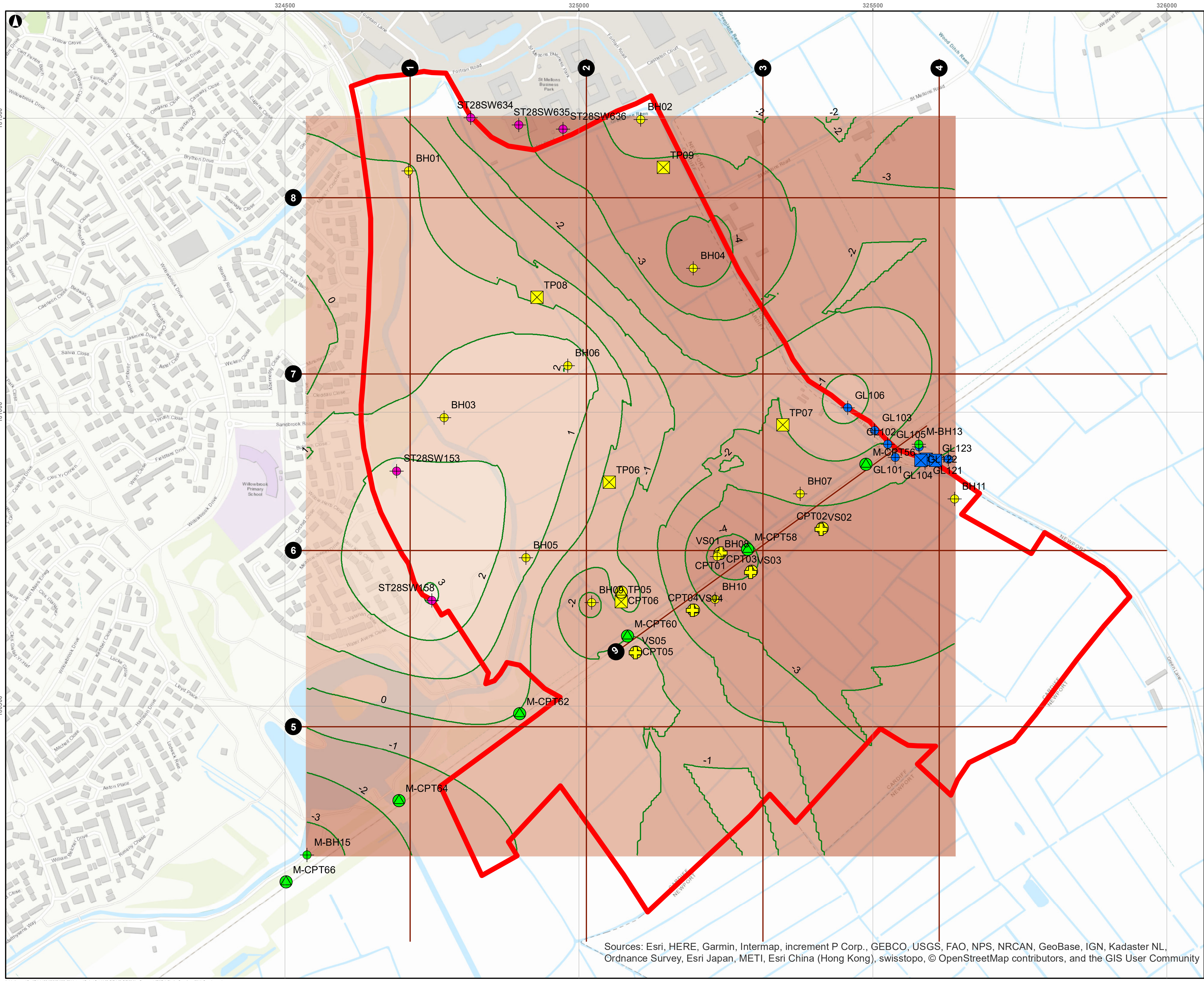
Drawing Status: Issue

Figure No: 5 - Site Plan: Dessicated Crust

Issue



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Legend

Site Boundary
- Site Boundary

BGS boreholes
- BGS boreholes

GWRM
- BH
- CPT

Green Lane Overbridge
- BH
- TP

Initial Ground Investigation
- BH
- TP
- VS
- CPT

Bedrock Surface Elevation mOD
- -4.67 - -4
- -3.99 - -3
- -2.99 - -2
- -1.99 - -1
- -0.99 - 0
- 0.01 - 1
- 1.01 - 2
- 2.01 - 3
- 3.01 - 3.1

P01	01/11/19	Ed Boss		
Issue	Date	By	Chkd	Appd

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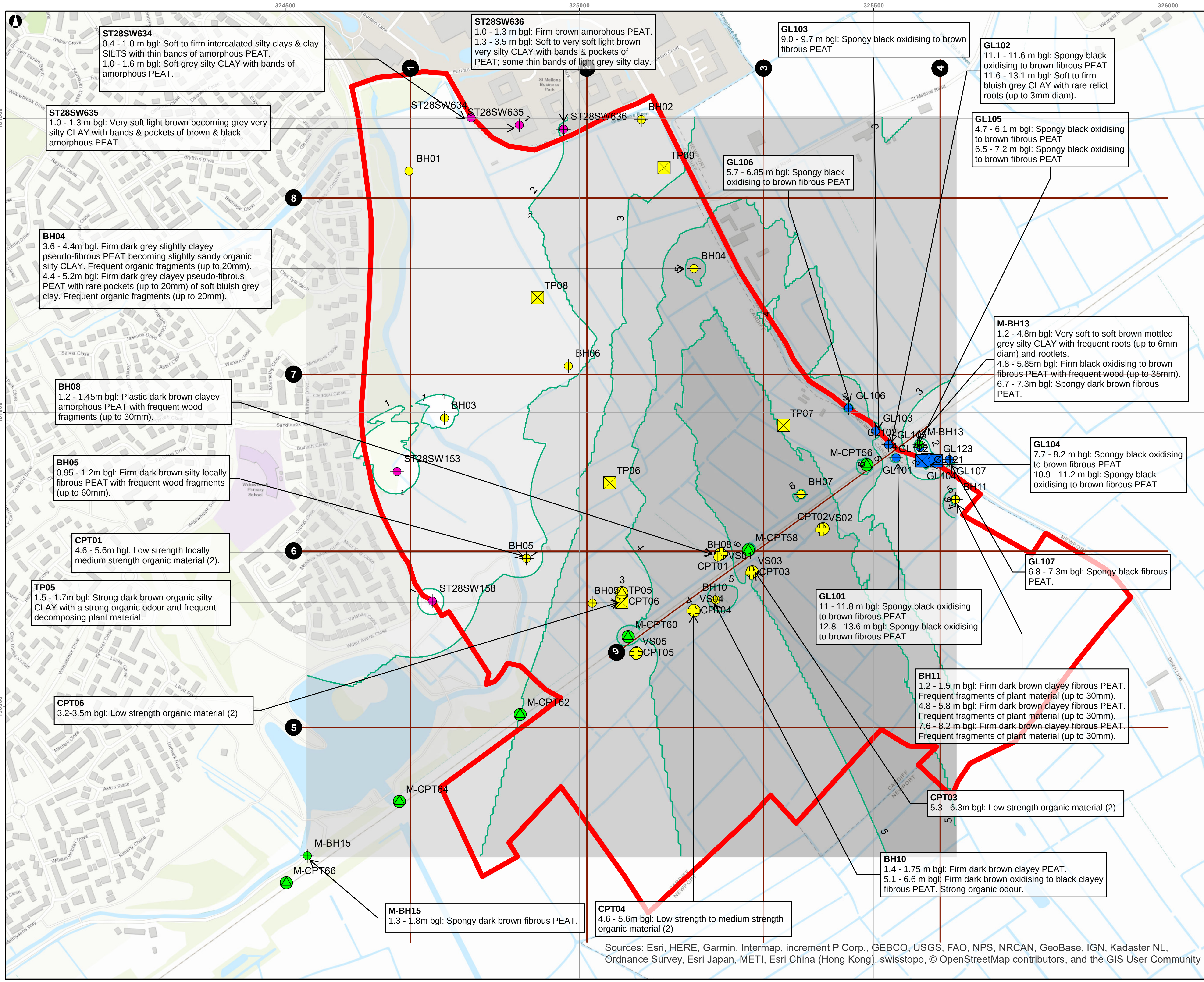
Changes in soft clay/peat thickness across the site

Scale at A3
1:6,000

Job No	Drawing Status
252199-00	Issue

Figure No	Issue
6 - Site Plan: Bedrock Elevation	



Legend

Site Boundary
- Site Boundary

BGS boreholes
- BGS boreholes

GWRM
- BH
- CPT

Green Lane Overbridge
- BH
- TP

Initial Ground Investigation
- BH
- TP
- VS
- CPT

Sclay_cntrs
- Sclay_cntrs

Soft clay/peat thickness (m)
- 0.14 - 1
- 1.01 - 2
- 2.01 - 3
- 3.01 - 4
- 4.01 - 5
- 5.01 - 6
- 6.01 - 7
- 7.01 - 7.2

[Note text highlighting thickness associated with Peat]

Issue	Date	By	Chkd	Appd
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Metres
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Changes in soft clay/peat thickness across the site

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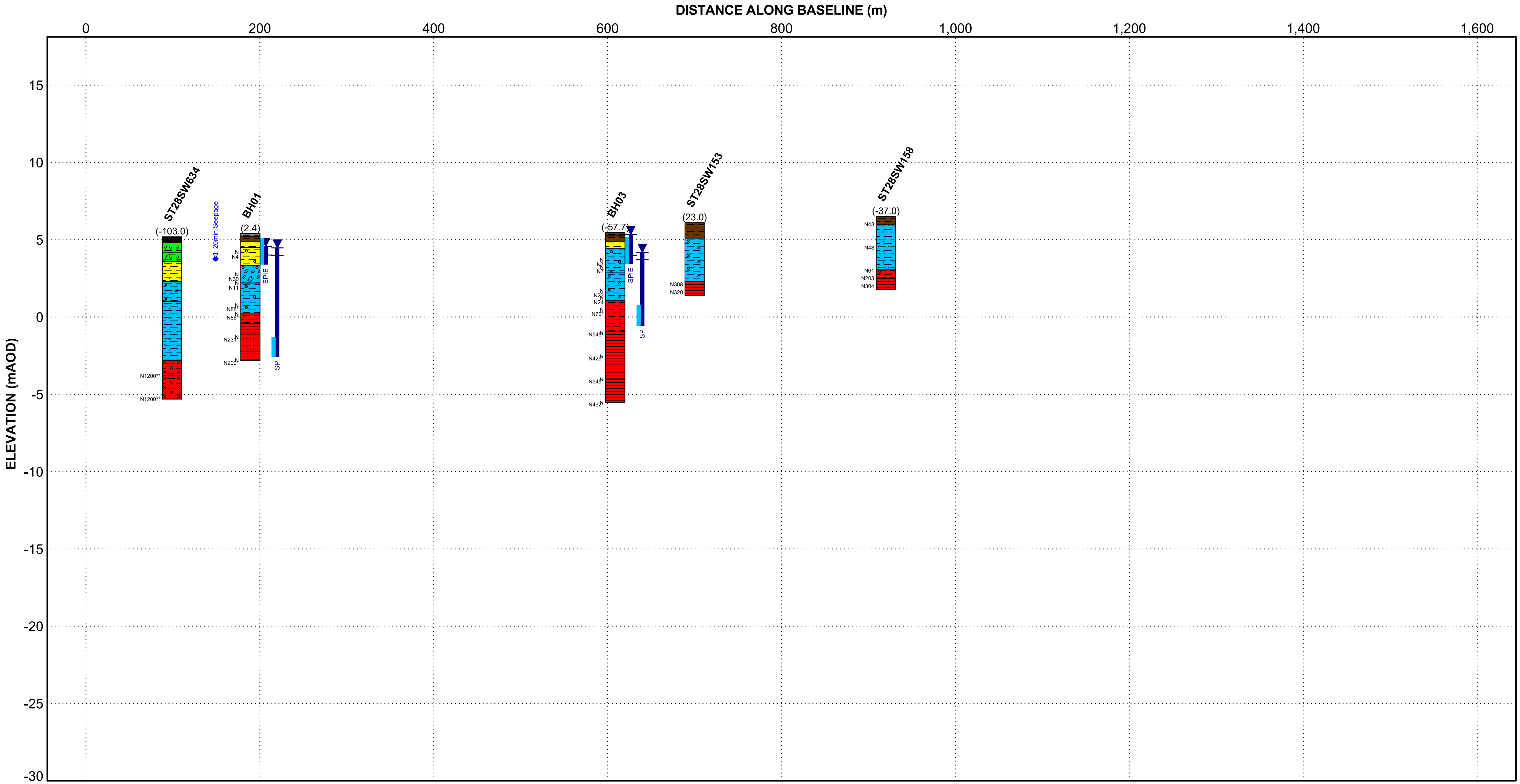
Job No
252199-00

Drawing Status
Issue

Figure No
7 - Site Plan: Clay/Peat Thickness

Issue



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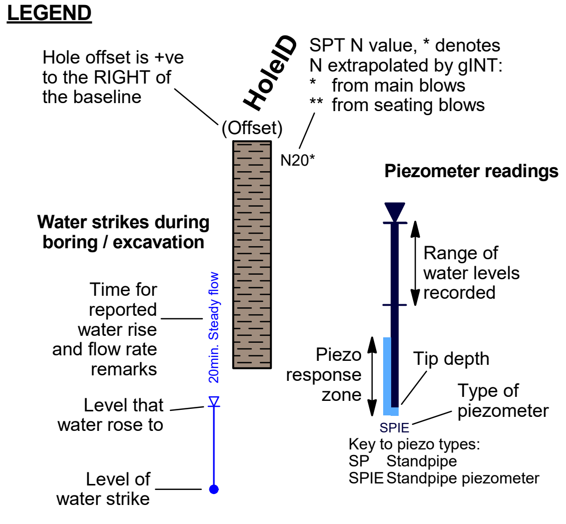

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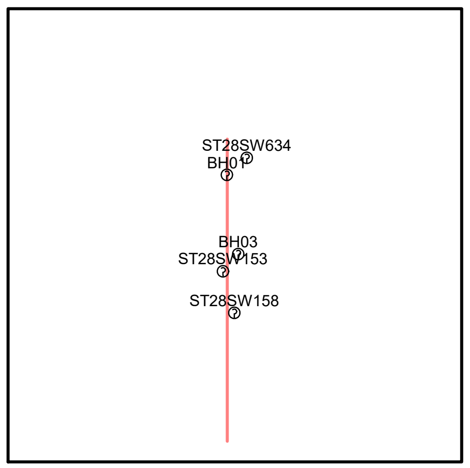

COLOUR LEGEND

- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TOPSOIL [TOP]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

MATERIALS

- CLAY
- Gravelly CLAY
- Sandy GRAVEL
- MUDSTONE
- SANDSTONE
- Silty Clay
- Sandy CLAY
- TOPSOIL
- PEAT
- Clayey PEAT
- Clayey SILT

CARDIFF PARKWAY

LONG SECTION N-S

SECTION (1) 252199 - Figure 8

ARUP. gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

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Source data status: of holes
Database check status: Full check (A) = 0% Partial/selective check (B) = 0% Minimum check (C) = 0% Unchecked (U) = 50% of holes
Zone filter: None (all keys) + Output Keys: (Data not currently available)
Filter: None
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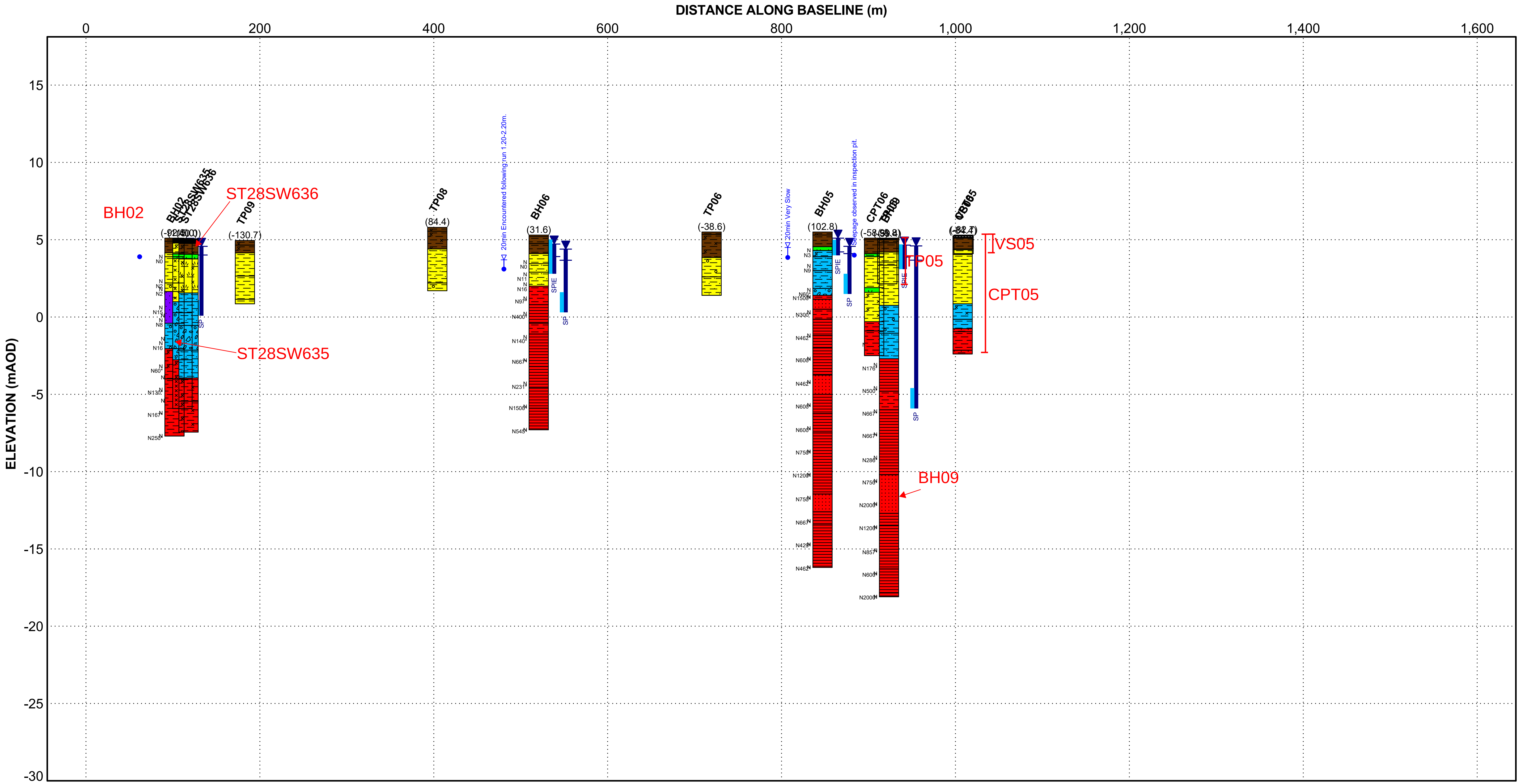

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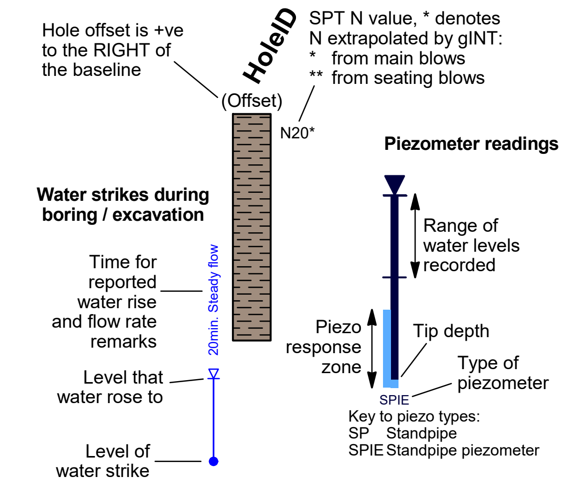

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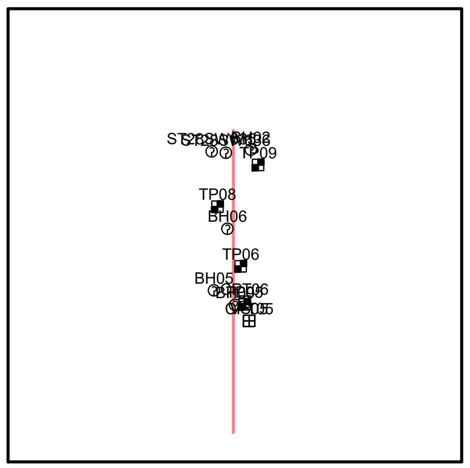

COLOUR LEGEND

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- GLACIOFLUVIAL DEPOSITS [GFD]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TOPSOIL [TOP]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

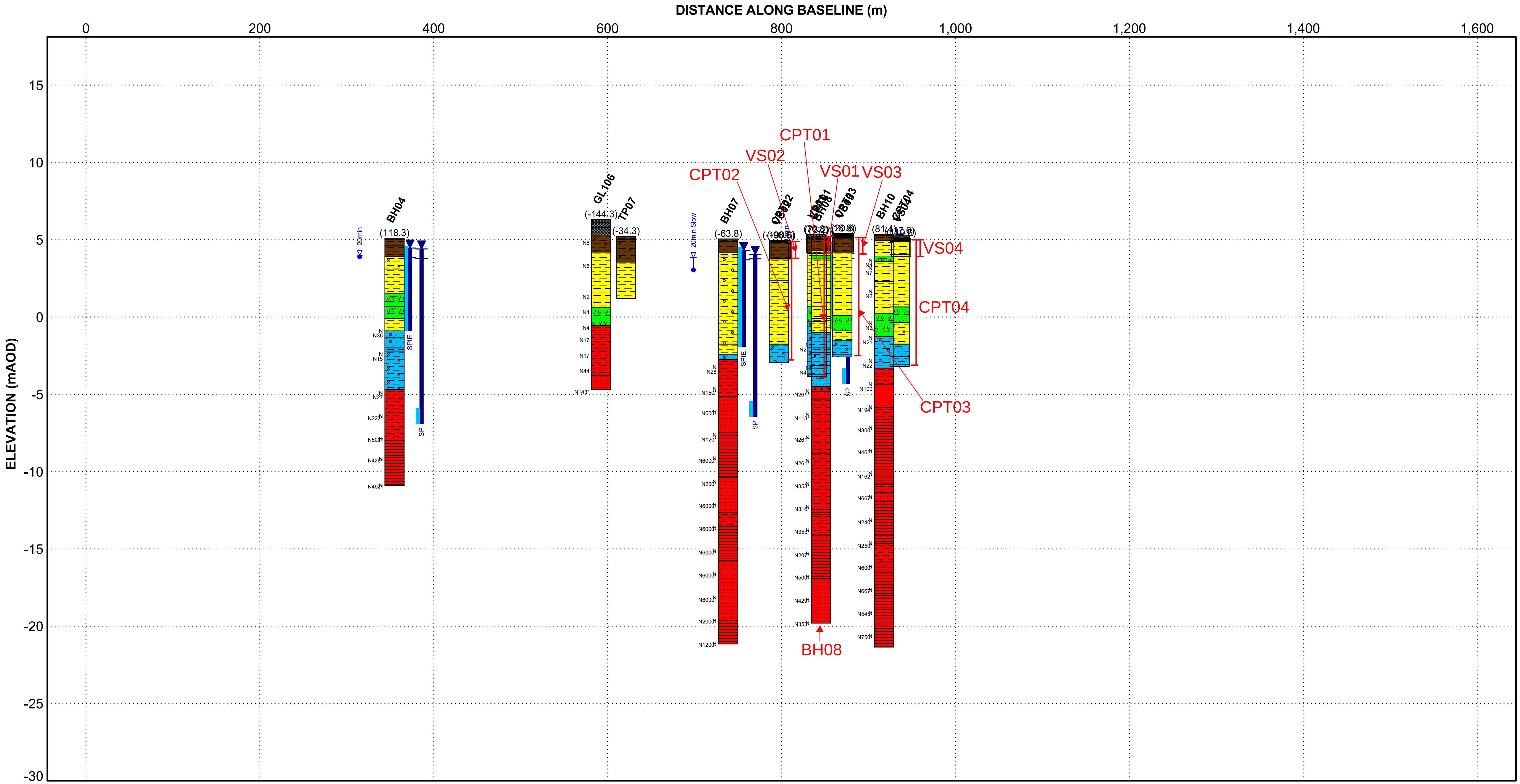
MATERIALS

- Made Ground - FILL
- Silty Clay
- Organic CLAY
- CLAY
- Gravelly CLAY
- Sandy CLAY
- Clayey SAND
- PEAT
- SAND
- Sandy GRAVEL
- SANDSTONE
- MUDSTONE
- TOPSOIL
- Clayey PEAT
- Clayey SILT
- SILTSTONE
- Silty PEAT

CARDIFF PARKWAY

LONG SECTION N-S
SECTION (2) 252199 - Figure 9

ARUP: gINT v8.30.004
Made by Alex Sadler on 4-Nov-19



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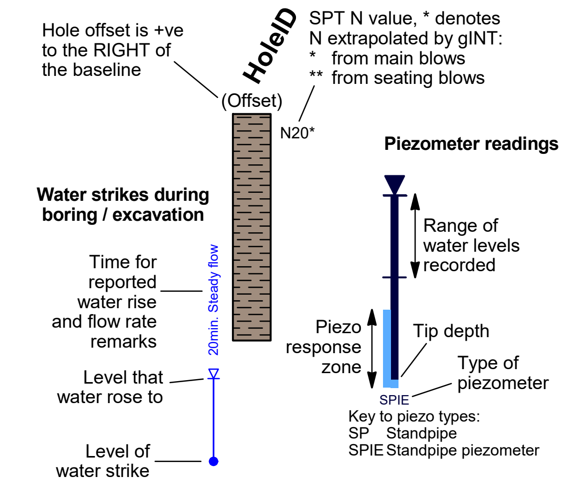

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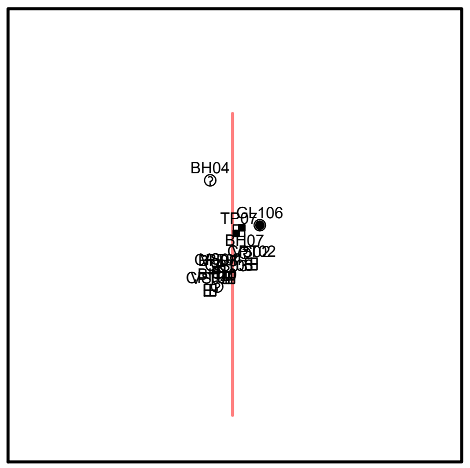

COLOUR LEGEND

- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TOPSOIL [TOP]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

MATERIALS

- Made Ground - FILL
- Silty Clay
- CLAY
- PEAT
- Sandy CLAY
- SANDSTONE
- Clayey SAND
- Gravelly SAND
- SILT
- Clayey PEAT
- MUDSTONE
- Gravelly CLAY
- SILTSTONE
- NO RECOVERY

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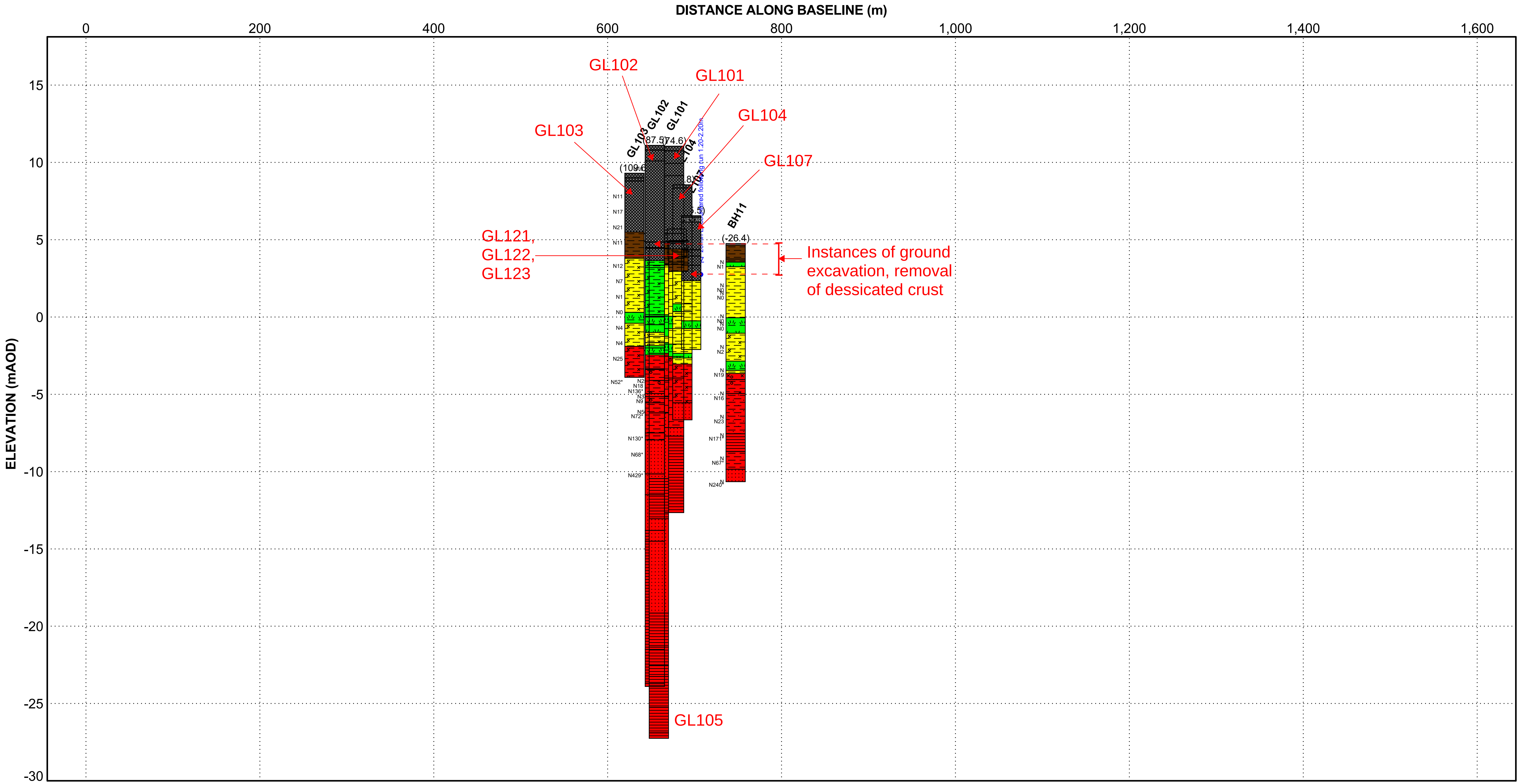
ARUP gINT v8.30.004
Made by Alex Sadler on 1-Nov-19

CARDIFF PARKWAY

LONG SECTION N-S
SECTION (3)

252199 - Figure 10



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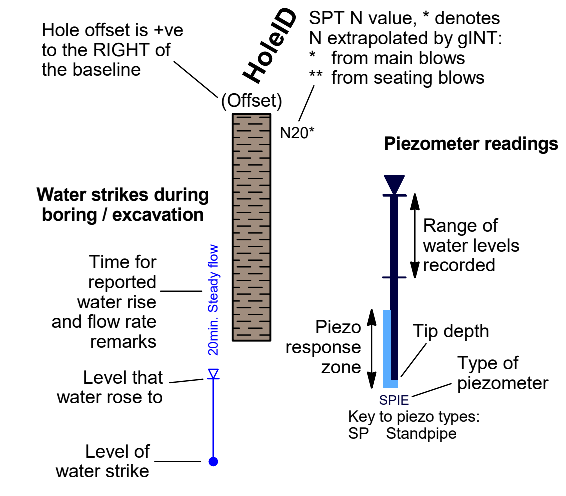
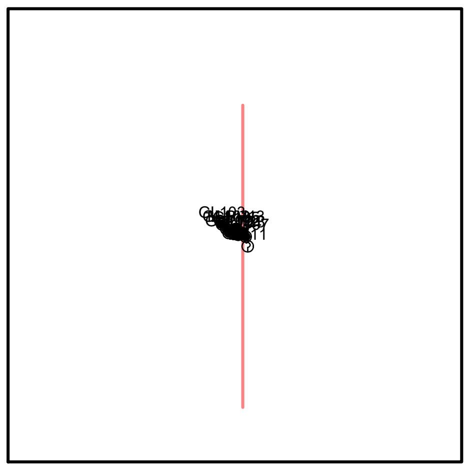
LEGEND



PLAN



COLOUR LEGEND

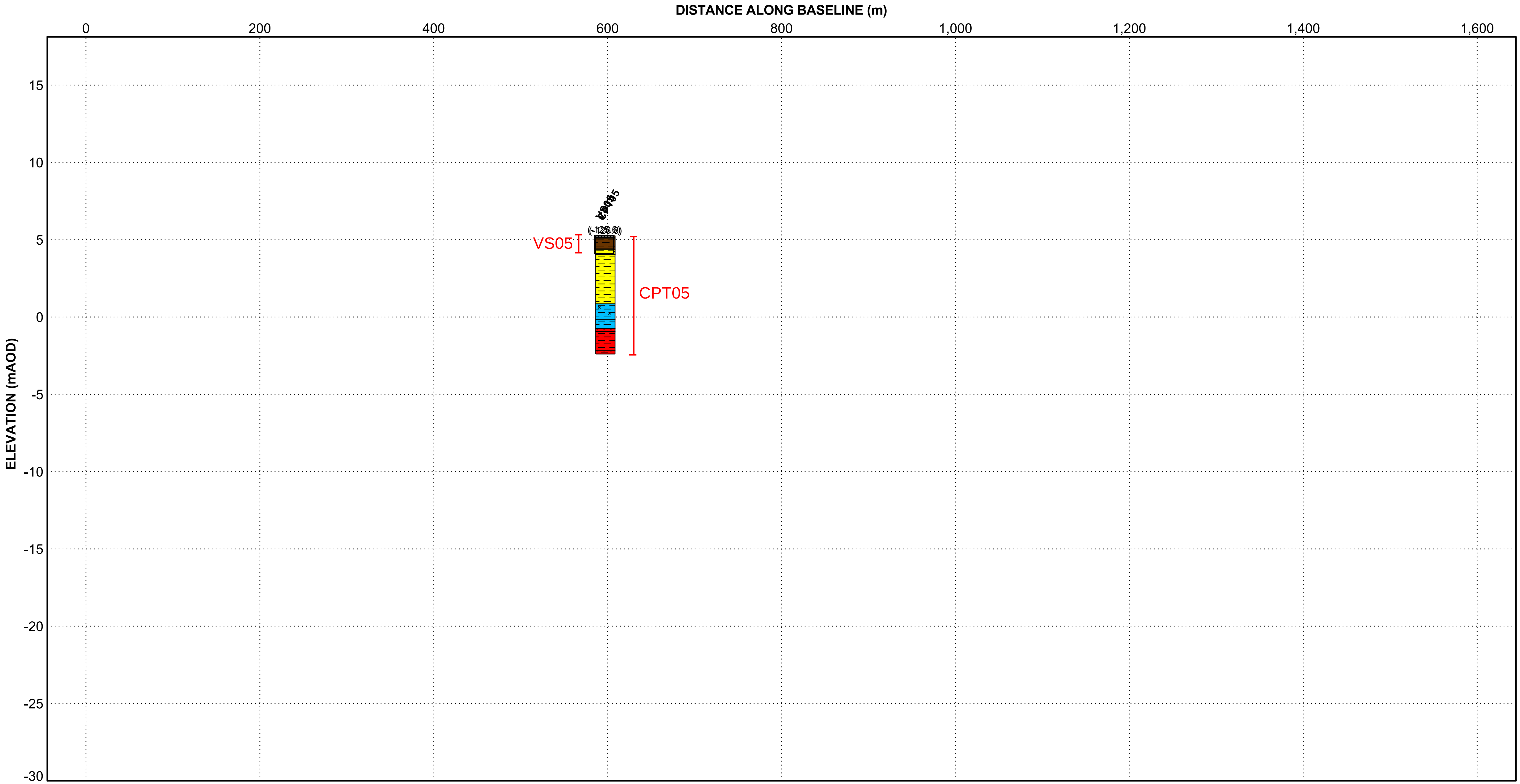
- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- MADE GROUND [MADE GROUND]

MATERIALS

- Made Ground - FILL
- Silty Clay
- PEAT
- CLAY
- Gravelly CLAY
- SANDSTONE
- MUDSTONE
- Sandy CLAY
- CONCRETE
- Gravelly SILT

ARUP gINT v8.30.004
Made by Alex Sadler on 1-Nov-19

CARDIFF PARKWAY
LONG SECTION N-S
SECTION (4) 252199 - Figure 11



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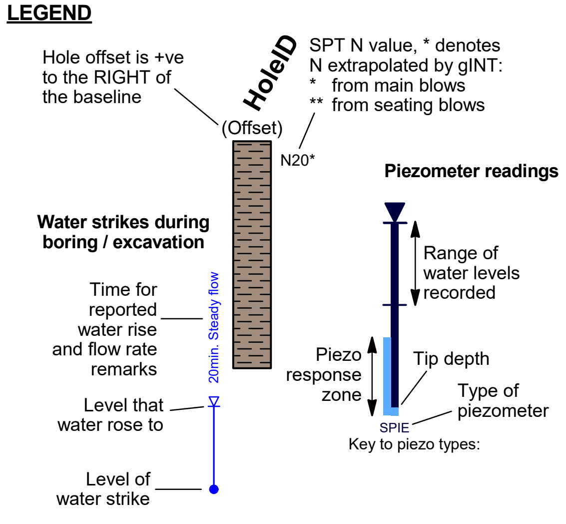

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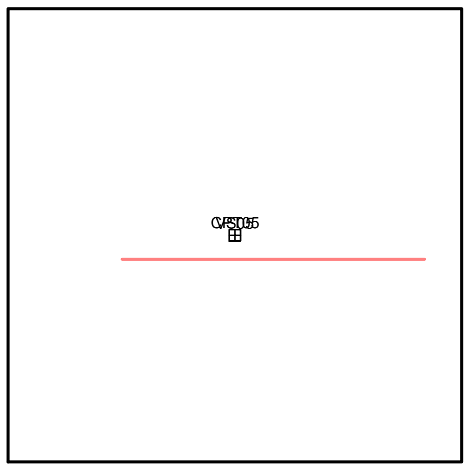


COLOUR LEGEND

- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

MATERIALS

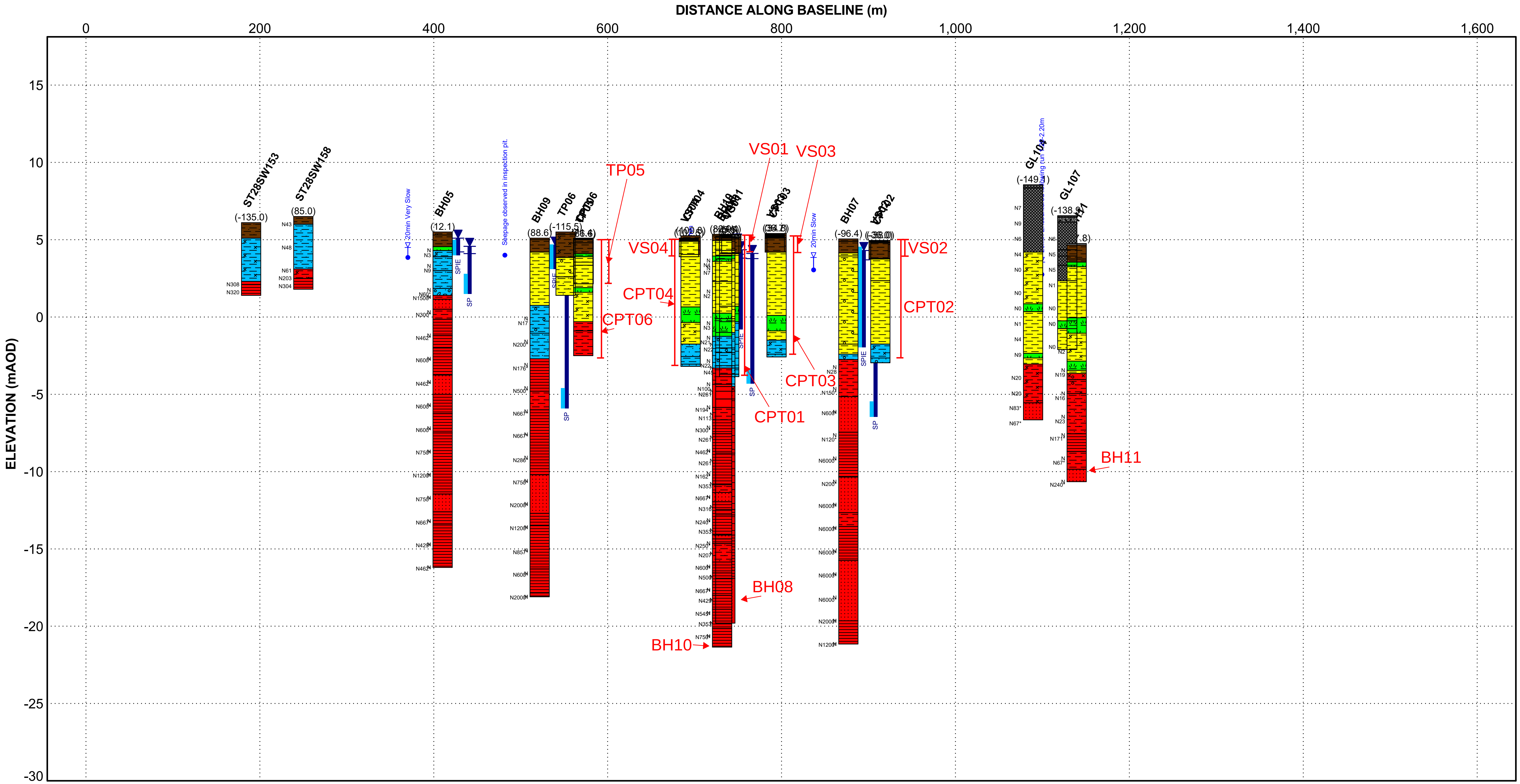
- Made Ground - FILL
- CLAY
- Silty Clay
- Clayey SAND

ARUP gINT v8.30.004
Made by Alex Sadler on 1-Nov-19

CARDIFF PARKWAY

LONG SECTION E-W

SECTION (5) 252199 - Figure 12



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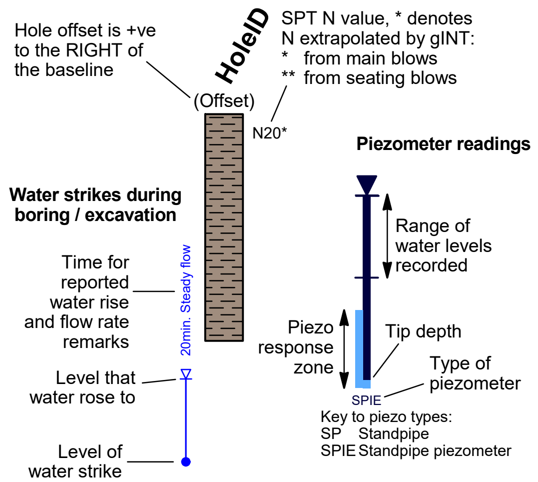

PLAN

COLOUR LEGEND

- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TOPSOIL [TOP]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

MATERIALS

Made Ground - FILL	Sandy CLAY	NO RECOVERY
Silty Clay	Clayey SAND	Gravelly SILT
PEAT	Gravelly SAND	
CLAY	SILT	
SANDSTONE	Sandy GRAVEL	
CONCRETE	MUDSTONE	
Organic CLAY	SILTSTONE	
Gravelly CLAY	Clayey PEAT	

ARUP gINT v8.30.004
Made by Alex Sadler on 1-Nov-19

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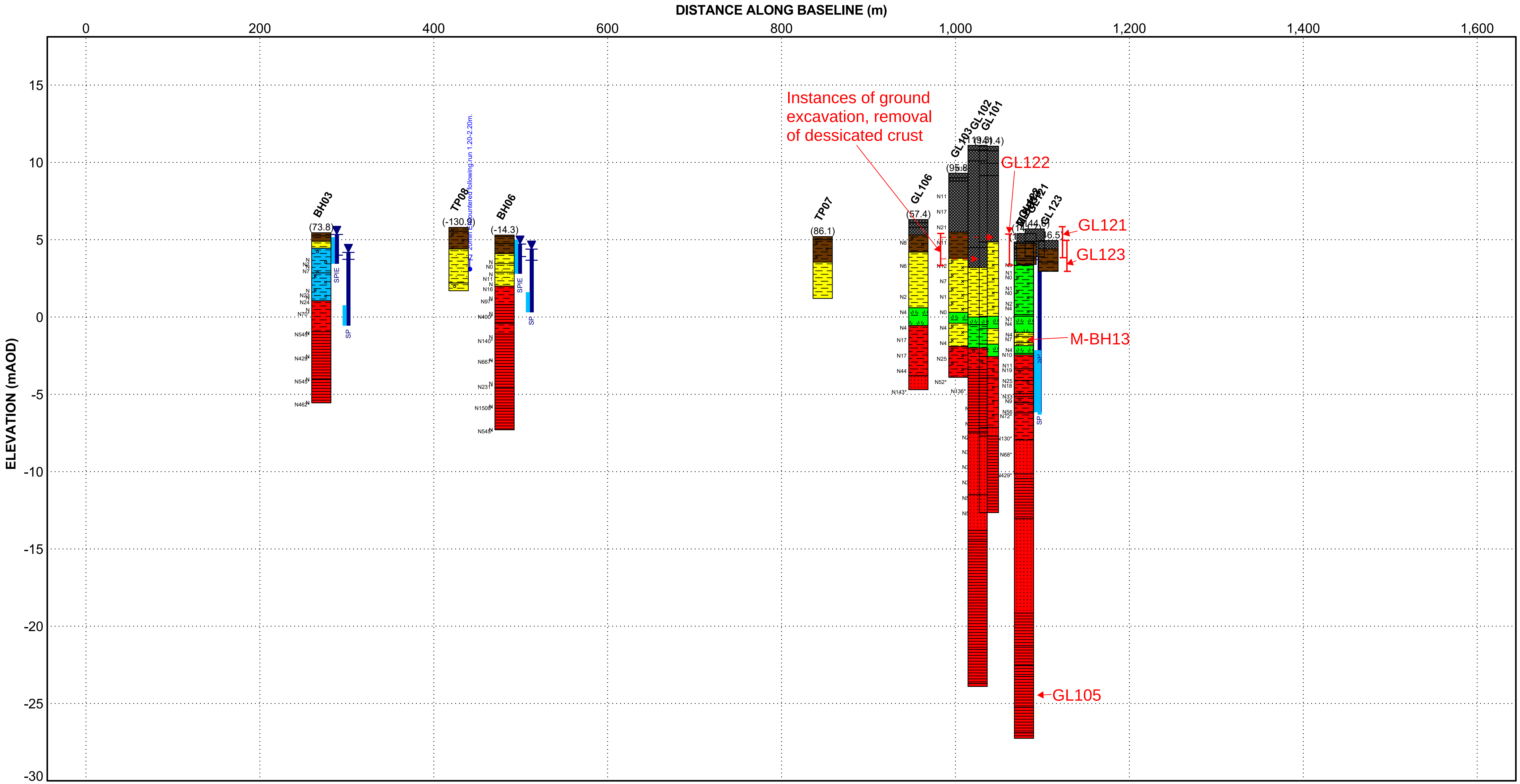
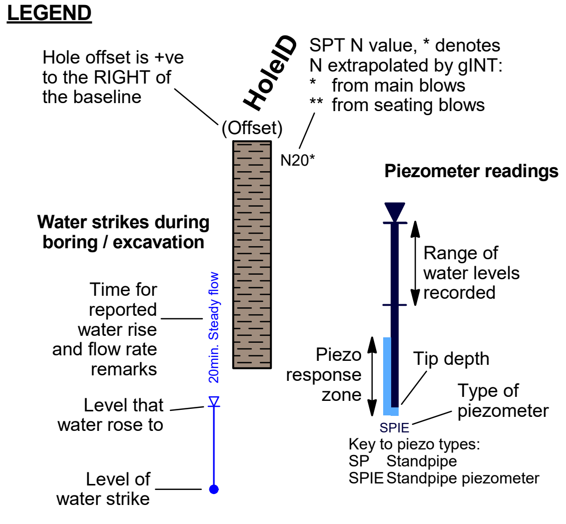
CARDIFF PARKWAY
LONG SECTION E-W
SECTION (6) 252199 - Figure 13

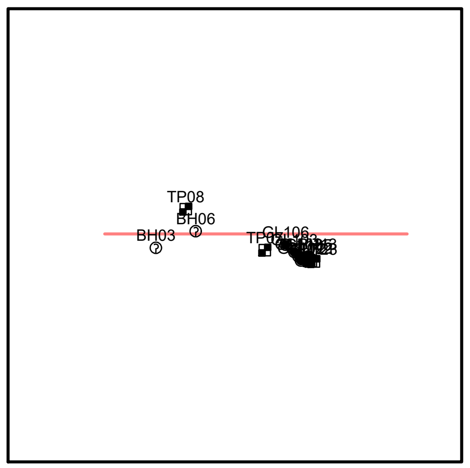


SCALE 1:250V 1:4444H @ A3-L

LEGEND



PLAN



COLOUR LEGEND

- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

MATERIALS

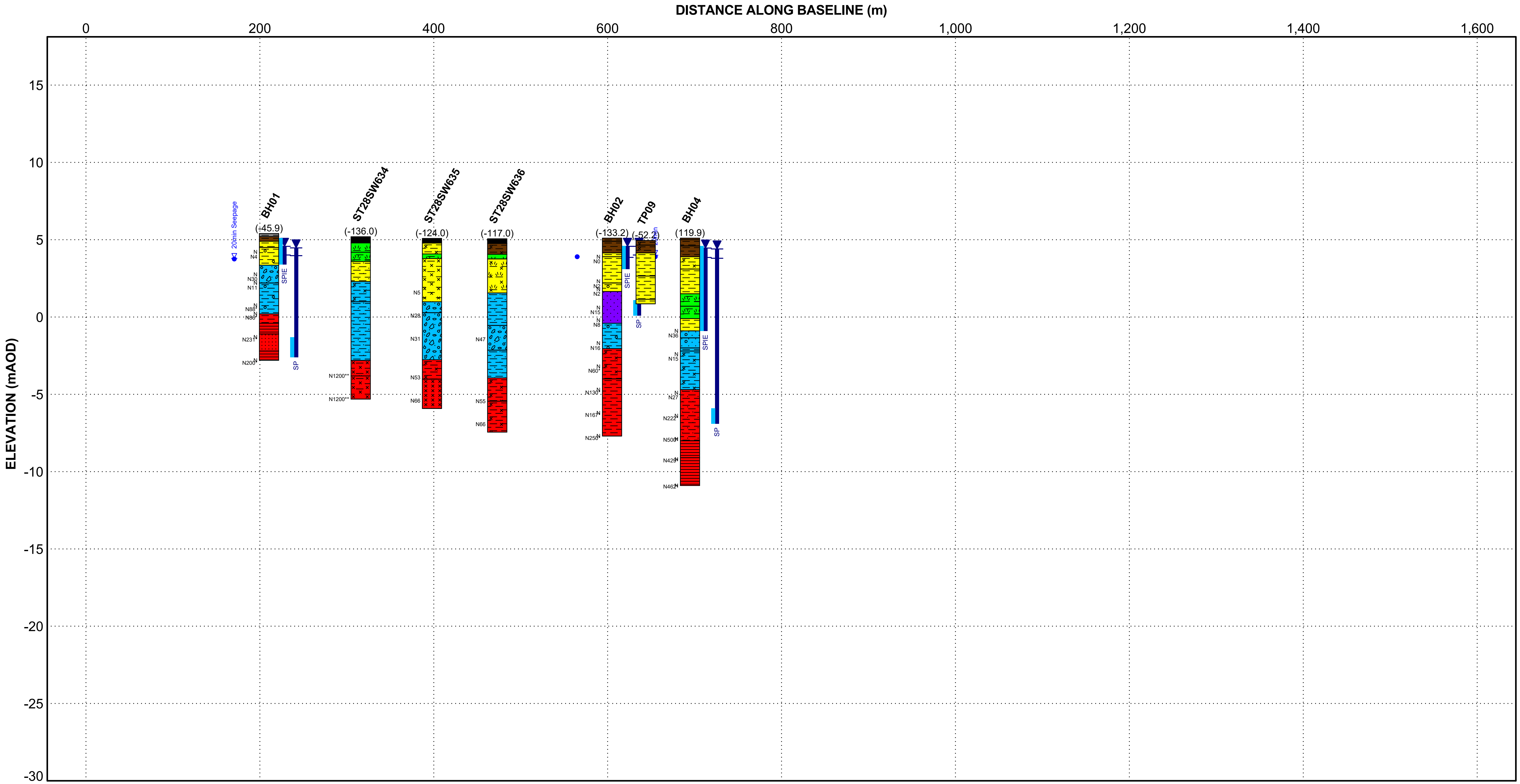
- Made Ground - FILL
- Silty Clay
- PEAT
- CLAY
- Gravelly CLAY
- SANDSTONE
- MUDSTONE
- Sandy CLAY

CARDIFF PARKWAY

LONG SECTION E-W

SECTION (7) 252199 - Figure 14

ARUP gINT v8.30.004
Made by Alex Sadler on 1-Nov-19



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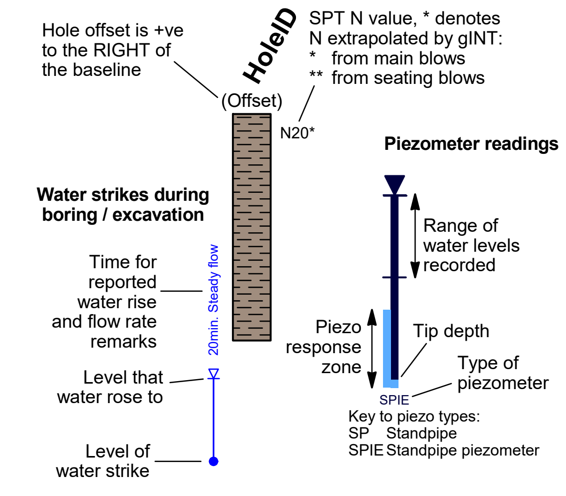
LEGEND



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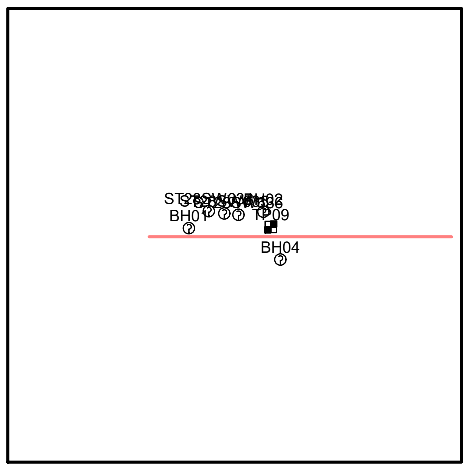


COLOUR LEGEND

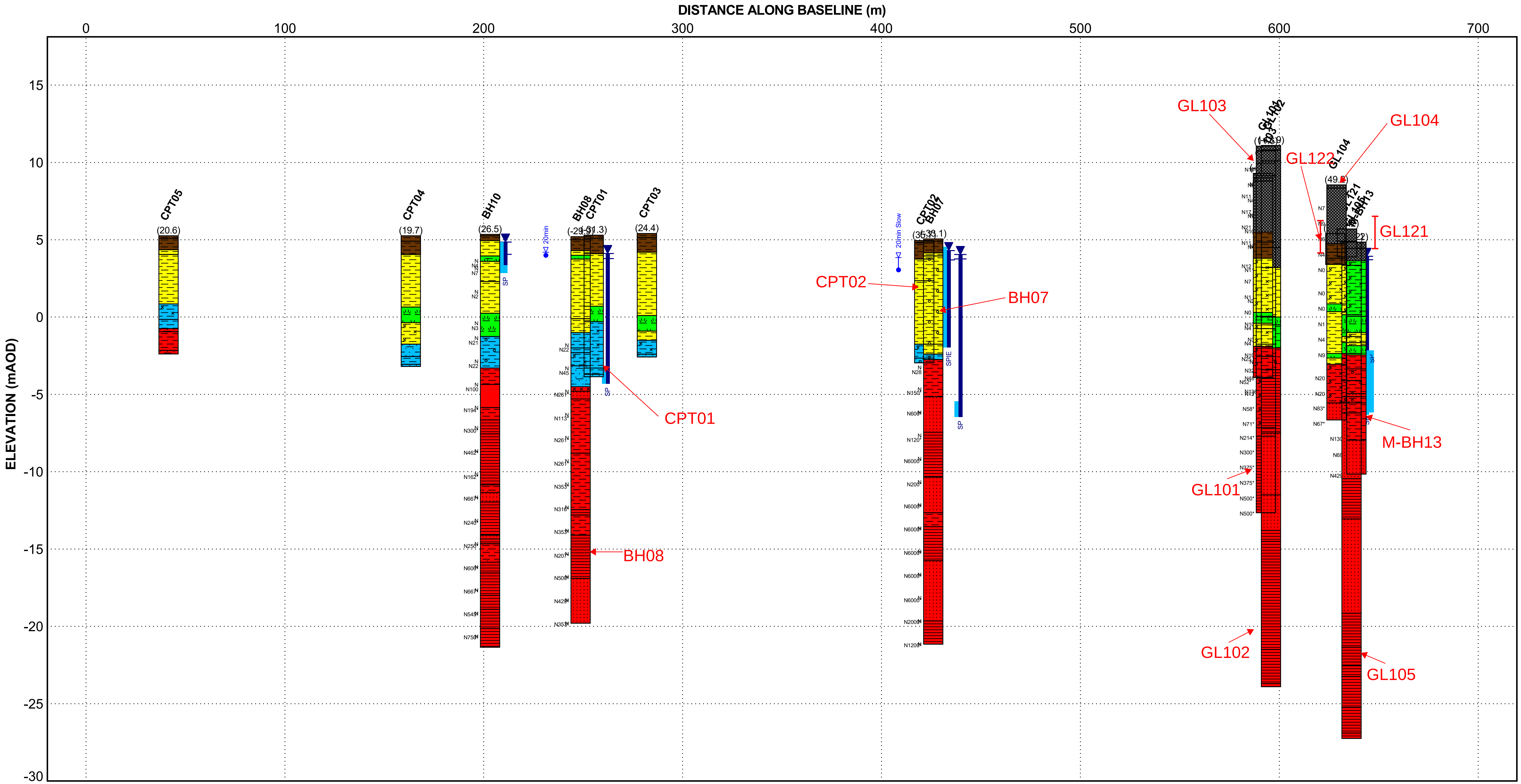
- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- GLACIOFLUVIAL DEPOSITS [GFD]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TOPSOIL [TOP]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

MATERIALS

- Silty Clay
- CLAY
- Organic CLAY
- Gravelly CLAY
- Sandy GRAVEL
- MUDSTONE
- SANDSTONE
- SAND
- Clayey PEAT
- Gravelly SAND
- Sandy CLAY
- TOPSOIL
- PEAT
- Clayey SILT
- SILTSTONE
- Silty PEAT

CARDIFF PARKWAY
LONG SECTION E-W
SECTION (8) 252199 - Figure 15

ARUP gINT v8.30.004
Made by Alex Sadlier on 4-Nov-19



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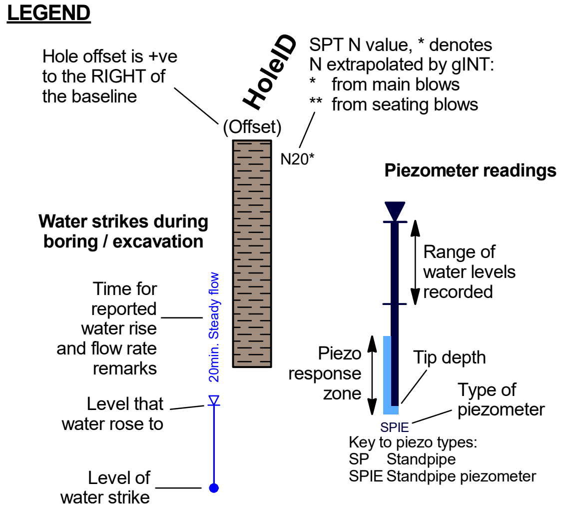
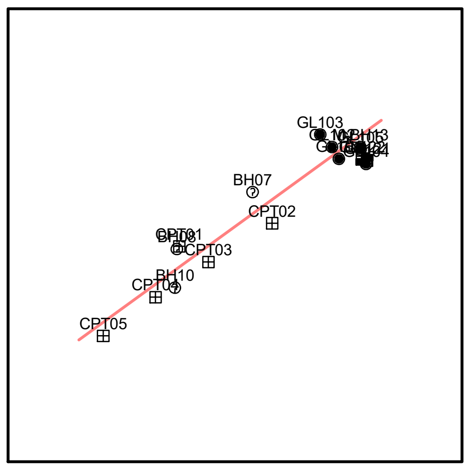
LEGEND



PLAN



COLOUR LEGEND

- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TOPSOIL [TOP]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

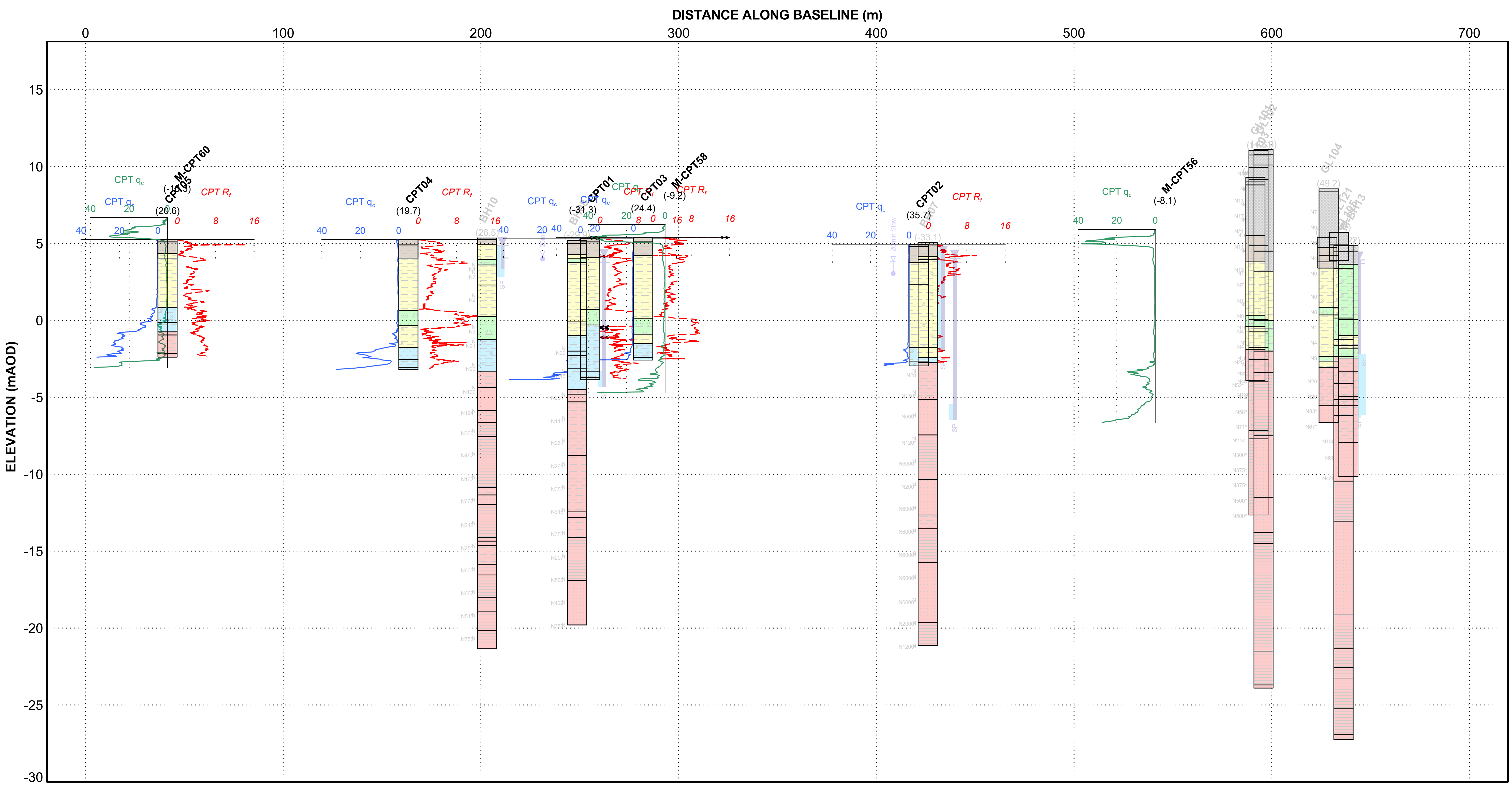
MATERIALS

- Made Ground - FILL
- Silty Clay
- PEAT
- CLAY
- Gravelly CLAY
- SANDSTONE
- MUDSTONE
- Sandy CLAY
- Clayey SAND
- Gravelly SAND
- SILT
- SILTSTONE
- Clayey PEAT
- NO RECOVERY

CARDIFF PARKWAY

LONG SECTION RAIL

SECTION (9) 252199 - Figure 16



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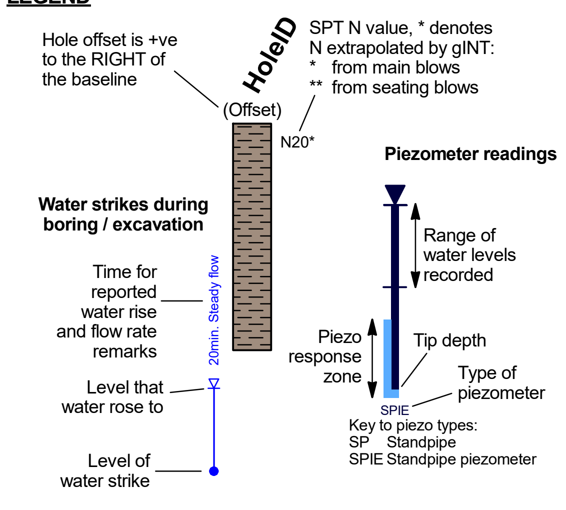
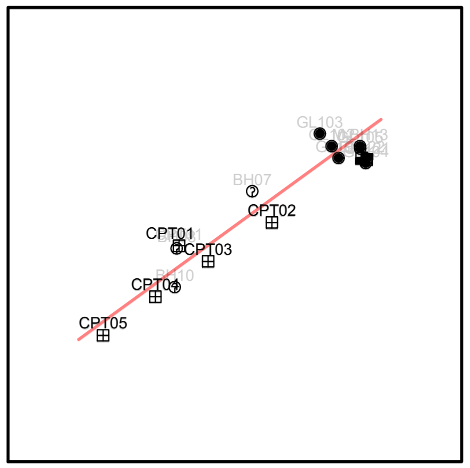


PLAN



COLOUR LEGEND

- TIDAL FLAT DEPOSIT CLAY - FIRM [TFD-F]
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE [UND]
- TOPSOIL [TOP]
- TIDAL FLAT DEPOSIT CLAY - SOFT [TFD]
- TIDAL FLAT DEPOSIT PEAT [PEAT]
- GLACIAL TILL DEPOSIT [GTD]
- MADE GROUND [MADE GROUND]

MATERIALS

- Made Ground - FILL
- Silty Clay
- PEAT
- CLAY
- Gravelly CLAY
- SANDSTONE
- MUDSTONE
- Sandy CLAY
- Clayey SAND
- Gravelly SAND
- SILT
- SILTSTONE
- Clayey PEAT
- NO RECOVERY

CPT

CPT data in GREEN - GWRM

CPT data in BLUE and RED - Initial Ground Investigation

ARUP_gINT v8.30.004
Made by Alex Sadlier on 5-Nov-19

CARDIFF PARKWAY

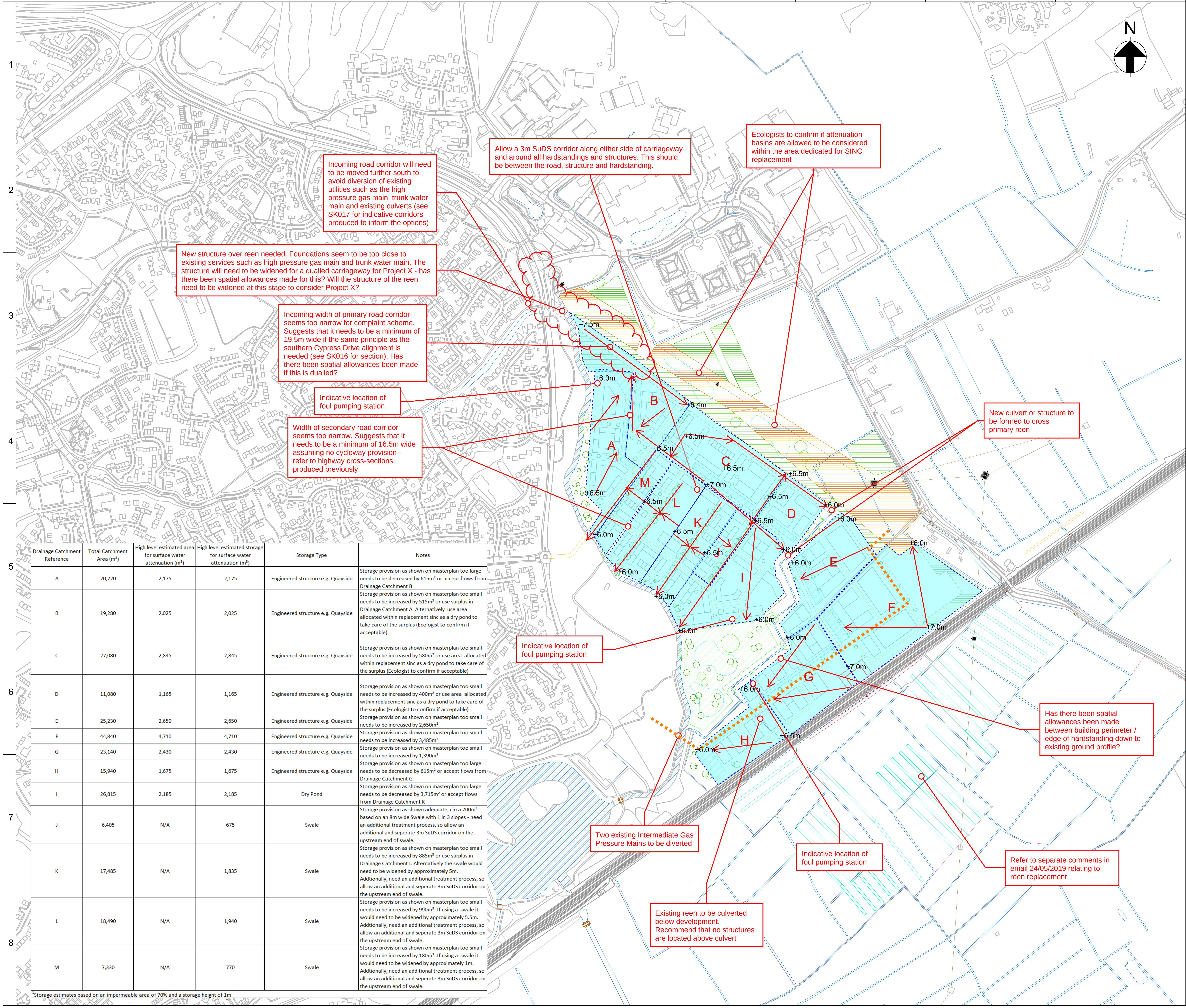
LONG SECTION RAIL w/ CPT

SECTION (10) 252199 - Figure 17

Appendix A

Project Proposal

A2



Drainage Catchment Reference	Total Catchment Area (m²)	High level estimated area for surface water attenuation (m²)	High level estimated storage for surface water attenuation (m³)	Storage Type	Notes
A	20,720	2,175	2,175	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too large needs to be decreased by 615m² or accept flows from Drainage Catchment B
B	19,280	2,025	2,025	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too small needs to be increased by 515m² or use surplus in Drainage Catchment A. Alternatively use area allocated within replacement sinc as a dry pond to take care of the surplus (Ecologist to confirm if acceptable)
C	27,080	2,845	2,845	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too small needs to be increased by 580m² or use area allocated within replacement sinc as a dry pond to take care of the surplus (Ecologist to confirm if acceptable)
D	11,080	1,165	1,165	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too small needs to be increased by 400m² or use area allocated within replacement sinc as a dry pond to take care of the surplus (Ecologist to confirm if acceptable)
E	25,230	2,650	2,650	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too small needs to be increased by 2,650m²
F	44,840	4,710	4,710	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too small needs to be increased by 3,485m²
G	23,140	2,430	2,430	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too small needs to be increased by 1,390m²
H	15,940	1,675	1,675	Engineered structure e.g. Quayside	Storage provision as shown on masterplan too large needs to be decreased by 615m² or accept flows from Drainage Catchment G
I	26,815	2,185	2,185	Dry Pond	Storage provision as shown on masterplan too large needs to be decreased by 3,715m² or accept flows from Drainage Catchment K
J	6,405	N/A	675	Swale	Storage provision as shown adequate, circa 700m³ based on an 8m wide Swale with 1 in 3 slopes - need an additional treatment process, so allow an additional and seperate 3m SuDS corridor on the upstream end of swale.
K	17,485	N/A	1,835	Swale	Storage provision as shown on masterplan too small needs to be increased by 885m³ or use surplus in Drainage Catchment I. Alternatively the swale would need to be widened by approximately 5m. Addtionally, need an additional treatment process, so allow an additional and seperate 3m SuDS corridor on the upstream end of swale.
L	18,490	N/A	1,940	Swale	Storage provision as shown on masterplan too small needs to be increased by 990m³. If using a swale it would need to be widened by approximately 5.5m. Addtionally, need an additional treatment process, so allow an additional and seperate 3m SuDS corridor on the upstream end of swale.
M	7,330	N/A	770	Swale	Storage provision as shown on masterplan too small needs to be increased by 180m³. If using a swale it would need to be widened by approximately 1m. Addtionally, need an additional treatment process, so allow an additional and seperate 3m SuDS corridor on the upstream end of swale.

[1]Storage estimates based on an impermeable area of 70% and a storage height of 1m

Rev	Date	By	Chkd	Appd
X	XX/XX/XX	-	--	---

ARUP

13 Fitzroy Street, London, W1T 4BQ
www.arup.com

Client

Project Title
Project X
17/05/2019

Key Plan

Drawing Title
Masterplan layout

Scale at A2 1:5000

Role

Suitability -

Arup Job No XX-XX-XX

Rev XX

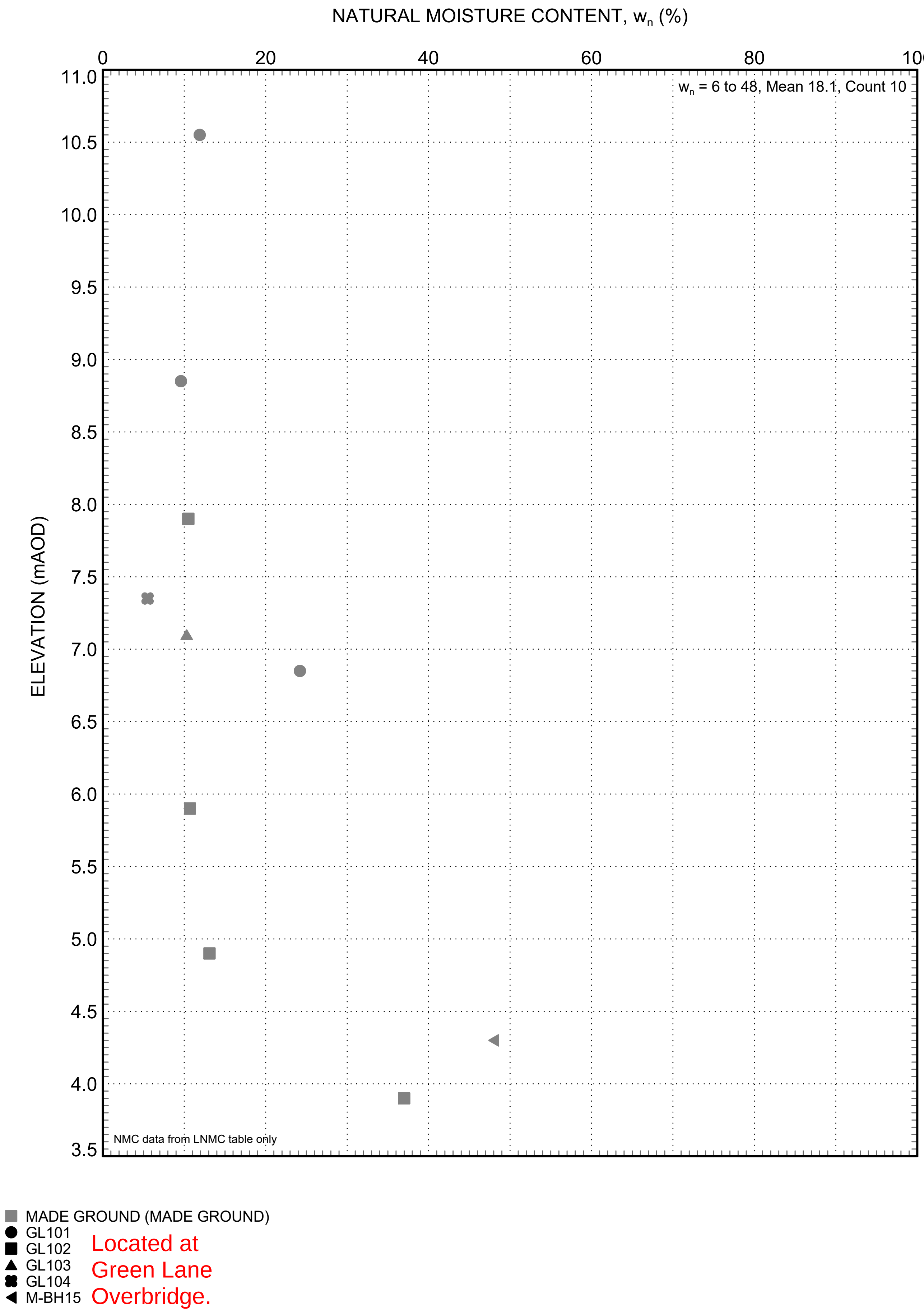
Drawing No

Do not scale

Appendix B

Parameter Plots

B1 Made Ground



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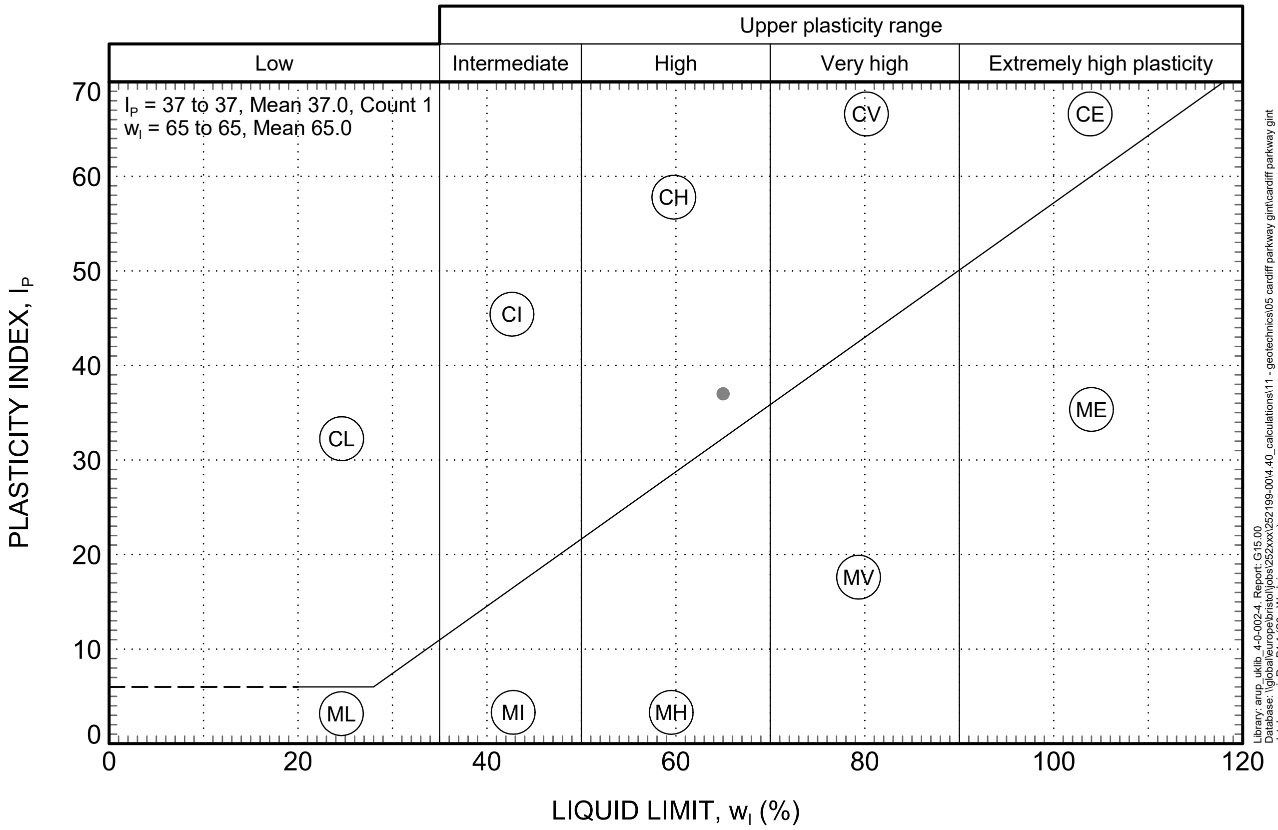
ARUP_gINT v8.30.004
Made by Alex Sadlier on 22-Oct-19

CARDIFF PARKWAY
MOISTURE CONTENT
MADE GROUND

252199 - Plot B.1.1



■ MADE GROUND (MADE GROUND)

● M-BH15, 4.3mOD

Located to the
west of the site

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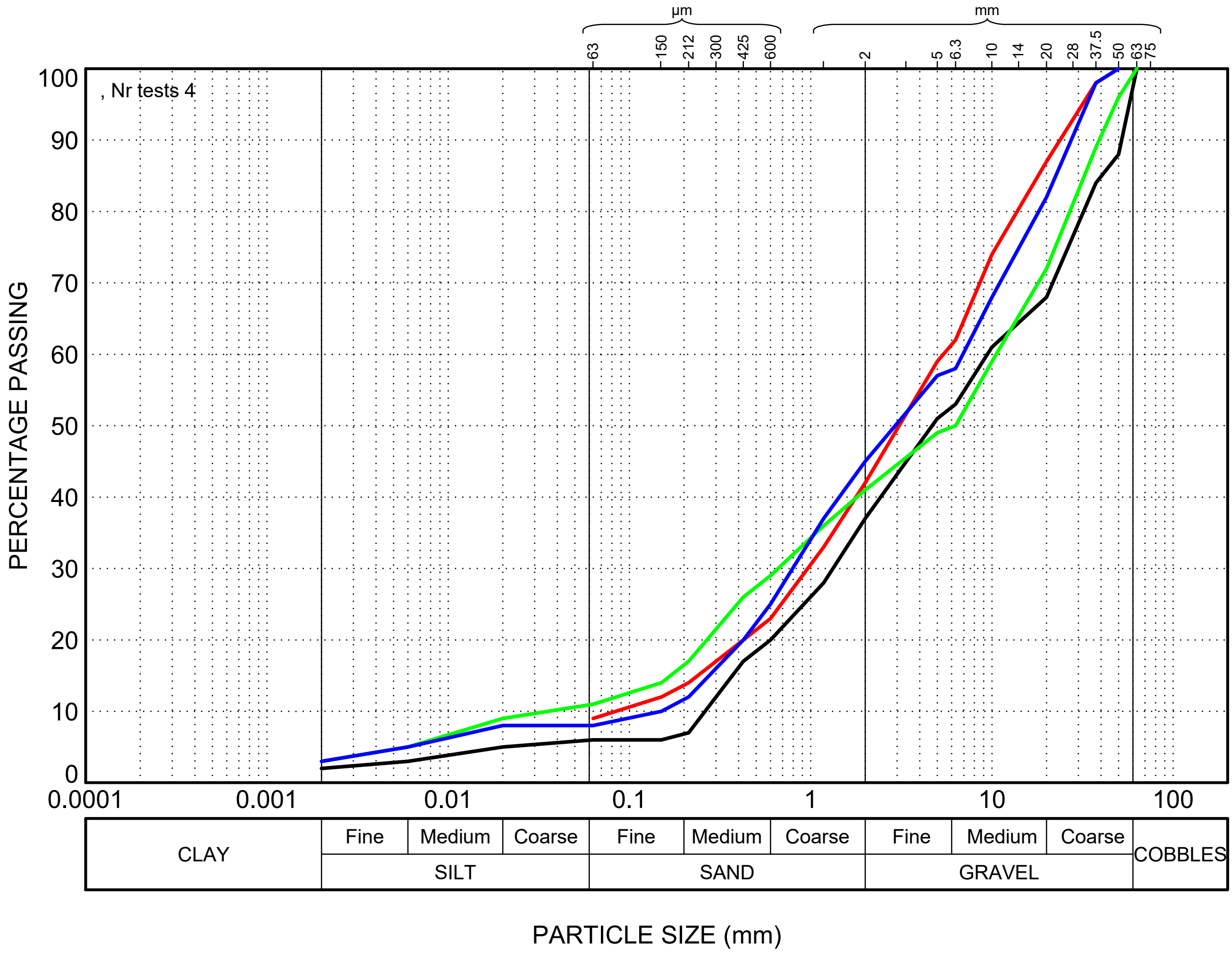
ARUP_gINT v8.30.004
Made by Alex Sadlier on 22-Oct-19

CARDIFF PARKWAY

PLASTICITY CHART

MADE GROUND

252199 - Plot B.1.2



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Filter: None.
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GL101, 6.9mOD
GL102, 7.9mOD
GL103, 7.1mOD
GL104, 7.0mOD

All are located at Green Lane Overbridge.

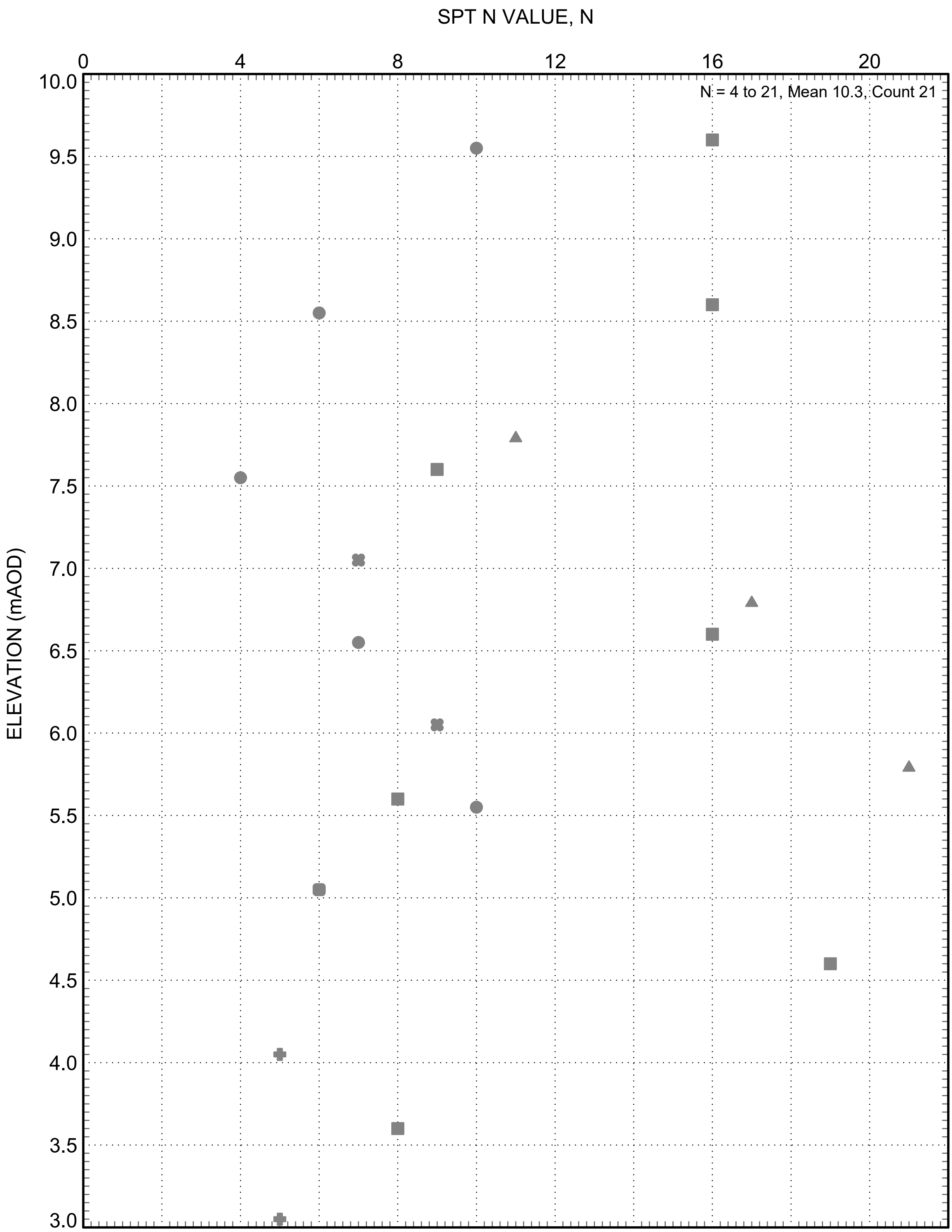
ARUP_gINT v8.30.004
Made by Alex Sadlier on 22-Oct-19

CARDIFF PARKWAY

PSD

MADE GROUND

252199 - Plot B.1.3



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Filter: None.
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], ([GEOL].[GEOL_GEOL] = 'MADE GROUND')
Script: C:\USERS\PUBLIC\DOCUMENTS\BENTLEY\GINT\TEMP\GSC89701.GSC

- ■ MADE GROUND (MADE GROUND)
- ● GL101
- ■ GL102
- ▲ GL103
- ✖ GL104
- ✚ GL107

All are located at Green Lane Overbridge.

ARUP_gINT v8.30.004
Made by Alex Sadlier on 22-Oct-19

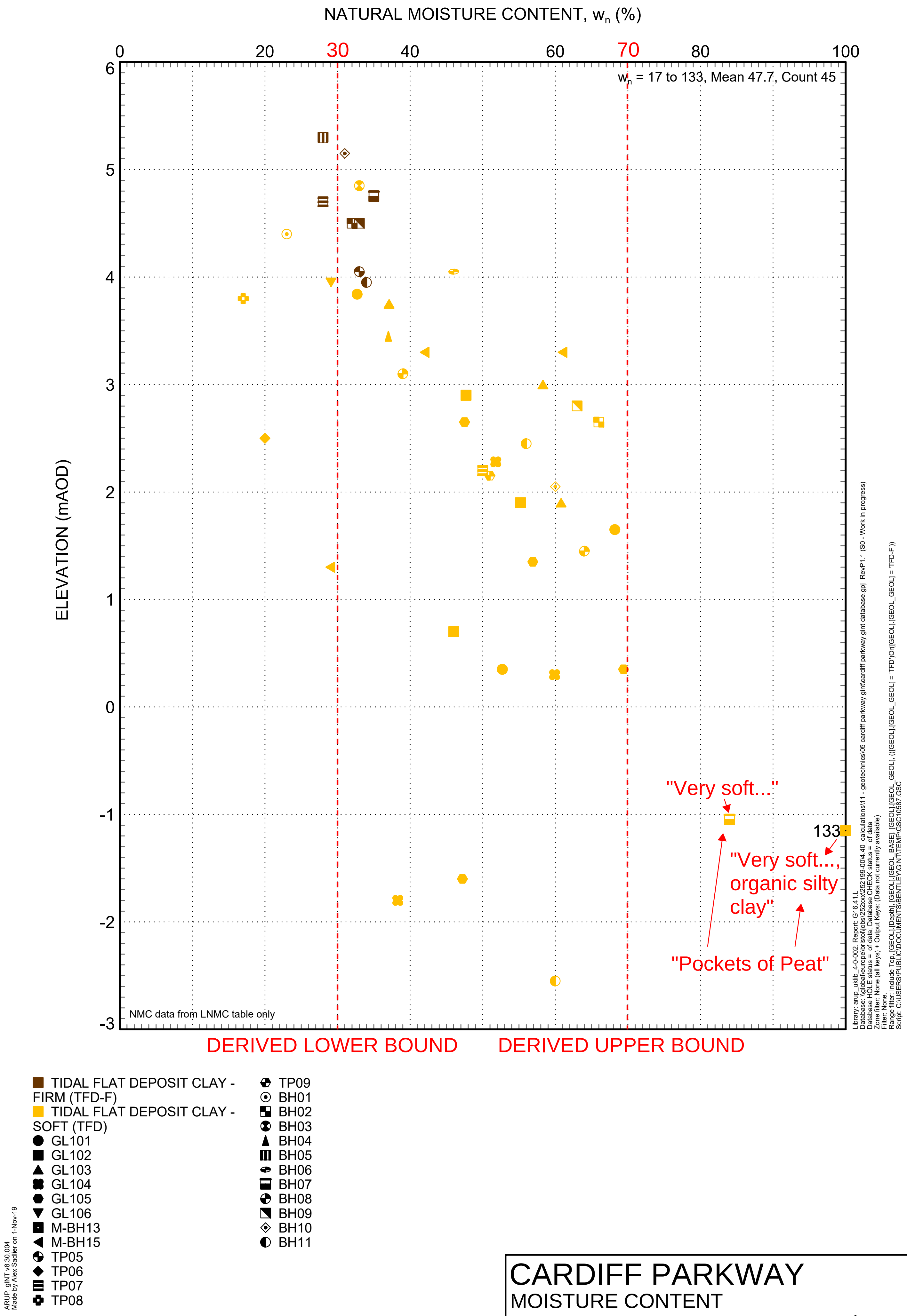
CARDIFF PARKWAY

SPT

MADE GROUND

252199 - Plot B.1.4

B2 Tidal Flat Deposit - Clay

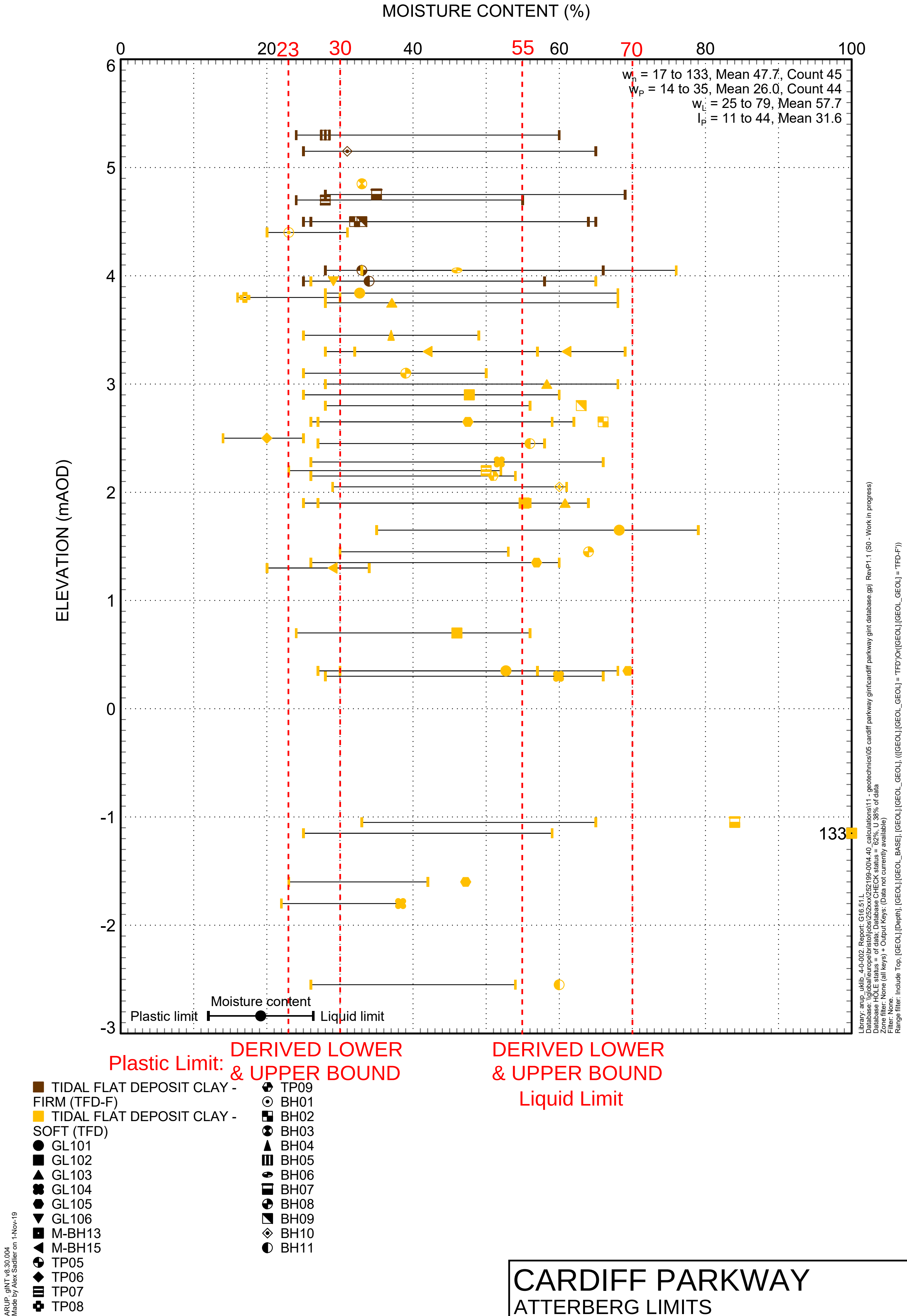


CARDIFF PARKWAY

MOISTURE CONTENT

TFD-CLAY

252199 - Plot B.2.1

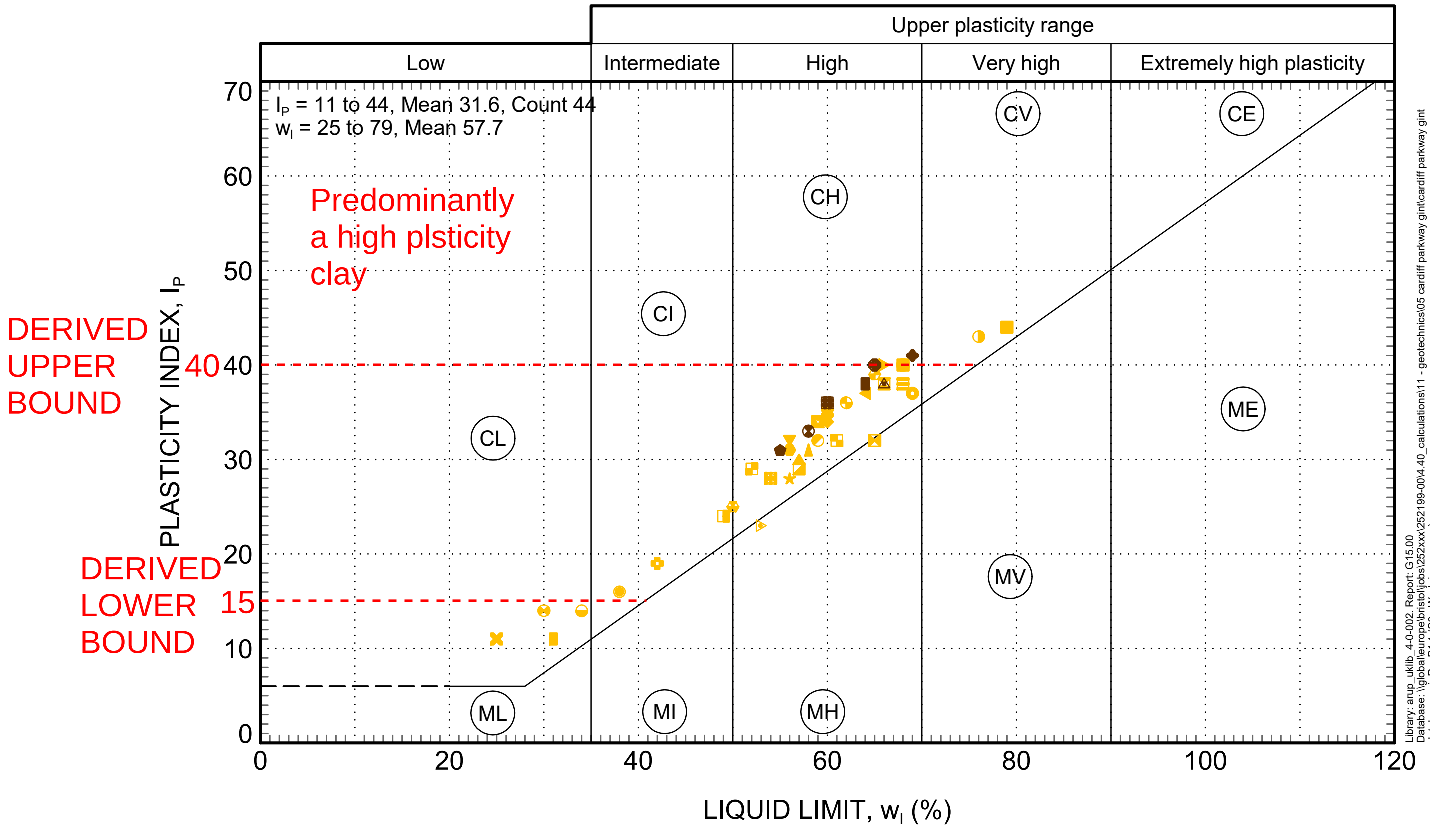


CARDIFF PARKWAY

ATTERBERG LIMITS

TFD-CLAY

252199 - Plot B.2.2



- TIDAL FLAT DEPOSIT CLAY - FIRM (TFD-F)
- TIDAL FLAT DEPOSIT CLAY - SOFT (TFD)
- GL101, 3.8mOD
- GL101, 1.7mOD
- GL101, 0.4mOD
- GL102, 2.9mOD
- GL102, 1.9mOD
- GL102, 0.7mOD
- GL103, 3.8mOD
- GL103, 3.0mOD
- GL103, 1.9mOD
- GL104, 2.3mOD
- GL104, 0.3mOD
- GL104, -1.8mOD
- GL105, 2.7mOD
- GL105, 1.4mOD
- GL105, 0.4mOD
- GL105, -1.6mOD
- GL106, 4.0mOD
- M-BH13, -1.2mOD
- M-BH15, 3.3mOD
- M-BH15, 3.3mOD
- M-BH15, 1.3mOD
- TP05, 4.1mOD
- TP06, 2.5mOD
- TP07, 4.7mOD
- TP07, 2.2mOD
- TP08, 3.8mOD
- TP09, 2.2mOD
- BH01, 4.4mOD
- BH02, 4.5mOD
- BH02, 2.7mOD
- BH04, 3.5mOD
- BH05, 5.3mOD
- BH06, 4.1mOD
- BH07, 4.8mOD
- BH07, -1.1mOD
- BH08, 3.1mOD
- BH08, 1.5mOD
- BH09, 4.5mOD
- BH09, 2.8mOD
- BH10, 5.2mOD
- BH10, 2.1mOD
- BH11, 4.0mOD
- BH11, 2.5mOD
- BH11, -2.6mOD

Library: arup_uklib_4-0-002. Report: G15.00
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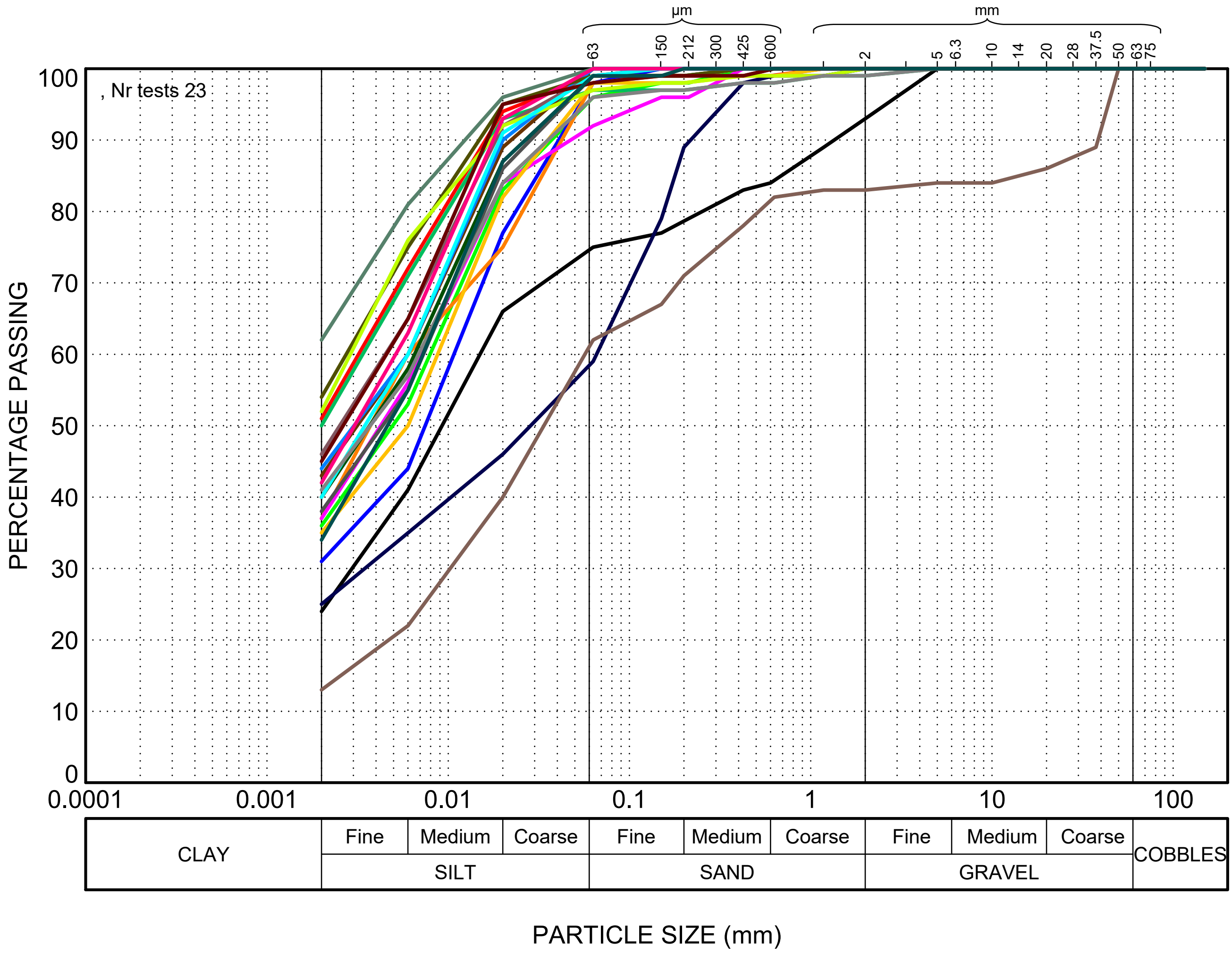
Filter: None.
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], (([GEOL].[GEOL_GEOL] = 'TFD')Or([GEOL].[GEOL_GEOL] = 'TFD-F'))
Script: C:\USERS\PUBLIC\DOCUMENTS\BENTLEY\GINT\TEMP\GSC10587.GSC

ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY
PLASTICITY CHART
TFD-CLAY

252199 - Plot B.2.3



- GL101, 0.4mOD
- GL103, 3.5mOD
- GL103, 1.6mOD
- GL103, -0.4mOD
- GL104, 3.7mOD
- GL105, 2.2mOD
- TP05, 4.1mOD
- TP06, 2.5mOD
- TP07, 4.7mOD
- TP07, 2.2mOD
- TP09, 2.2mOD
- BH01, 4.4mOD
- BH02, 2.6mOD
- BH04, 3.5mOD
- BH05, 5.3mOD
- BH06, 4.0mOD
- BH07, 4.8mOD
- BH07, -1.1mOD
- BH08, 1.2mOD
- BH09, 2.5mOD
- BH10, 2.2mOD
- BH11, 2.5mOD
- BH11, -2.6mOD

Library: arup_uklib_4-0-002. Report: G10B.00
Database: i:\bristol\jobs\252xxx\252199-00\4.40_calculations\11 - geotechnics\05 cardiff parkway gint\cardiff parkway gint database.gpj RevP1.1 (S0 - Work in progress)
Database HOLE status = of data; Database CHECK status = 74%, U 26% of data
Zone filter: None (all keys) + Output Keys: (Data not currently available)
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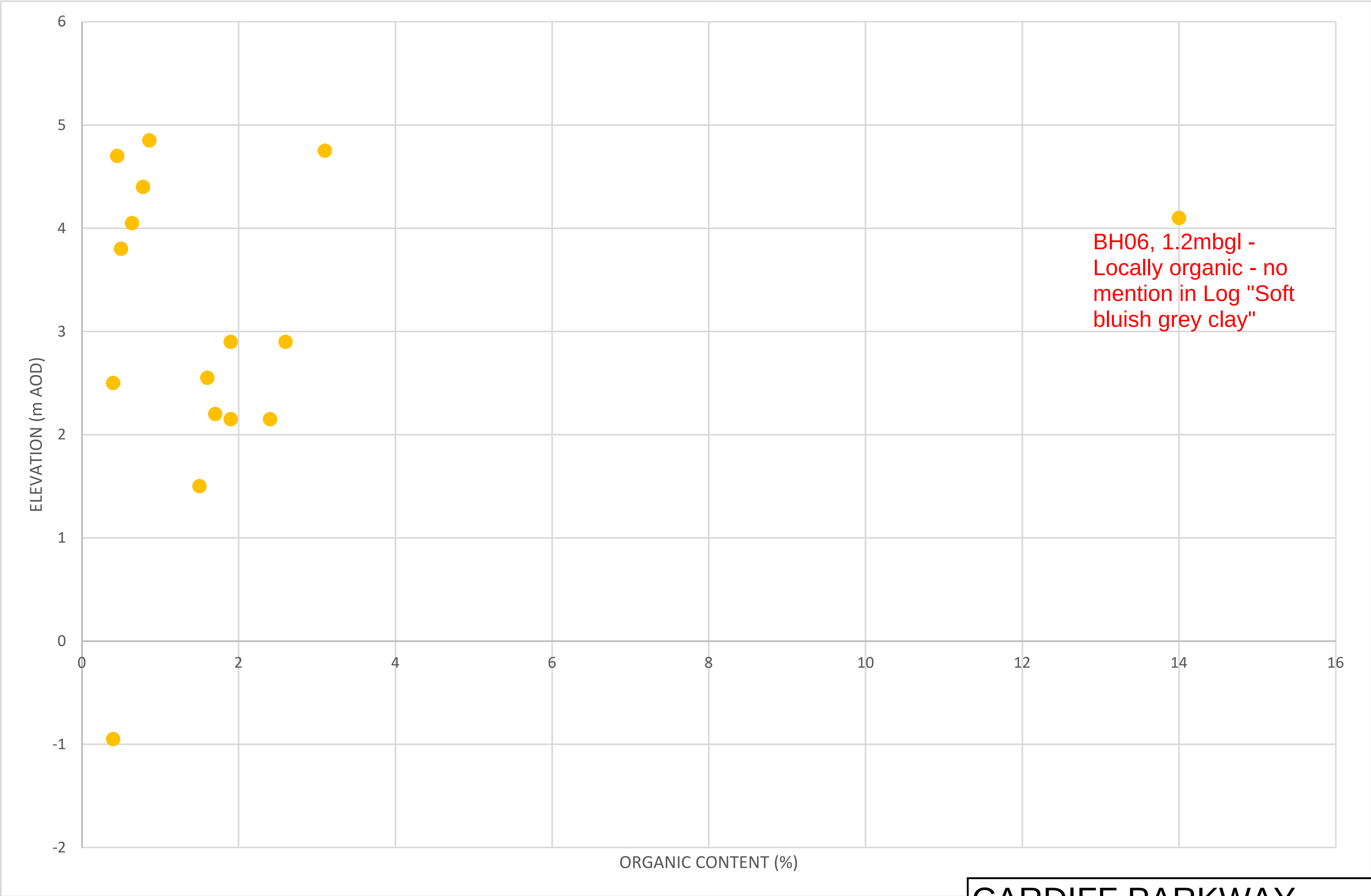
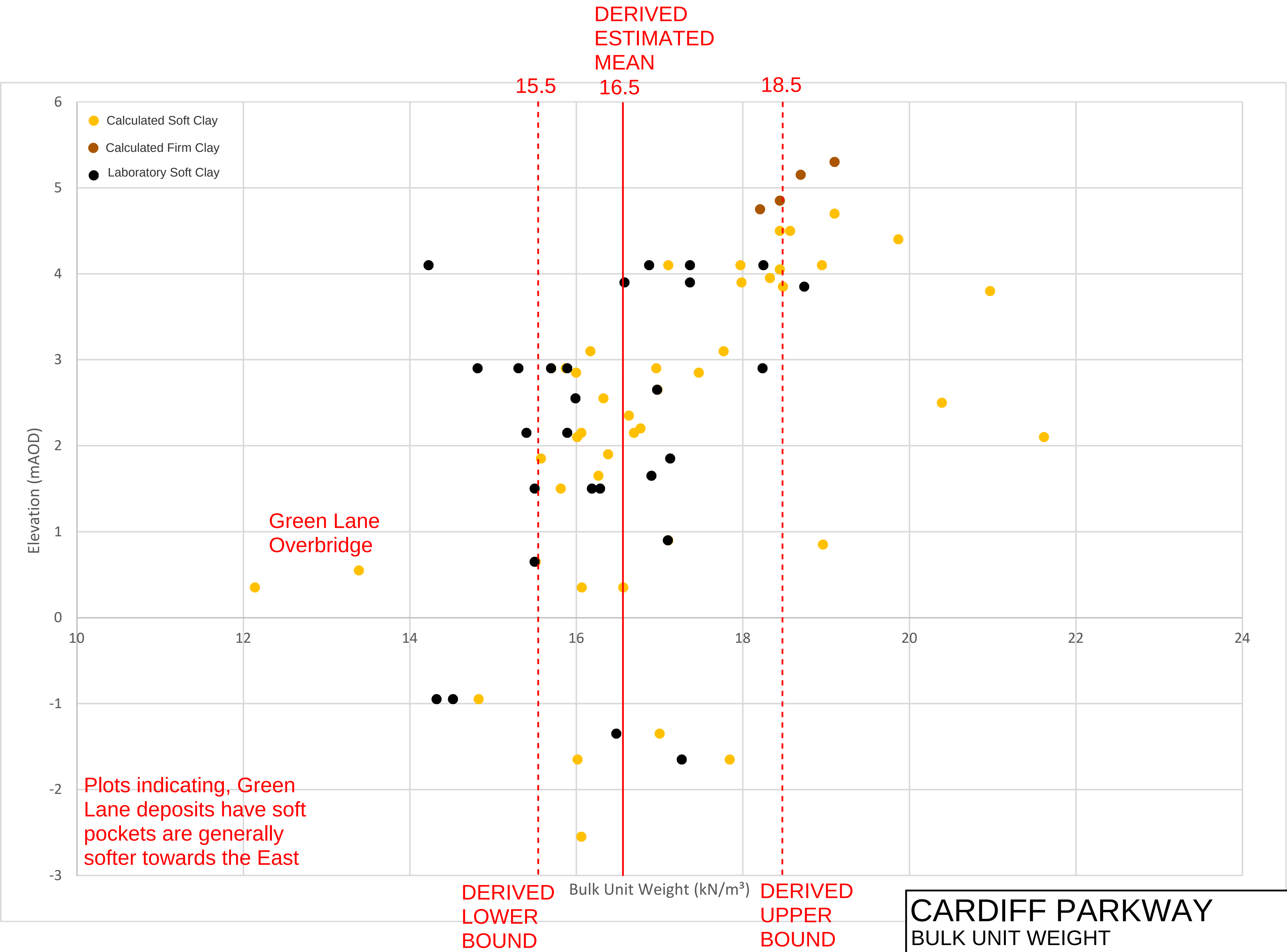
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], (([GEOL].[GEOL_GEOL] = 'TFD')Or([GEOL].[GEOL_GEOL] = 'TFD-F'))
Script: C:\USERS\PUBLIC\DOCUMENTS\BENTLEY\GINT\TEMP\GSC10587.GSC

ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

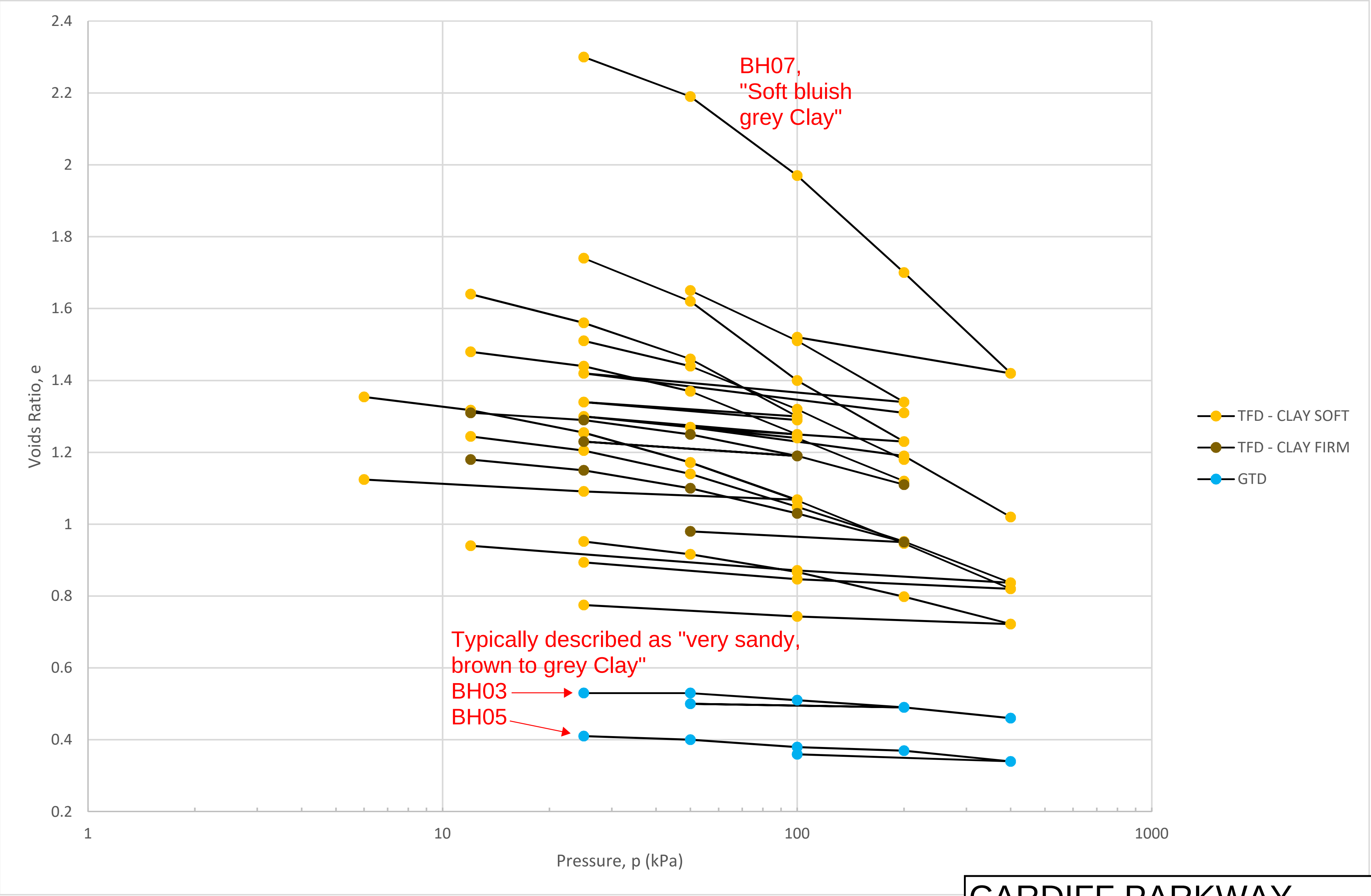
CARDIFF PARKWAY
PARTICLE SIZE DISTRIBUTION
TFD-CLAY 252199 - Plot B.2.4



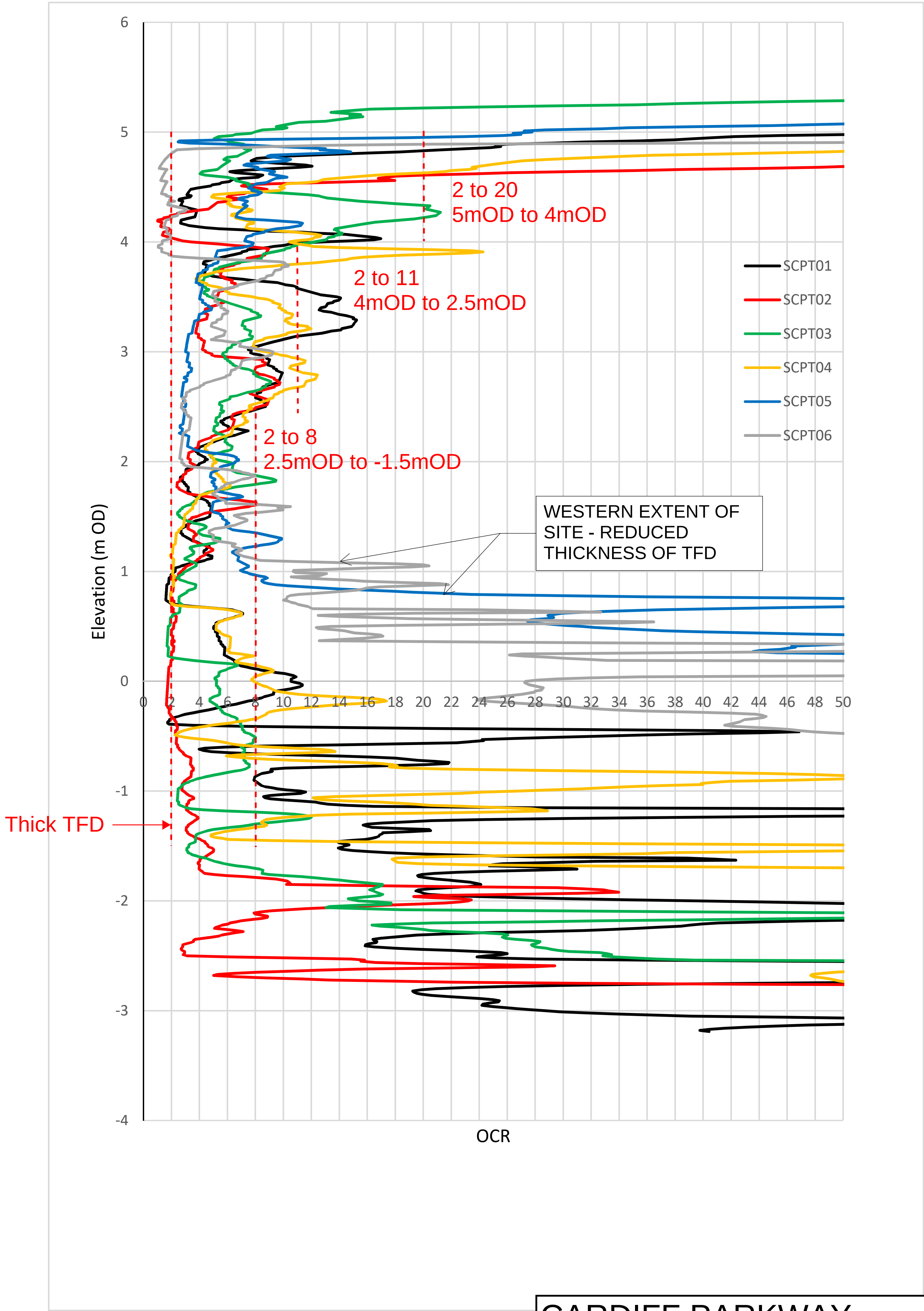
CARDIFF PARKWAY
ORGANIC CONTENT
TFD-CLAY
252199 - Plot B.2.5



CARDIFF PARKWAY
BULK UNIT WEIGHT
TFD-CLAY
252199 - Plot B.2.6



CARDIFF PARKWAY
OEDOMETER TESTS
TFD-CLAY
252199 - Plot B.2.7

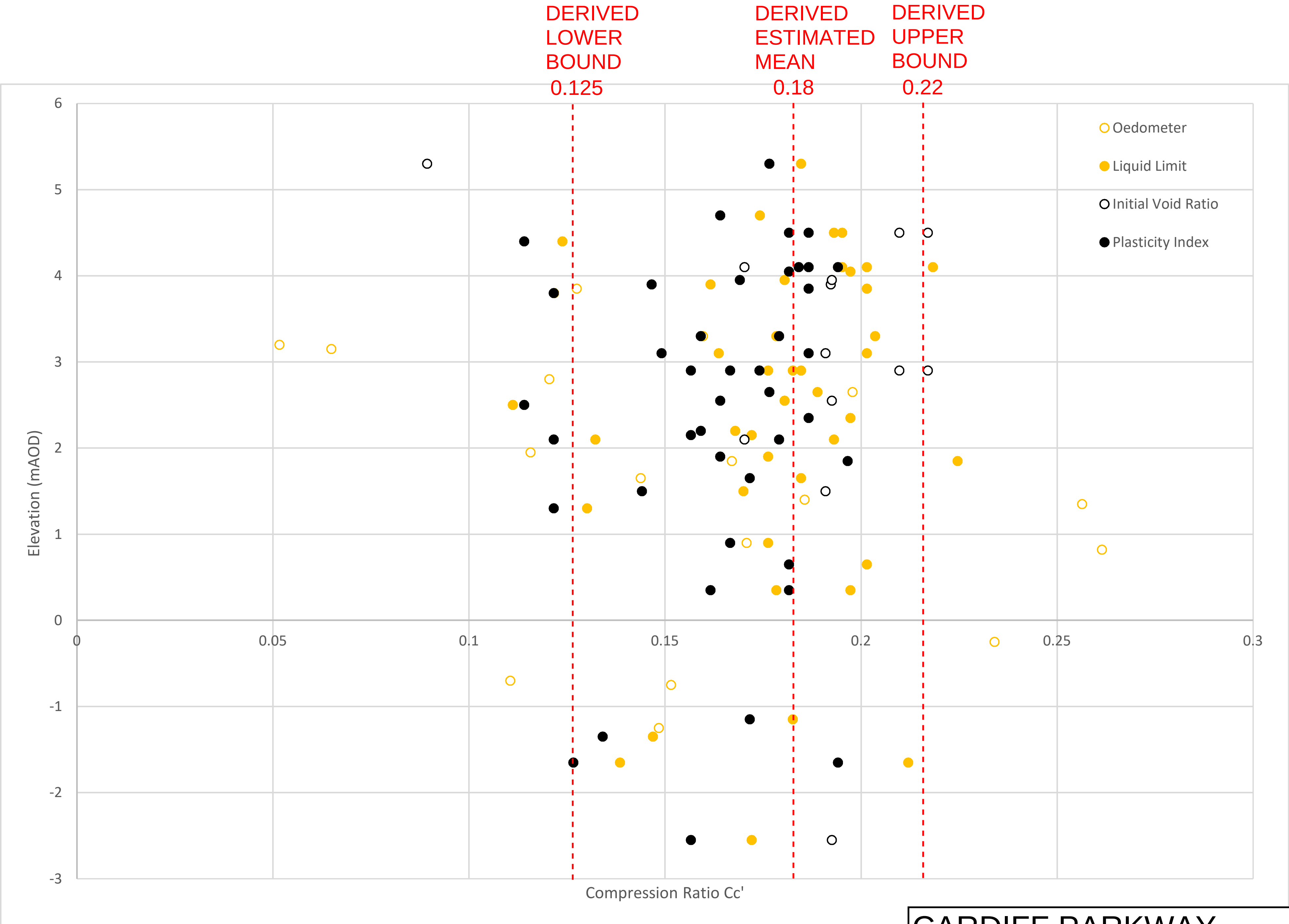


CARDIFF PARKWAY

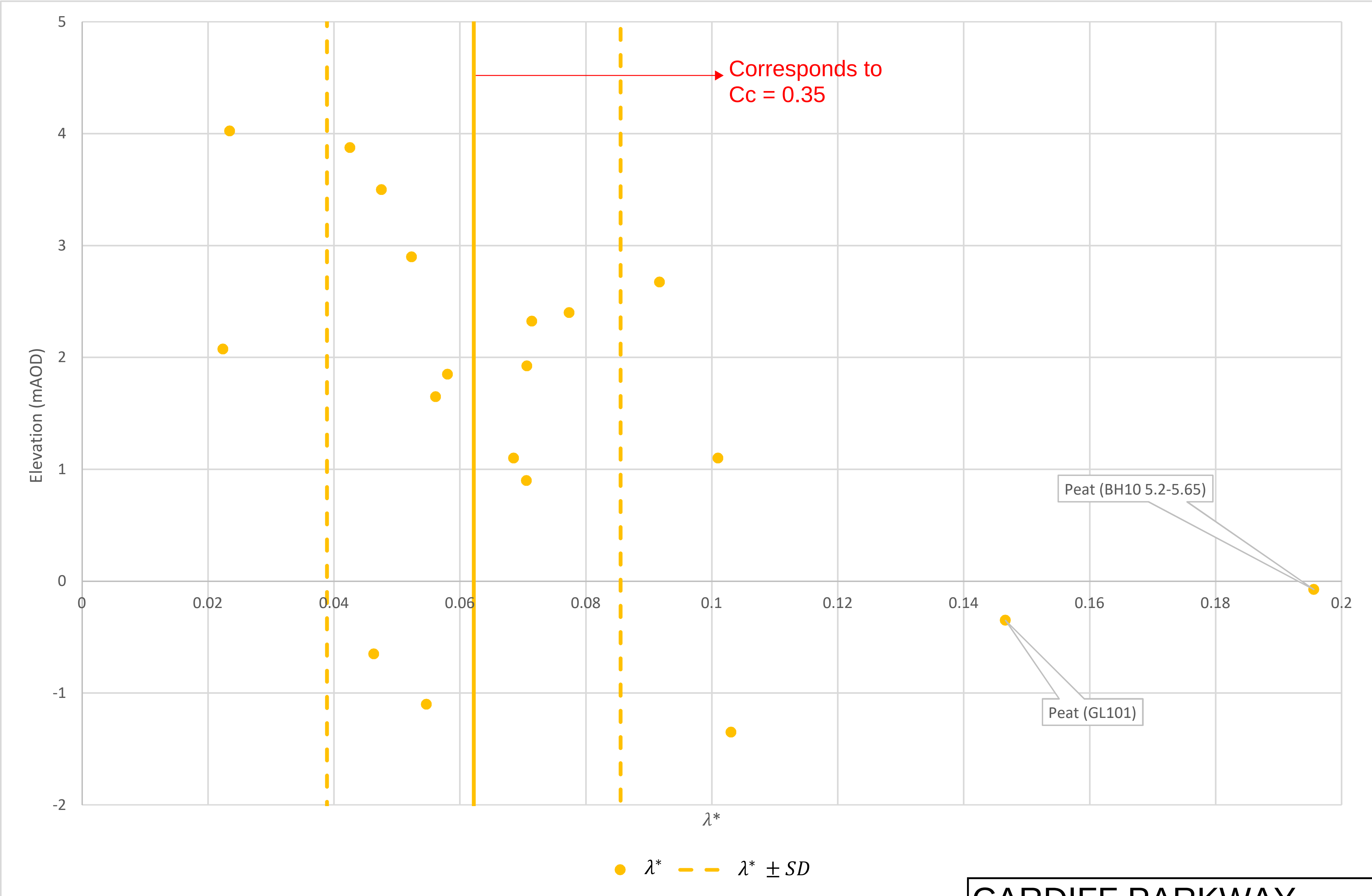
OCR PROFILE

TFD-CLAY

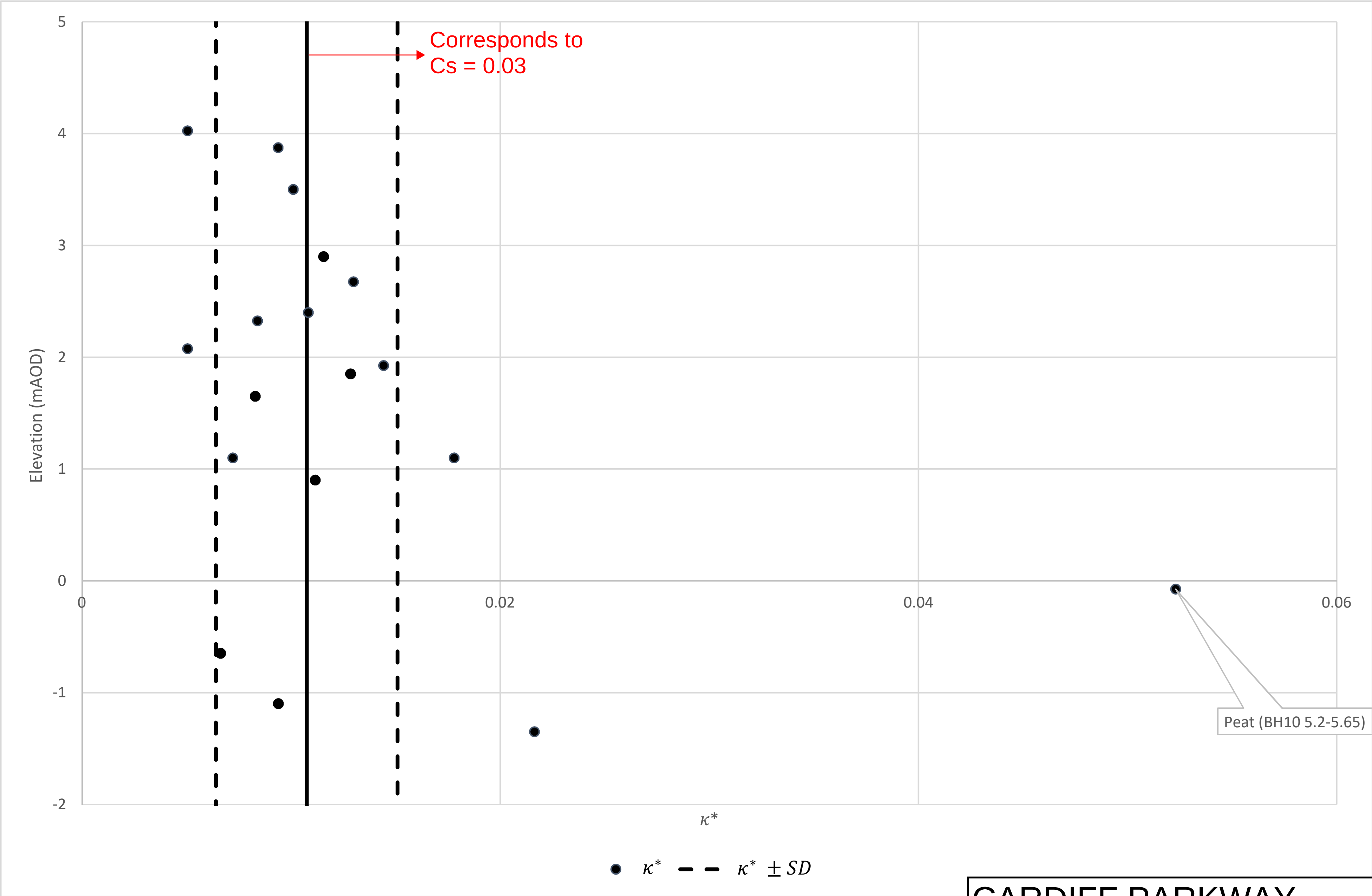
252199 - Plot B.2.8



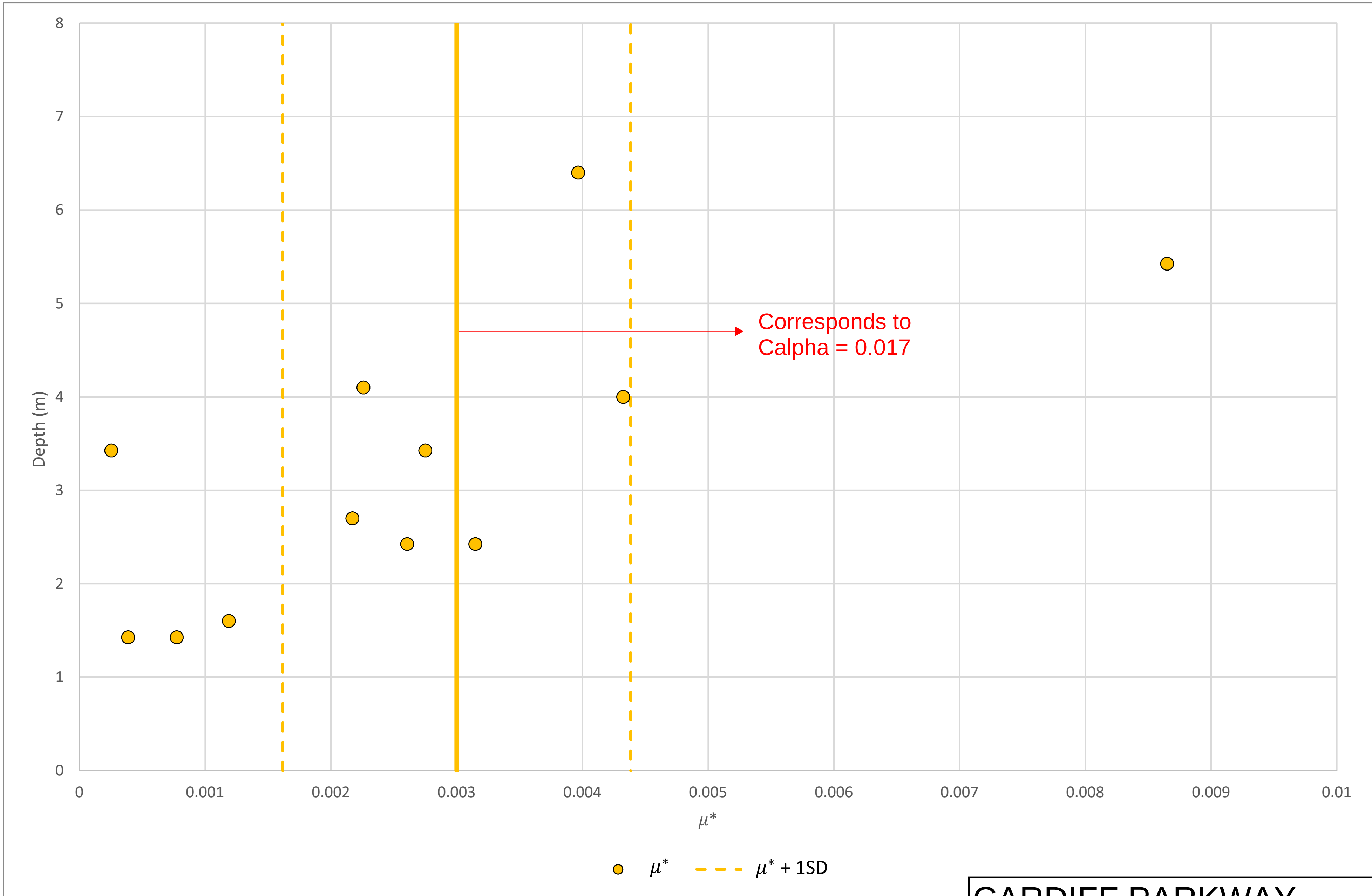
CARDIFF PARKWAY
Cc' with ELEVATION
TFD-CLAY
252199 - Plot B.2.9



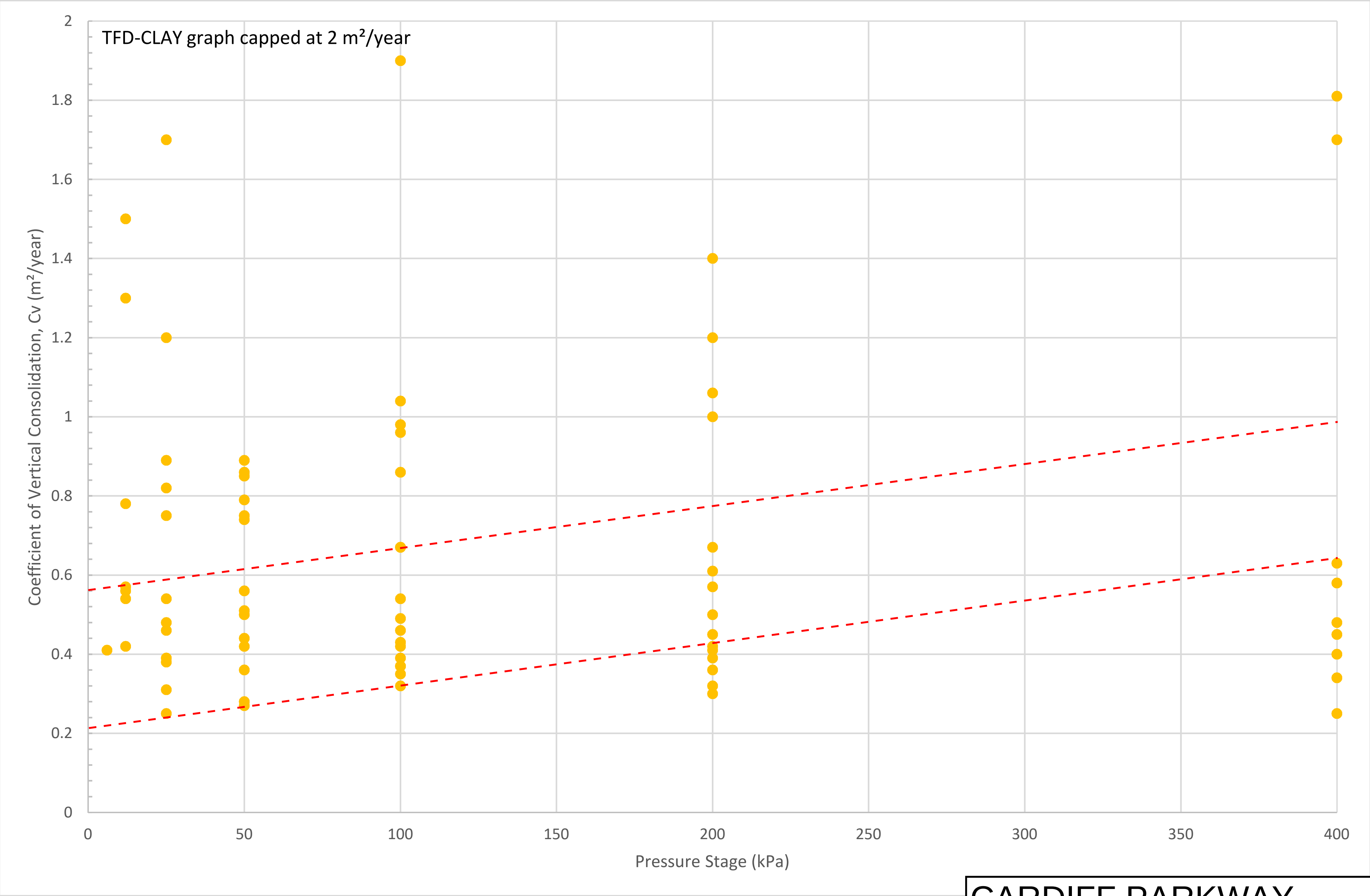
CARDIFF PARKWAY
MODIFIED COMPRESSION INDEX
TFD-CLAY 252199 - Plot B.2.10



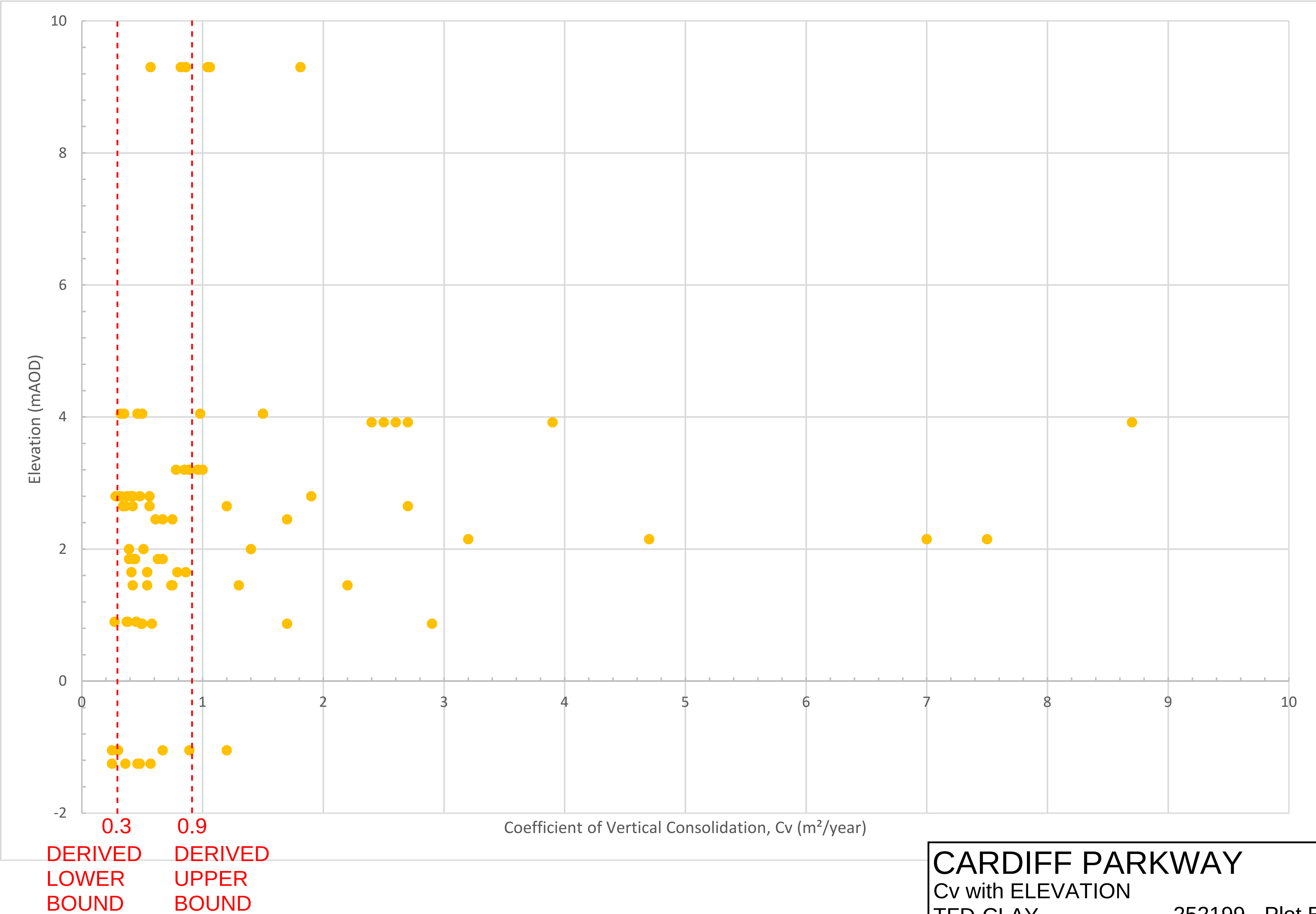
CARDIFF PARKWAY
MODIFIED SWELLING INDEX
TFD-CLAY 252199 - Plot B.2.11



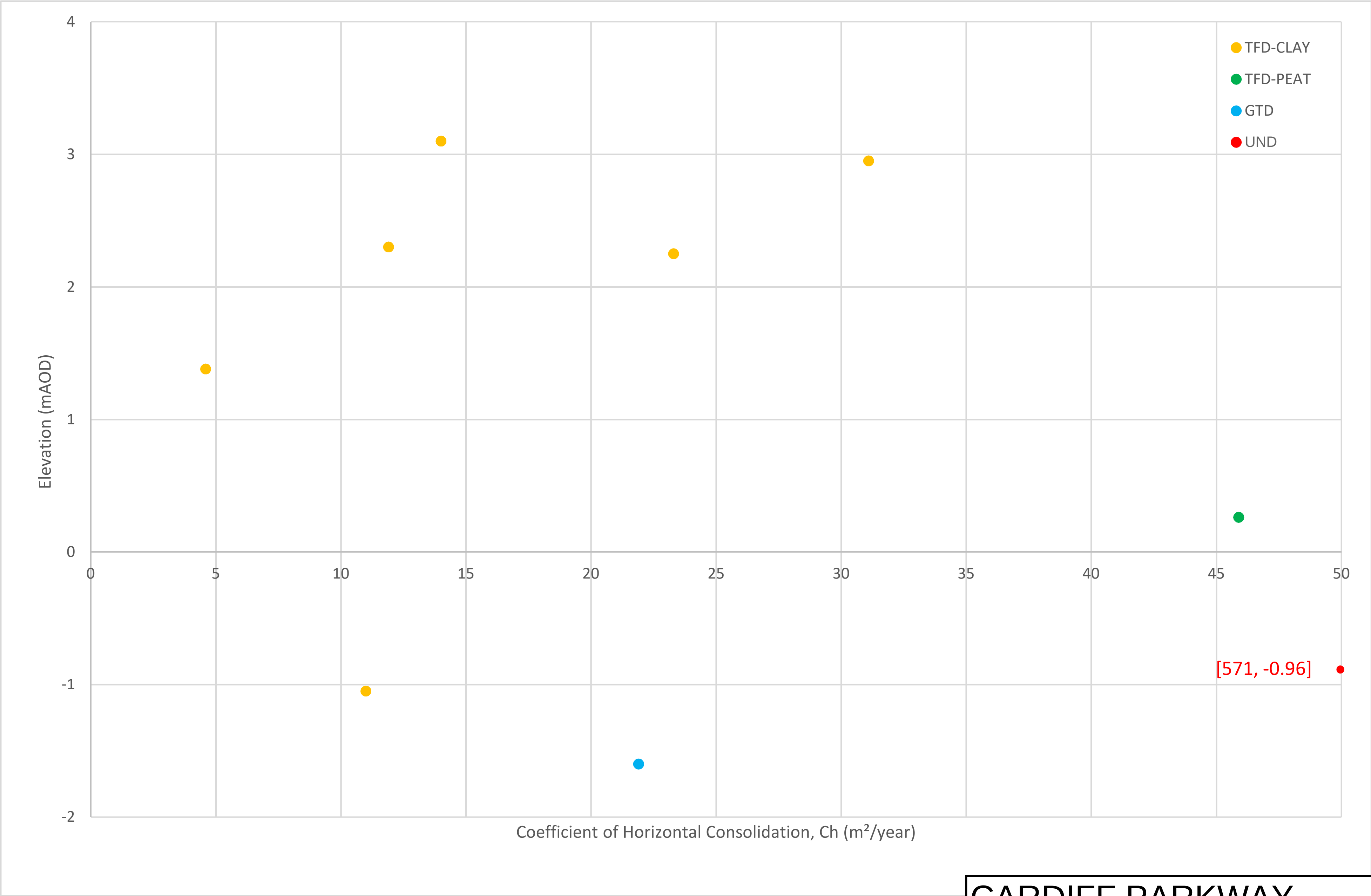
CARDIFF PARKWAY
MODIFIED CREEP INDEX
TFD-CLAY 252199 - Plot B.2.12



CARDIFF PARKWAY
Cv with PRESSURE STAGE
TFD-CLAY 252199 - Plot B.2.13



CARDIFF PARKWAY
Cv with ELEVATION
TFD-CLAY
252199 - Plot B.2.14

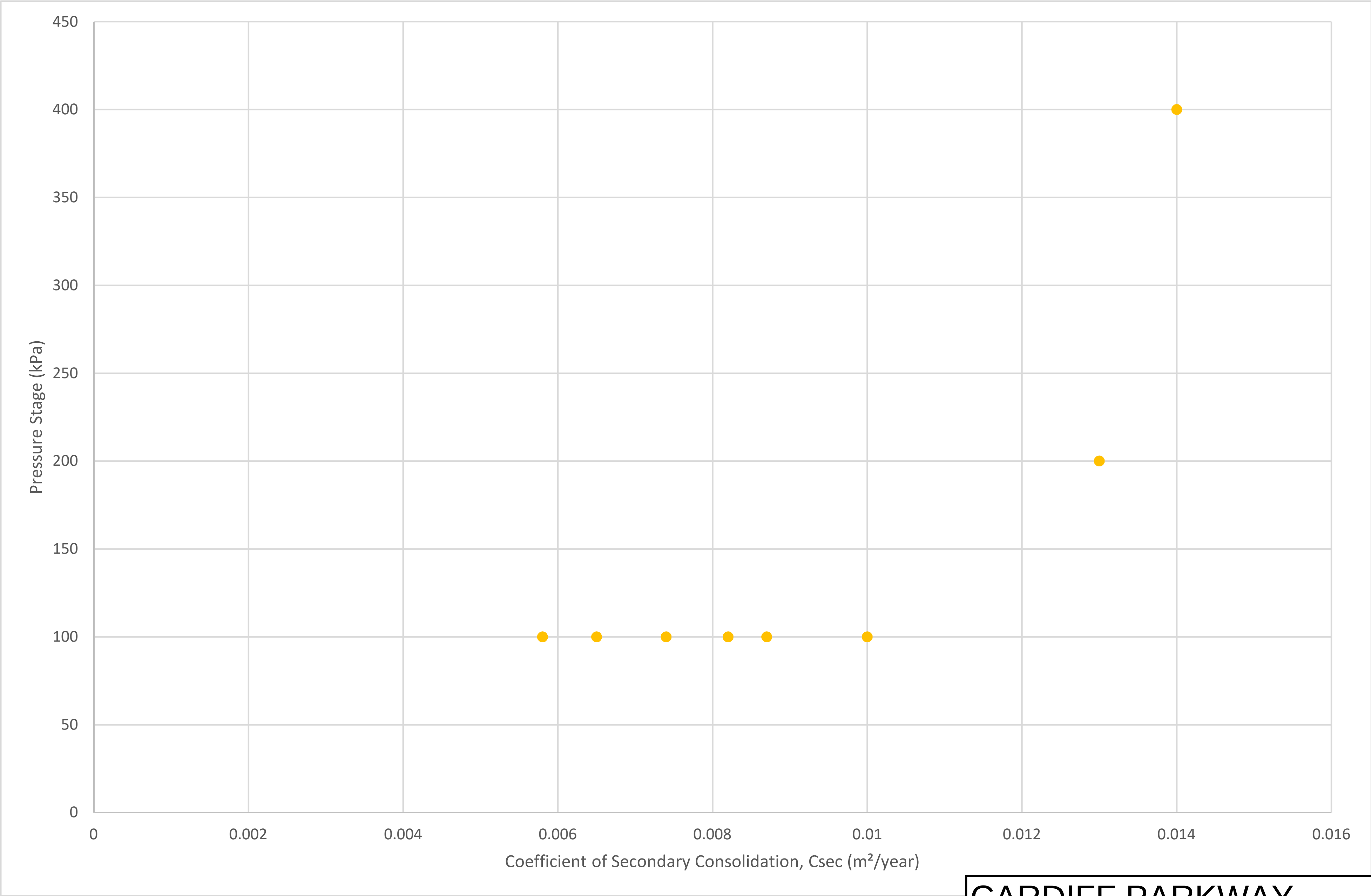


CARDIFF PARKWAY

Ch with ELEVATION

TFD-CLAY

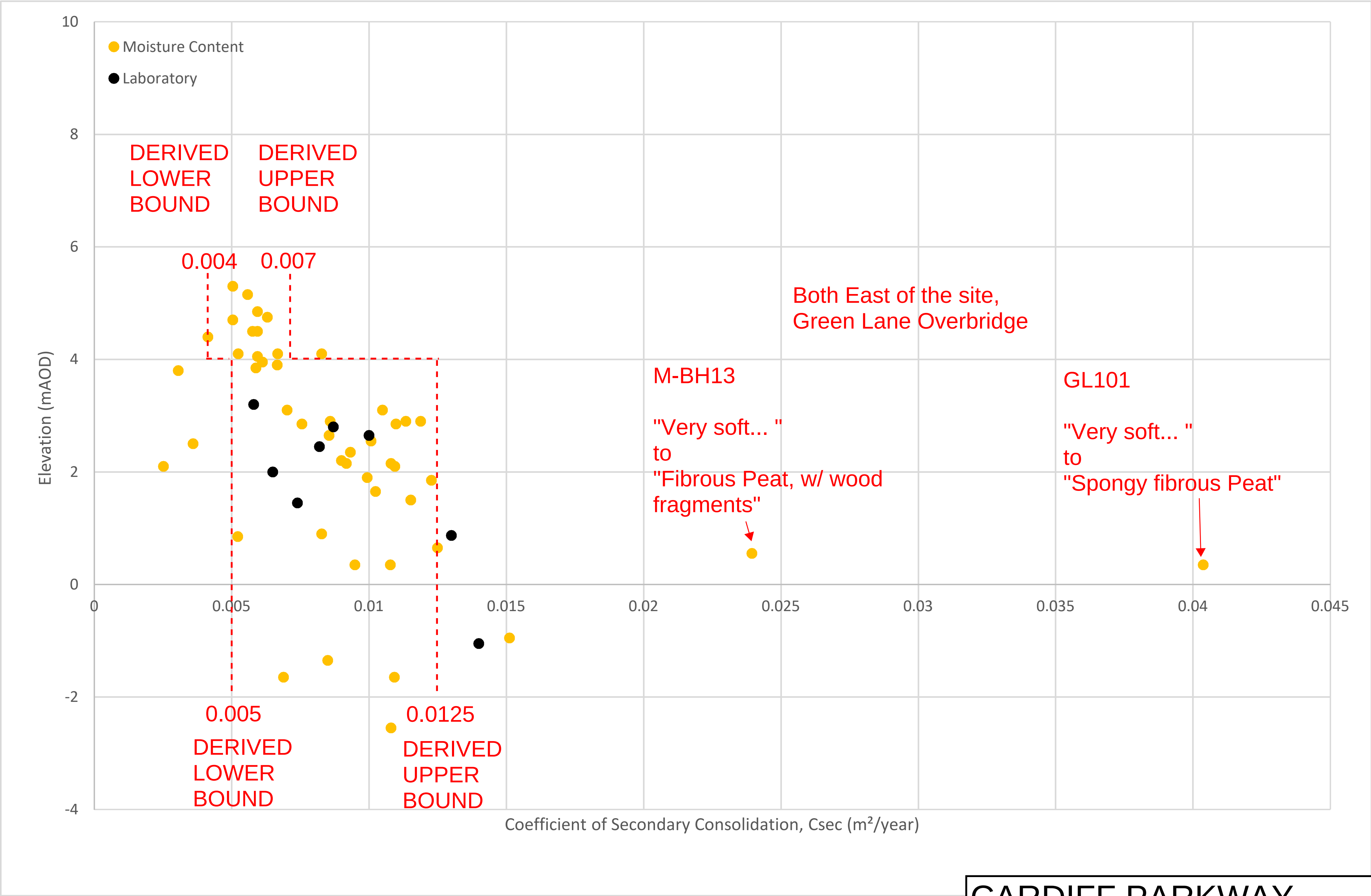
252199 - Plot B.2.15



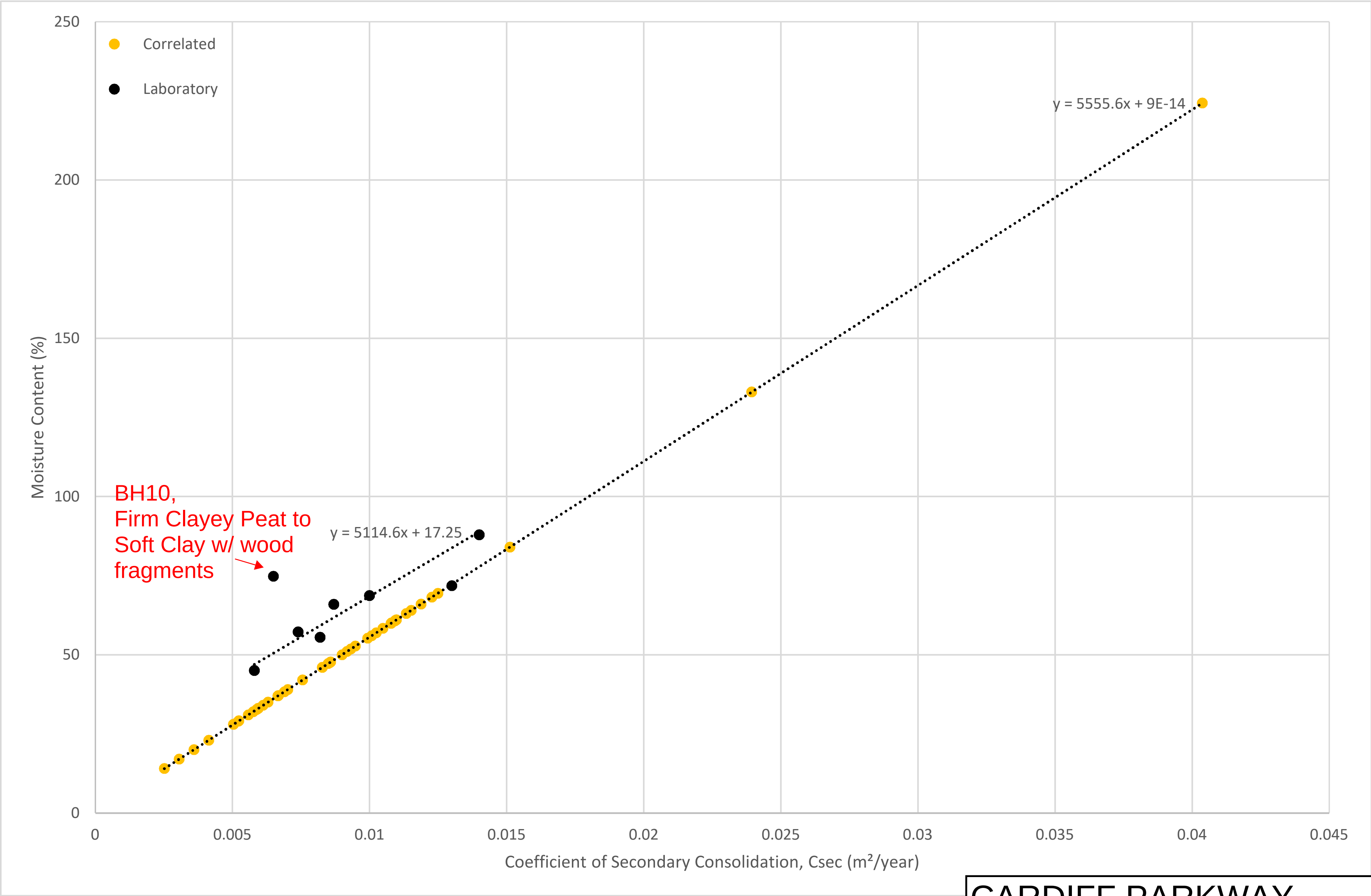
CARDIFF PARKWAY

Csec with PRESSURE STAGE

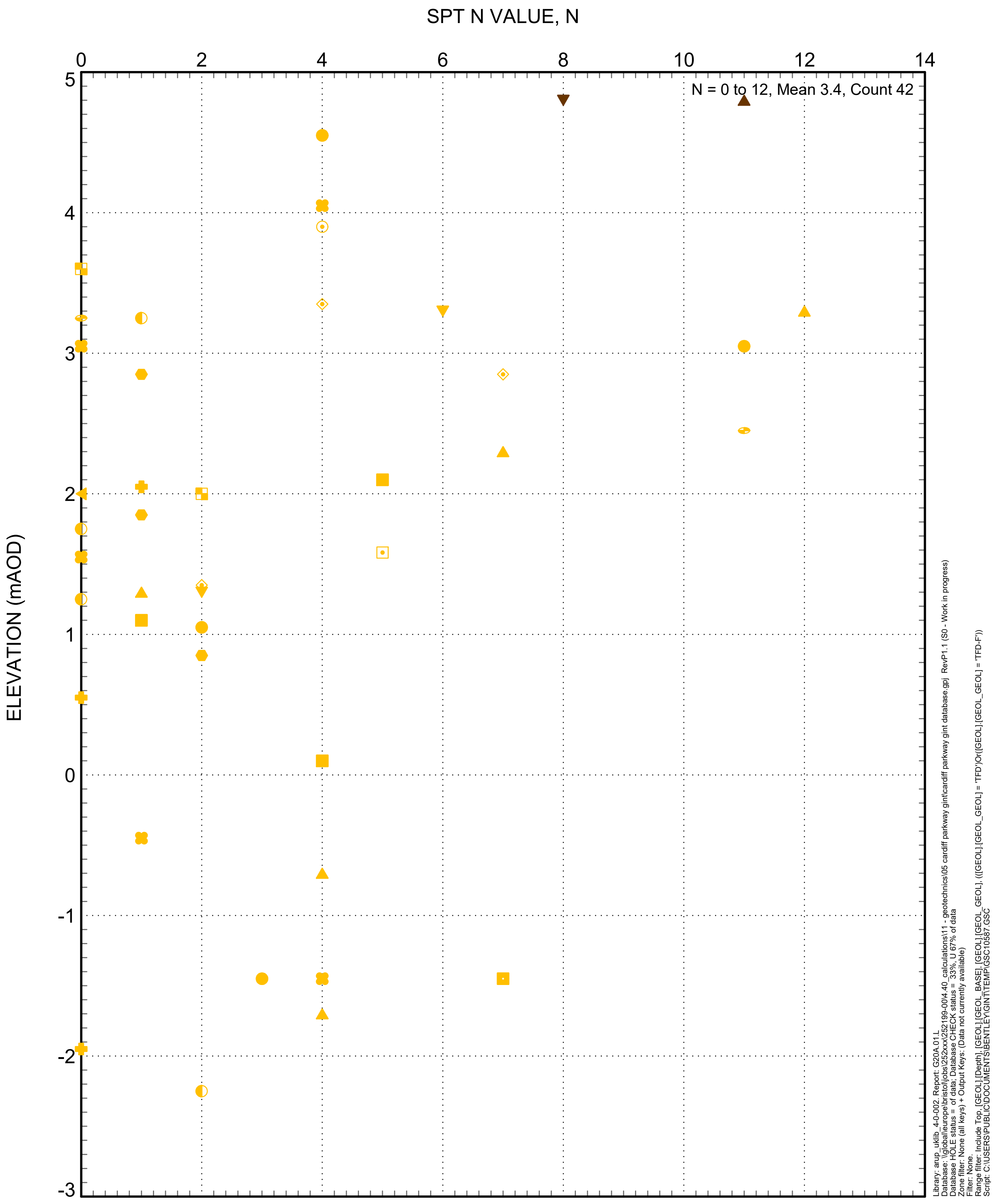
TFD-CLAY 252199 - Plot B.2.16



CARDIFF PARKWAY
Csec with ELEVATION
TFD-CLAY
252199 - Plot B.2.17



CARDIFF PARKWAY
Csec with MOISTURE CONTENT
TFD-CLAY
252199 - Plot C.2.18



TIDAL FLAT DEPOSIT CLAY - FIRM (TFD-F)
TIDAL FLAT DEPOSIT CLAY - SOFT (TFD)
GL101
GL102
GL103
GL104
GL105
GL106
GL107
M-BH13
M-BH15
BH01
BH02
BH06
BH10
BH11
ST28SW635

Where SPT N VALUES = 0 the materials are typically described as:
"Pocket of Peat"
"Roof fragments"
"Very soft Clay"

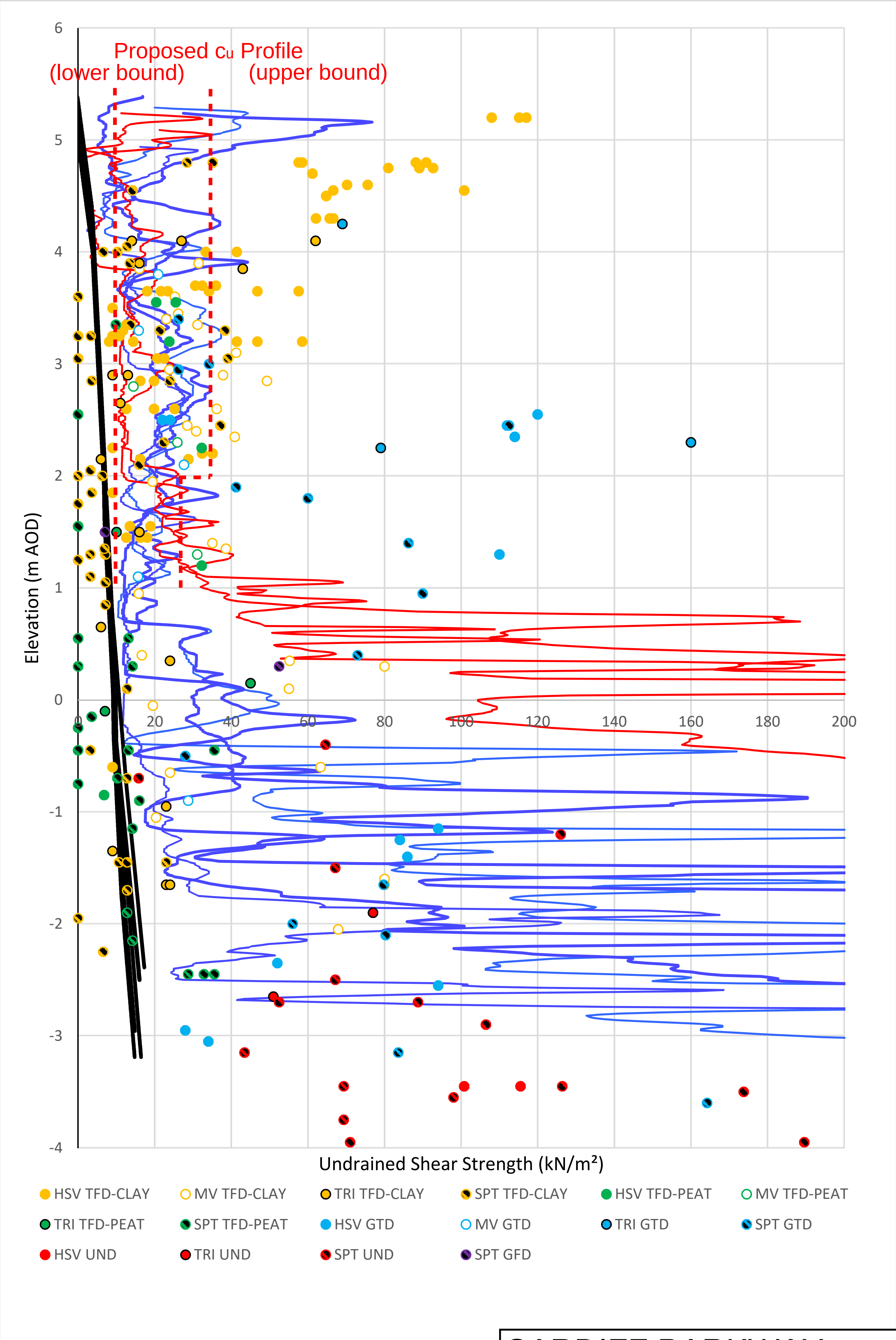
ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY

SPT

TFD-CLAY

252199 - Plot B.2.19

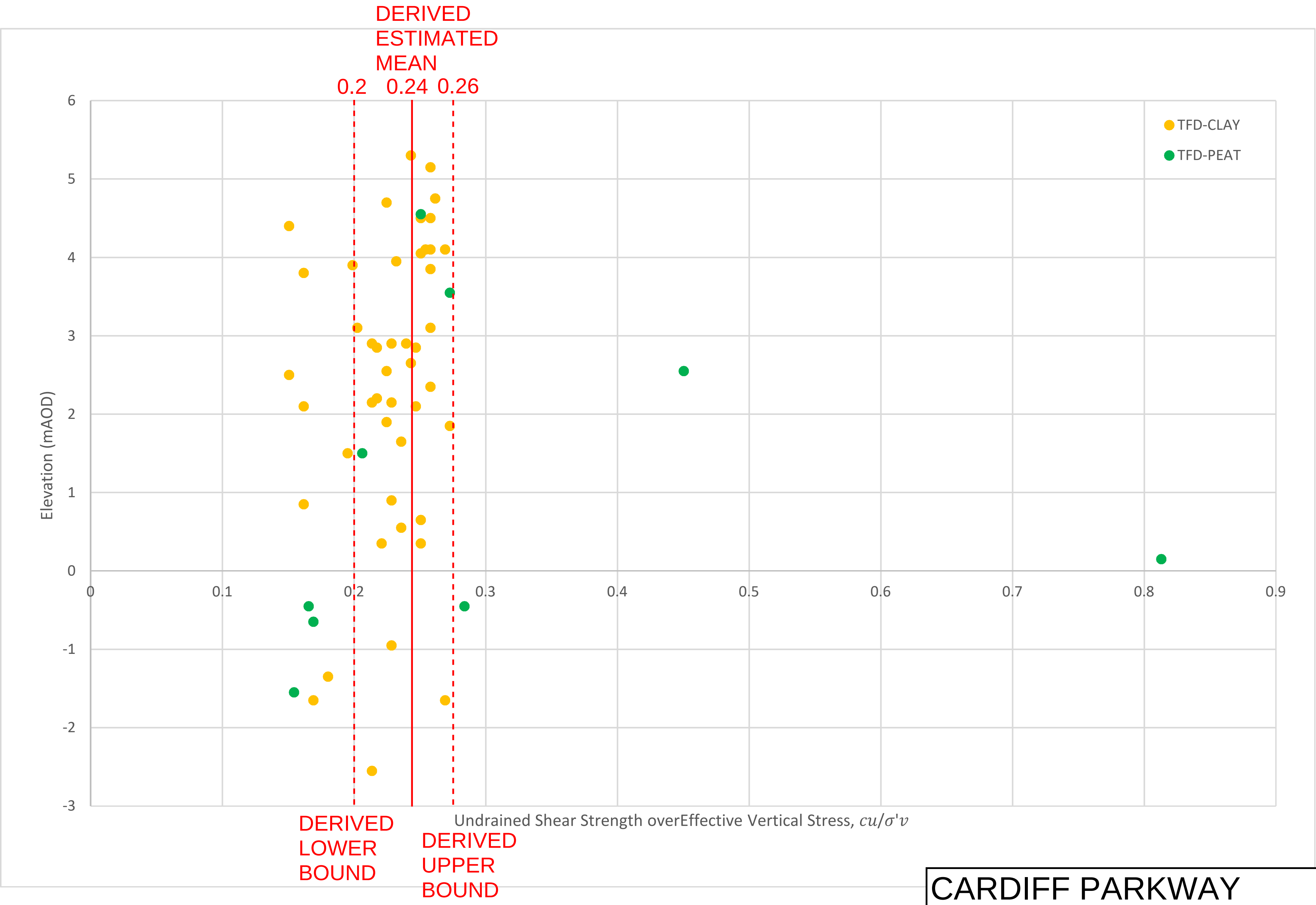


CARDIFF PARKWAY

Cu with ELEVATON

TFD-CLAY

252199 - Plot B.2.20

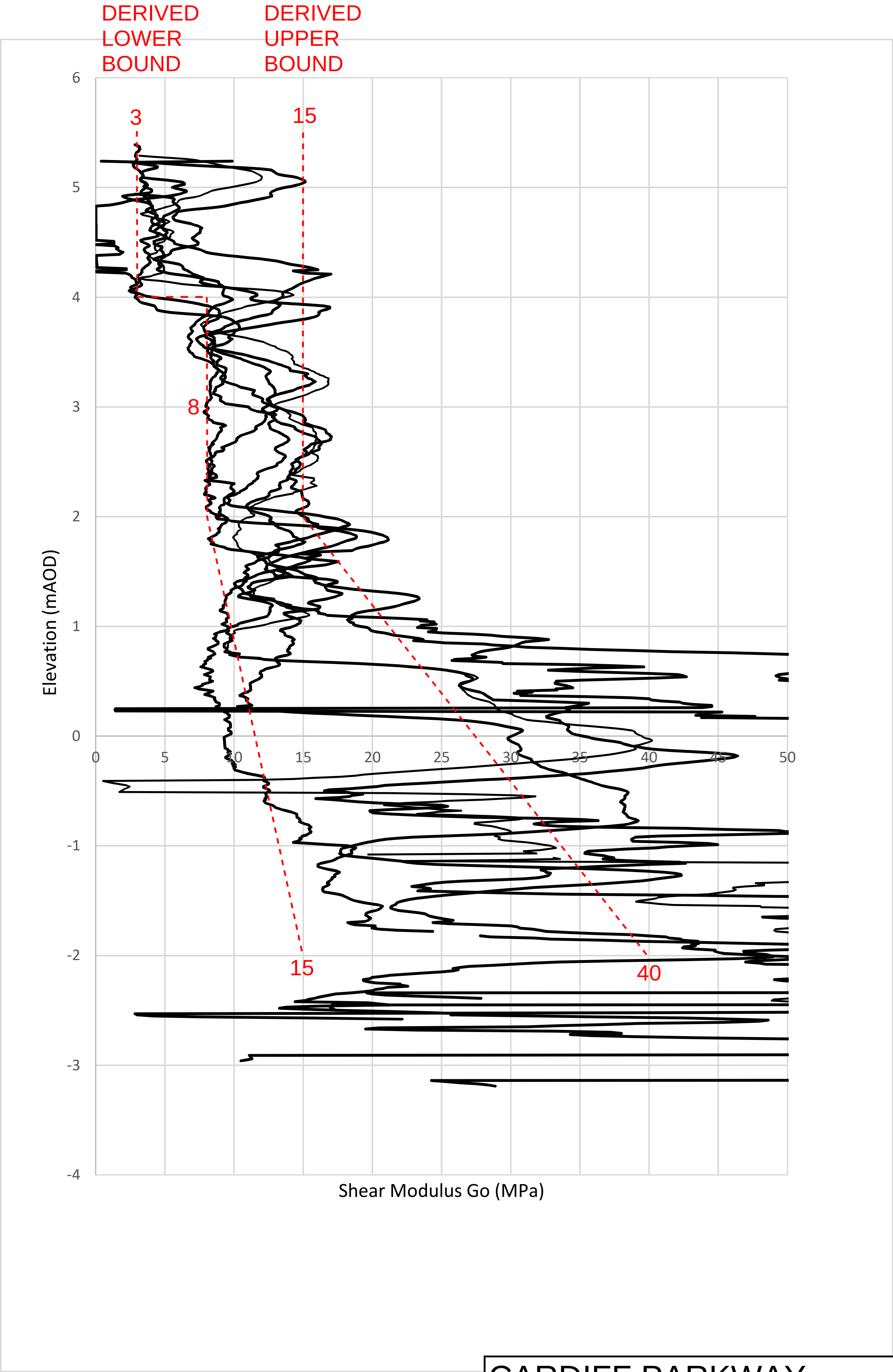


CARDIFF PARKWAY

CORRELATED DATA: cu/σ'v RATIO with ELEVATION

TFD-CLAY

252199 - Plot B.2.21



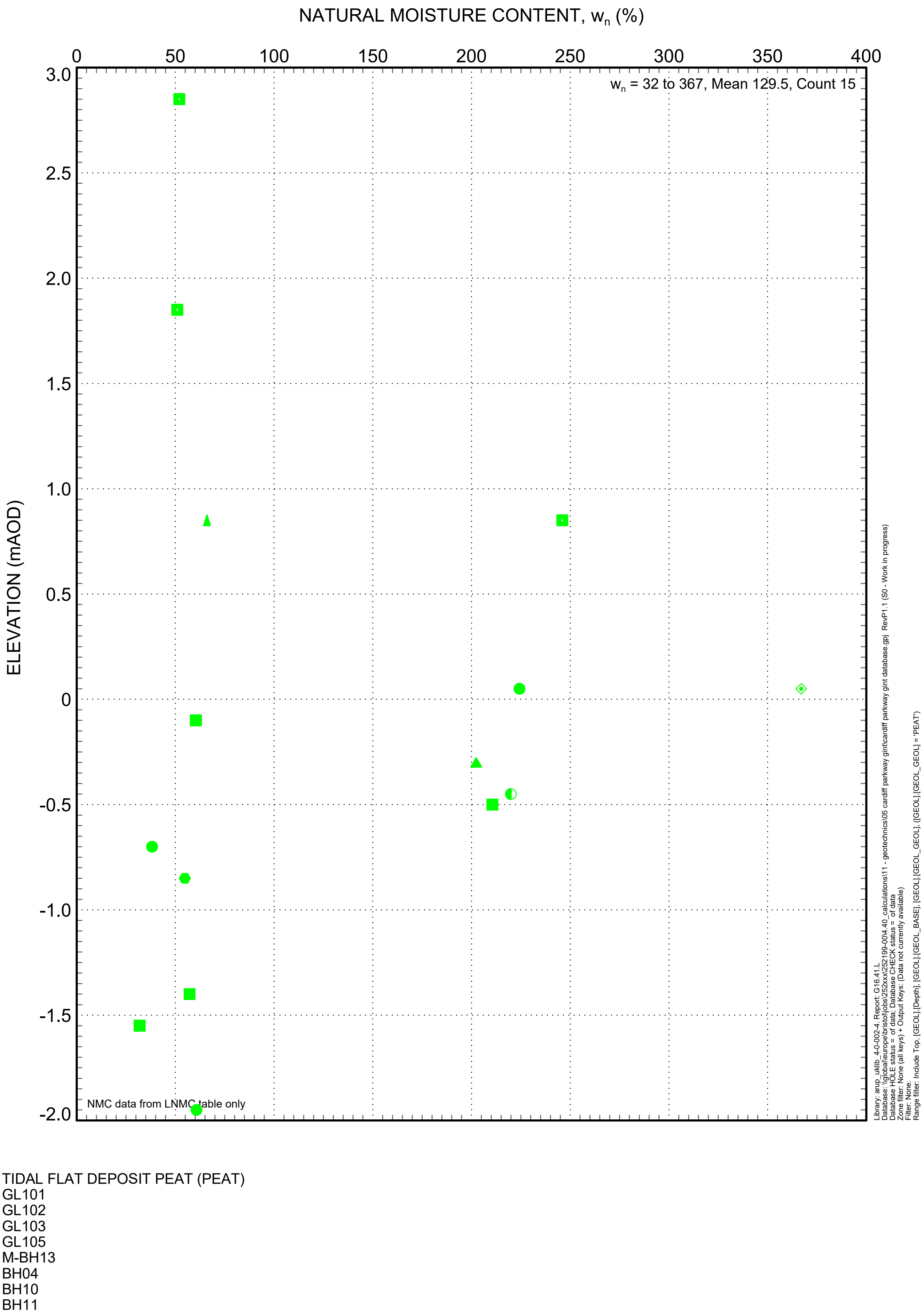
CARDIFF PARKWAY

SHEAR MODULUS

TFD-CLAY

252199 - Plot B.2.22

B3 Tidal Flat Deposit - Peat



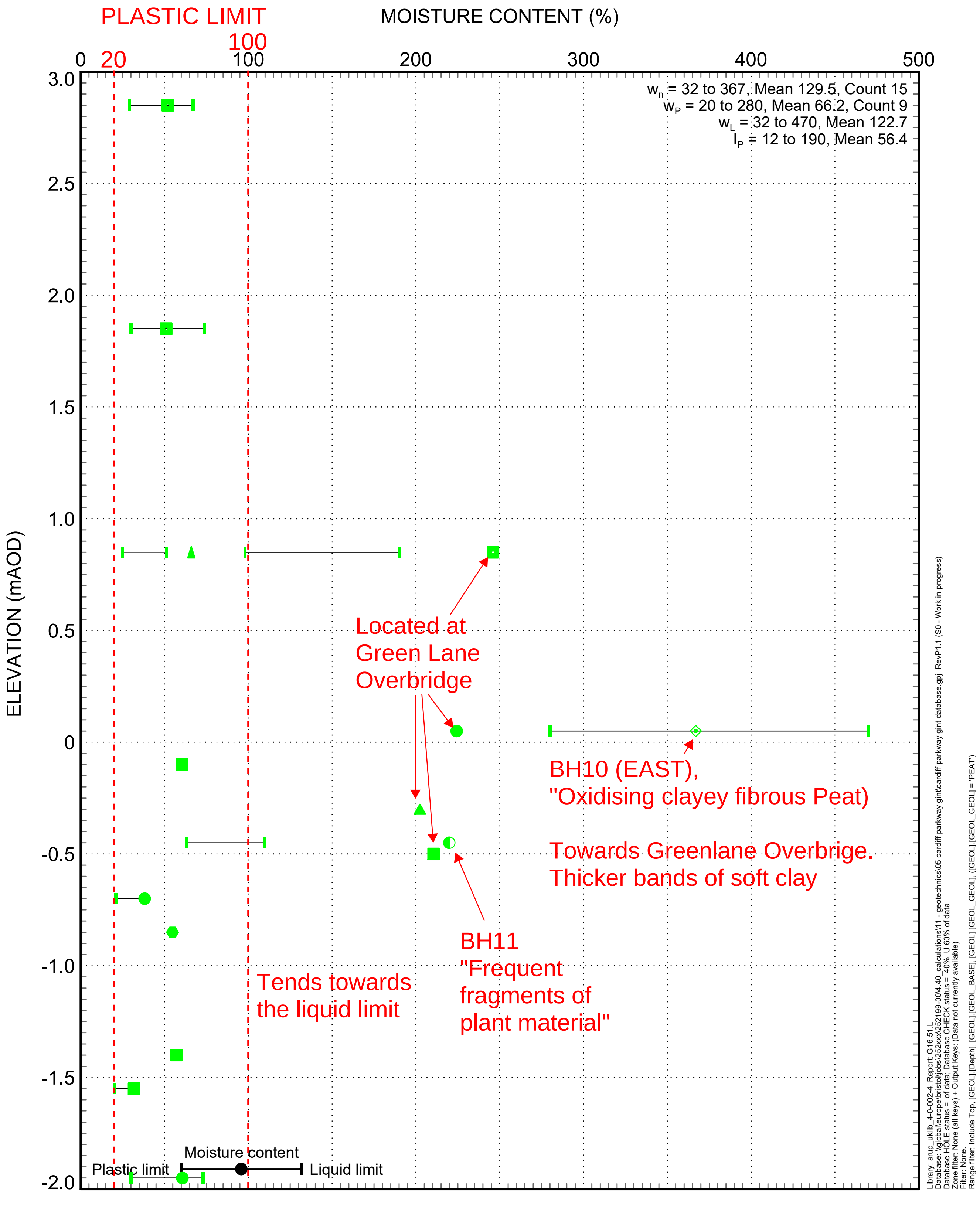
ARUP_gINT v8.30.004
Made by Alex Sadlier on 23-Oct-19

CARDIFF PARKWAY

MOISTURE CONTENT

TFD-PEAT

252199 - Plot B.3.1

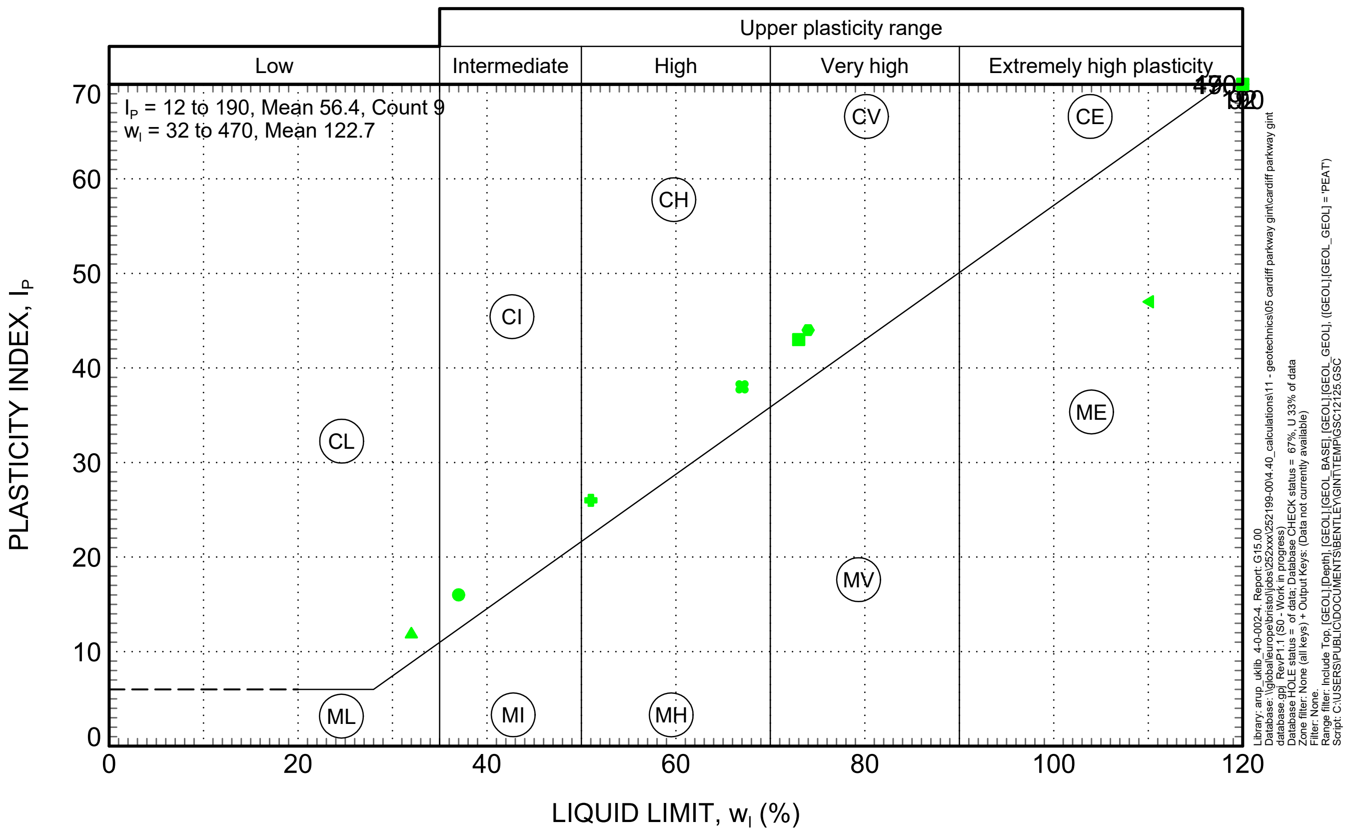


- TIDAL FLAT DEPOSIT PEAT (PEAT)
- ● GL101
- ■ GL102
- ▲ GL103
- ⬣ GL105
- ◼ M-BH13
- ▲ BH04
- ◈ BH10
- ◐ BH11

ARUP_gINT v8.30.004
Made by Alex Sadlier on 22-Oct-19

CARDIFF PARKWAY
ATTERBERG LIMITS
TFD-PEAT

252199 - Plot B.3.2



- TIDAL FLAT DEPOSIT PEAT (PEAT)
- ● GL101, -0.7mOD
- ■ GL101, -2.0mOD
- ▲ GL102, -1.6mOD
- ✖ M-BH13, 2.9mOD
- ⬢ M-BH13, 1.9mOD
- ▼ M-BH13, 0.9mOD
- ✚ BH04, 0.9mOD
- ▣ BH10, 0.0mOD
- ◀ BH11, -0.5mOD

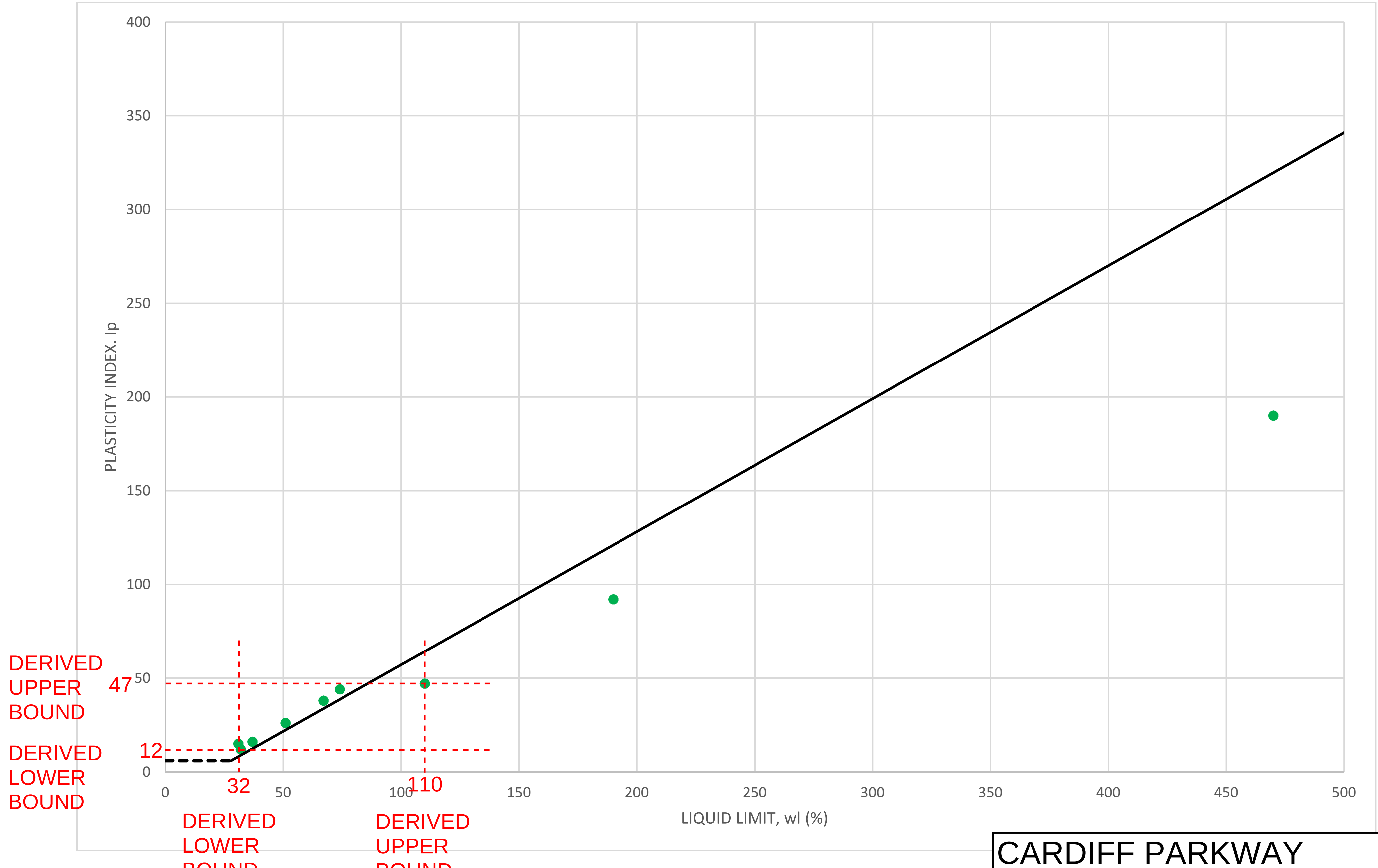
ARUP_gINT v8.30.004
Made by Alex Sadlier on 22-Oct-19

CARDIFF PARKWAY

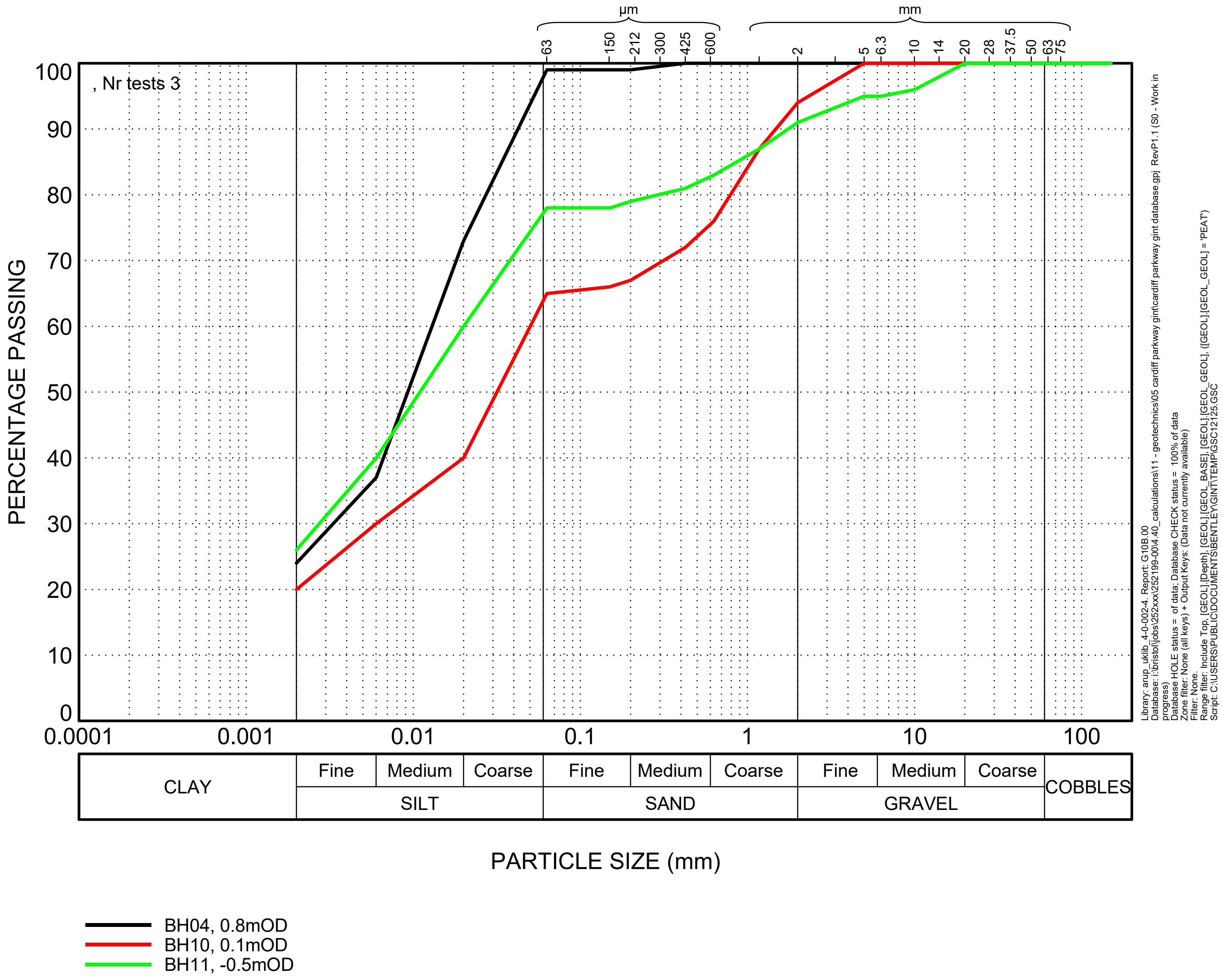
PLASTICITY CHART

TFD-PEAT

252199 - Plot B.3.3



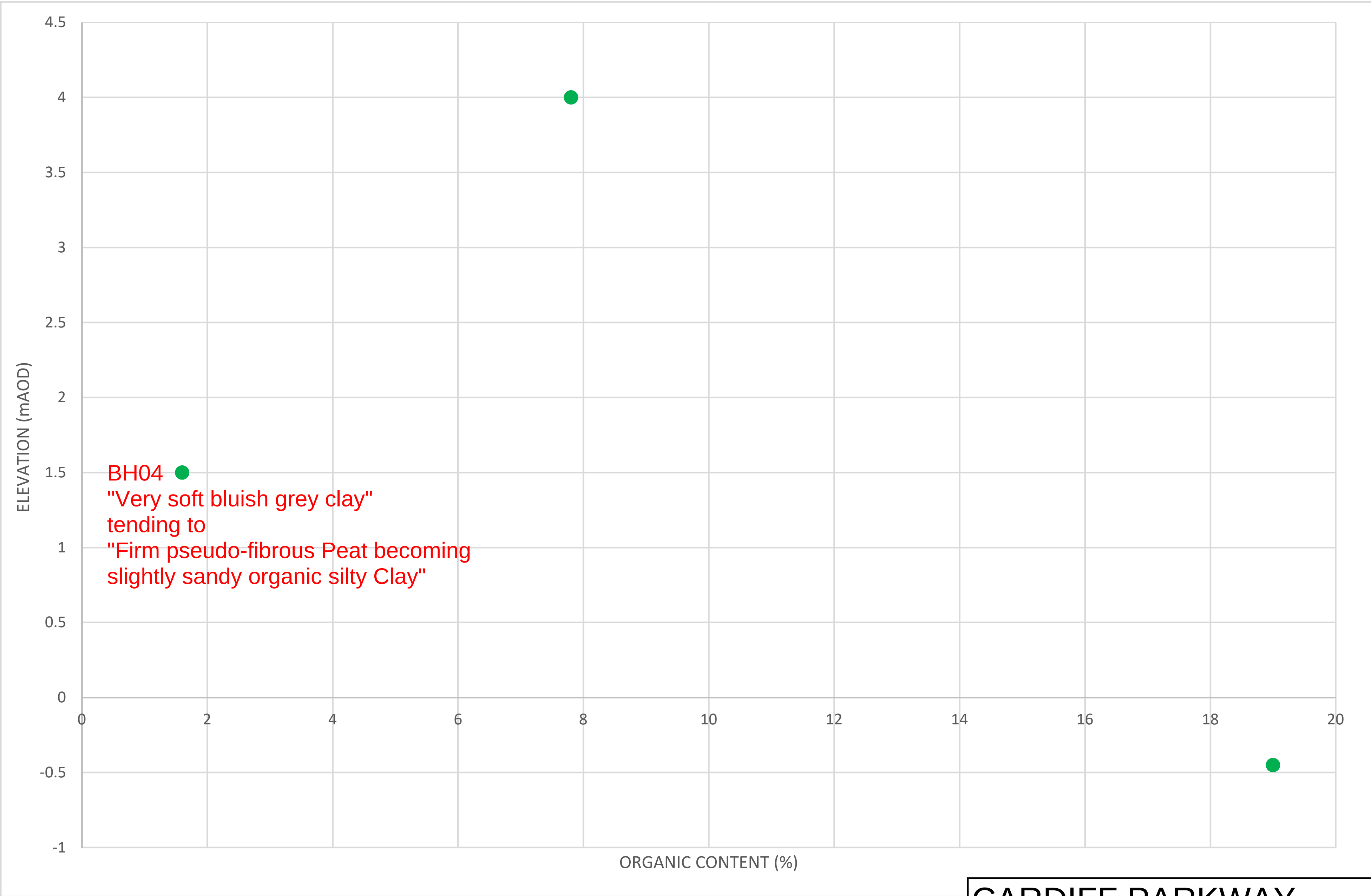
CARDIFF PARKWAY
EXTENDED PLASTICITY CHART
TFD-PEAT
252199 - Plot B.3.4



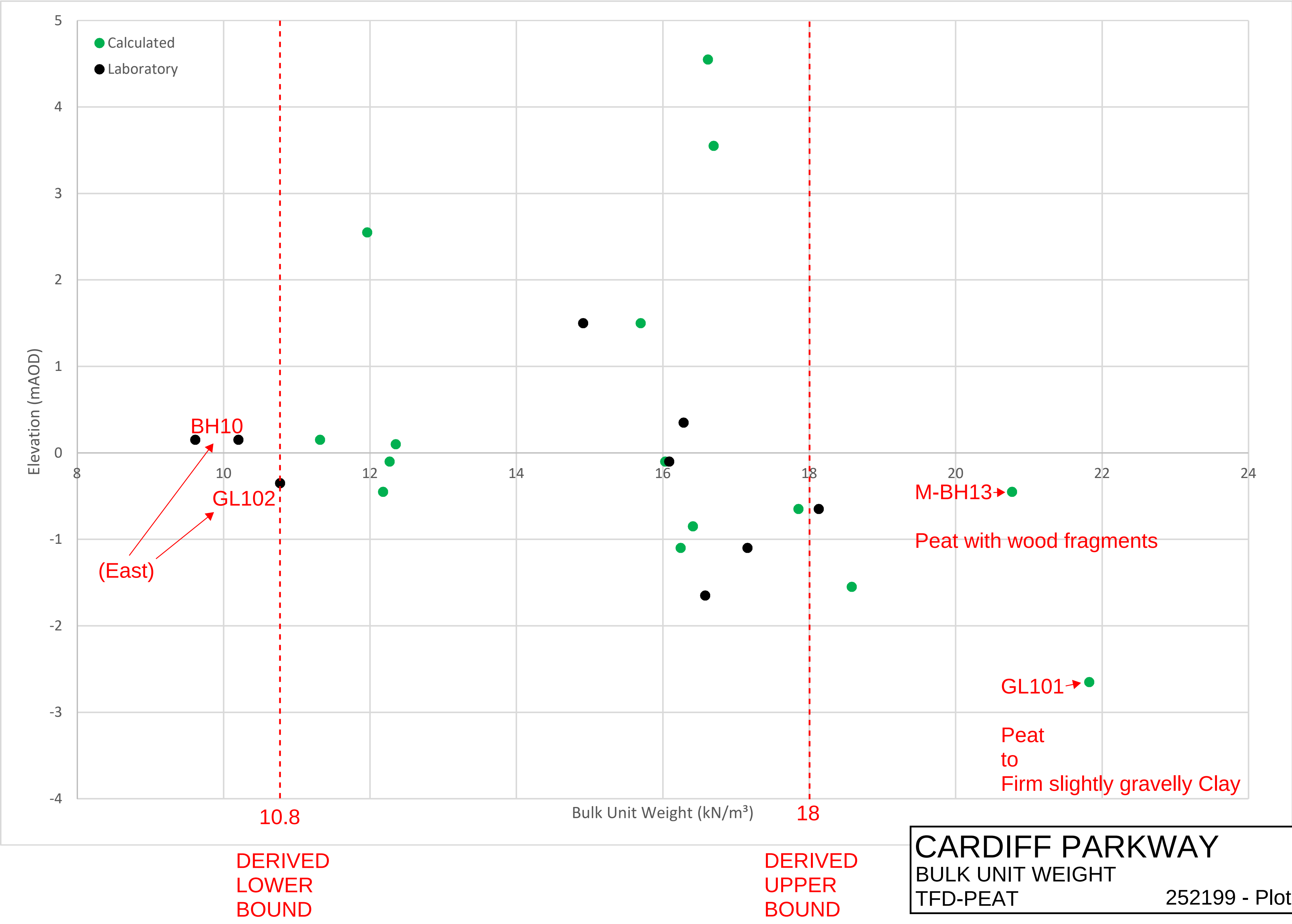
CARDIFF PARKWAY

PARTICLE SIZE DISTRIBUTION

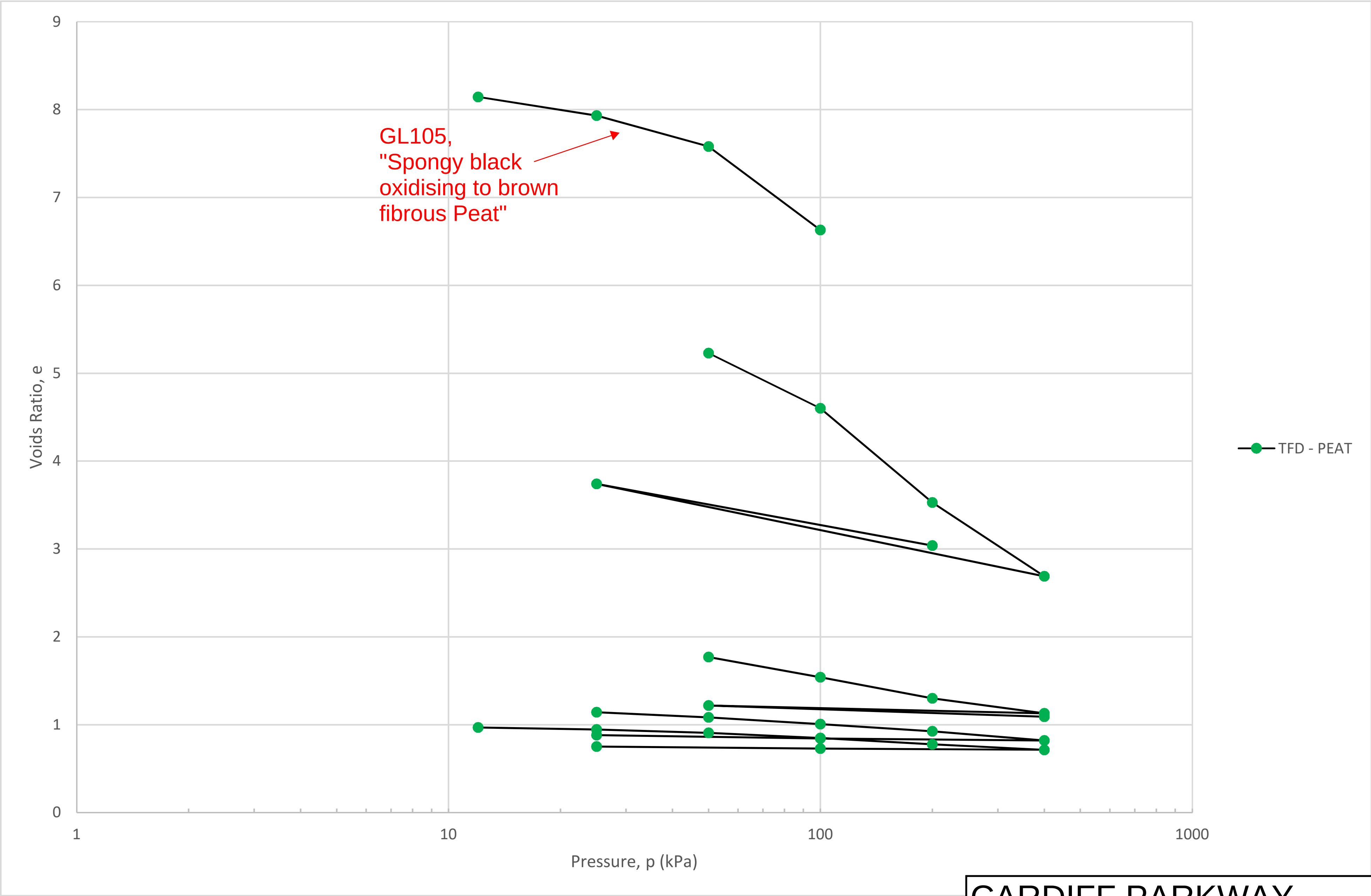
TFD-PEAT 252199 - Plot B.3.5



CARDIFF PARKWAY
ORGANIC CONTENT
TFD-PEAT
252199 - Plot B.3.6



CARDIFF PARKWAY
BULK UNIT WEIGHT
TFD-PEAT
252199 - Plot B.3.7

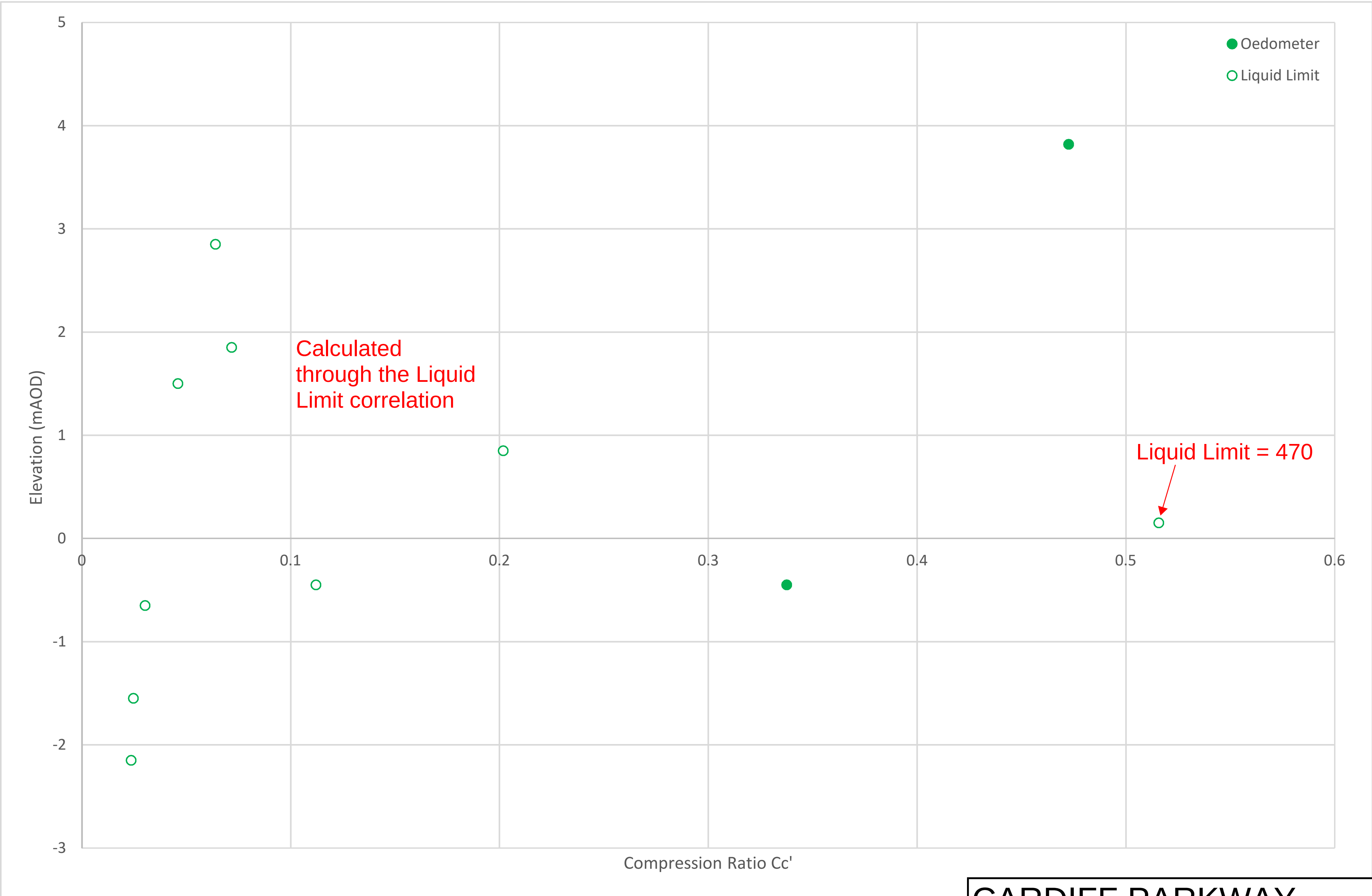


CARDIFF PARKWAY

OEDOMETER TESTS

TFD-PEAT

252199 - Plot B.3.8

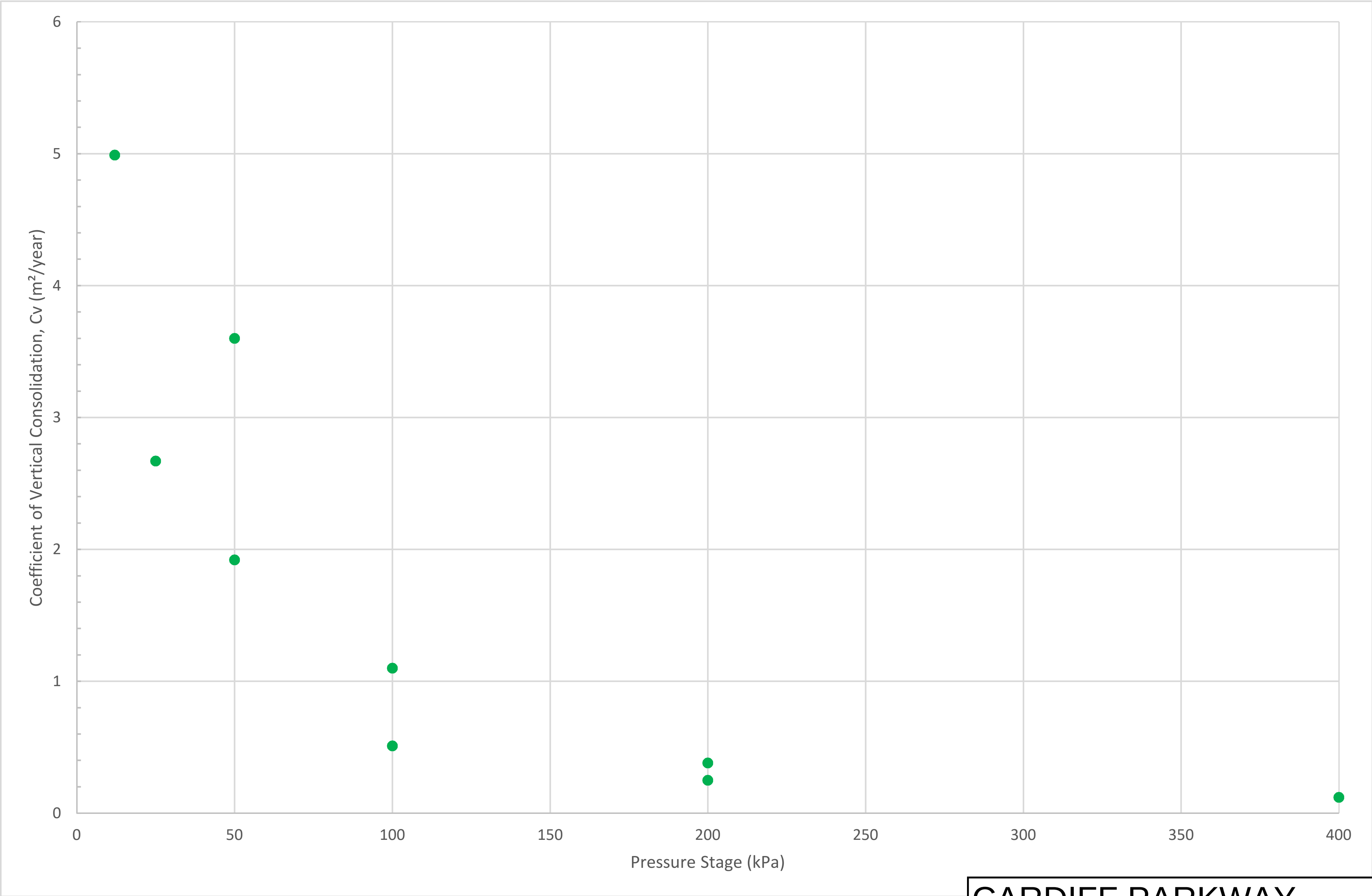


CARDIFF PARKWAY

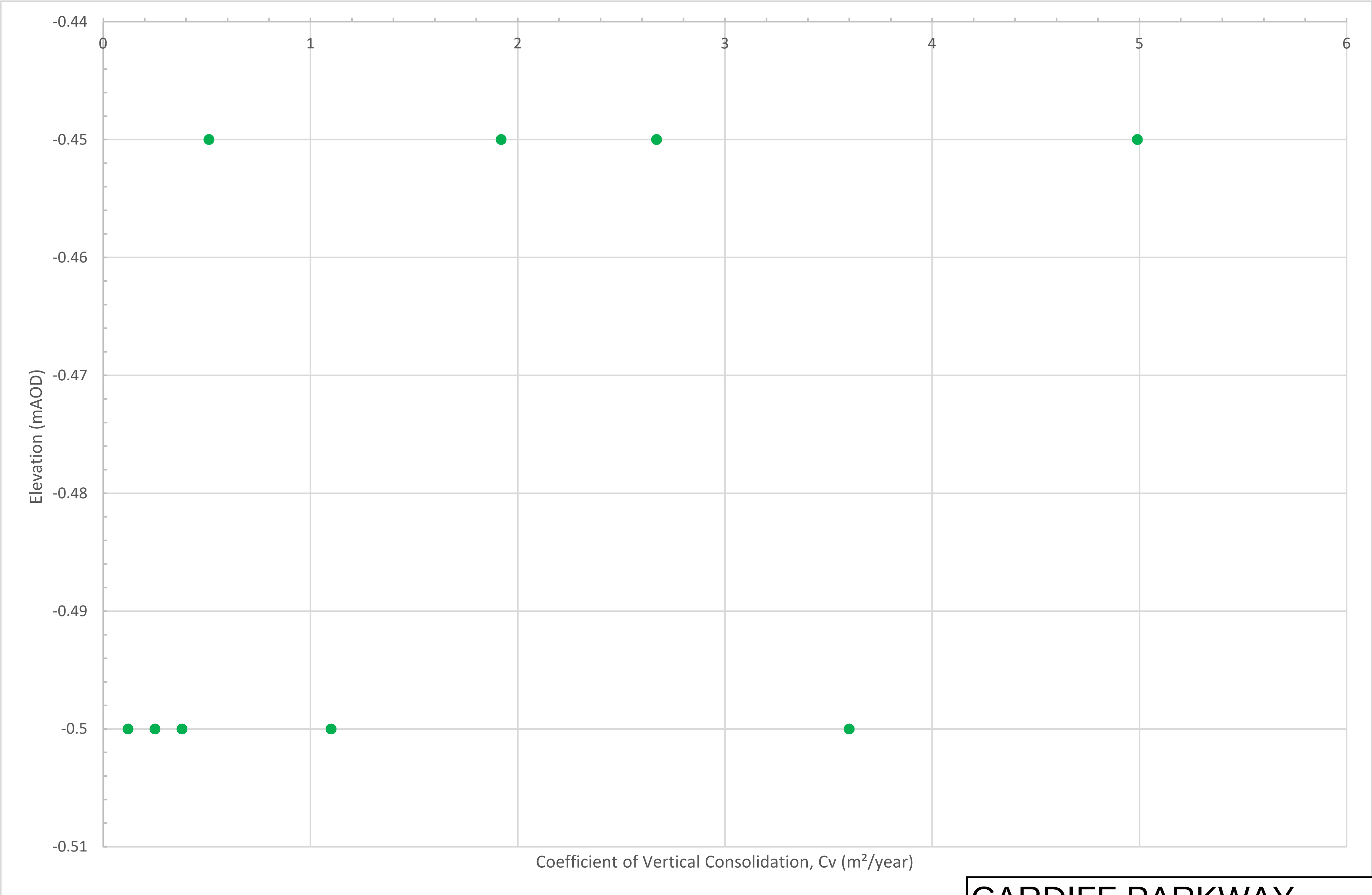
Cc' with ELEVATION

TFD-PEAT

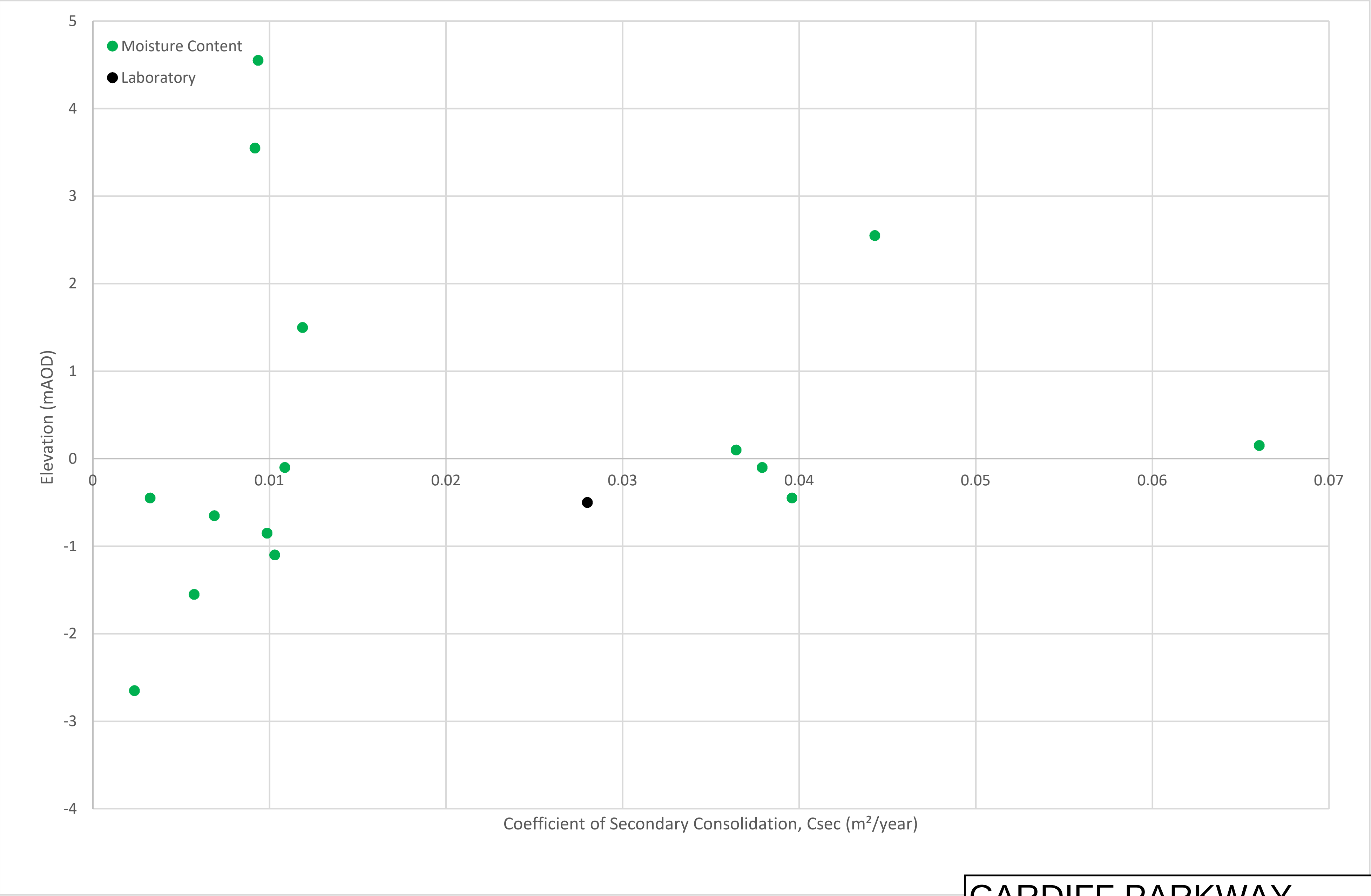
252199 - Plot B.3.9



CARDIFF PARKWAY
Cv with PRESSURE STAGE
TFD-PEAT
252199 - Plot B.3.10



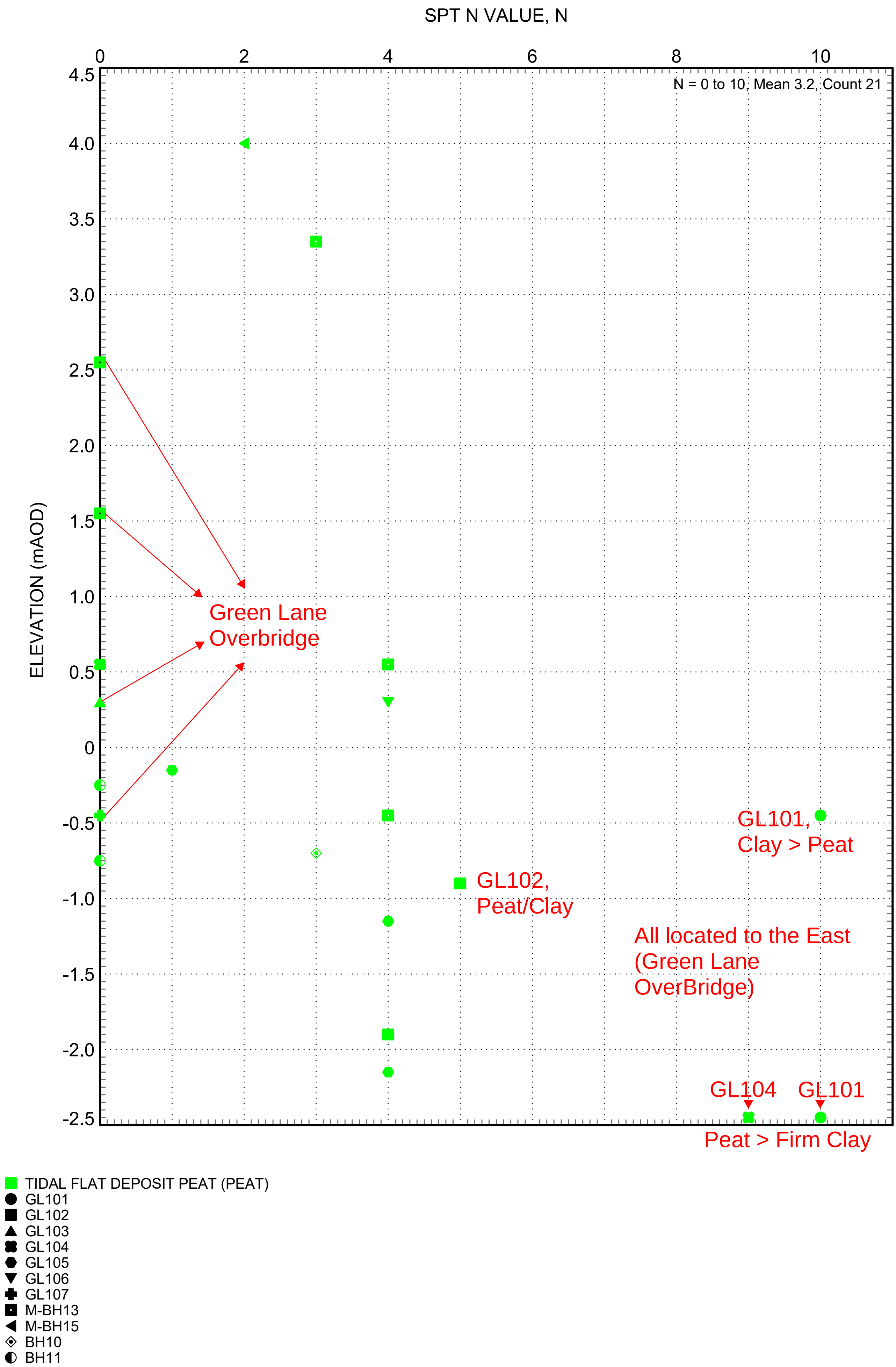
CARDIFF PARKWAY
Cv with ELEVATION
TFD-PEAT 252199 - Plot B.3.11



CARDIFF PARKWAY

Csec with ELEVATION

TFD-PEAT 252199 - Plot B.3.12



Library: arup_uklib_4-0-002-4. Report: G20A.01.L
Database: \\global\europe\bristol\jobs\252xxx\252199-00\4.40_calculations\11 - geotechnics\05 cardiff parkway gint\cardiff parkway gint database.gpj RevP1.1 (S0 - Work in progress)
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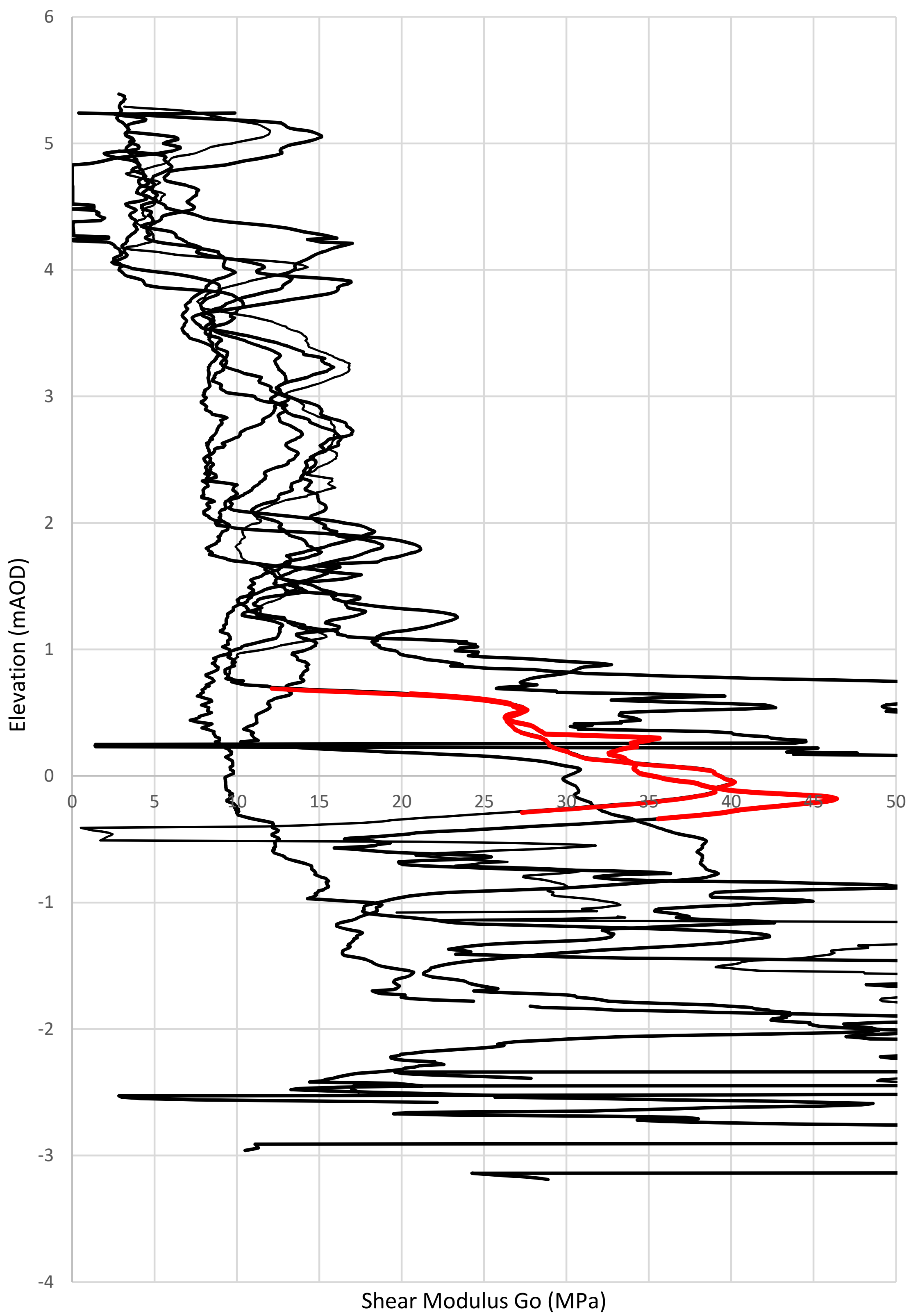
Zone filter: None (all keys) + Output Keys: (Data not currently available)
Filter: None.
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], ([GEOL].[GEOL_GEOL] = 'PEAT')
Script: C:\USERS\PUBLIC\DOCUMENTS\BENTLEY\GINT\TEMP\GSC12125.GSC

ARUP_gINT v8.30.004
Made by Alex Sadlier on 22-Oct-19

CARDIFF PARKWAY

SPT

TFD-PEAT 252199 - Plot B.3.13

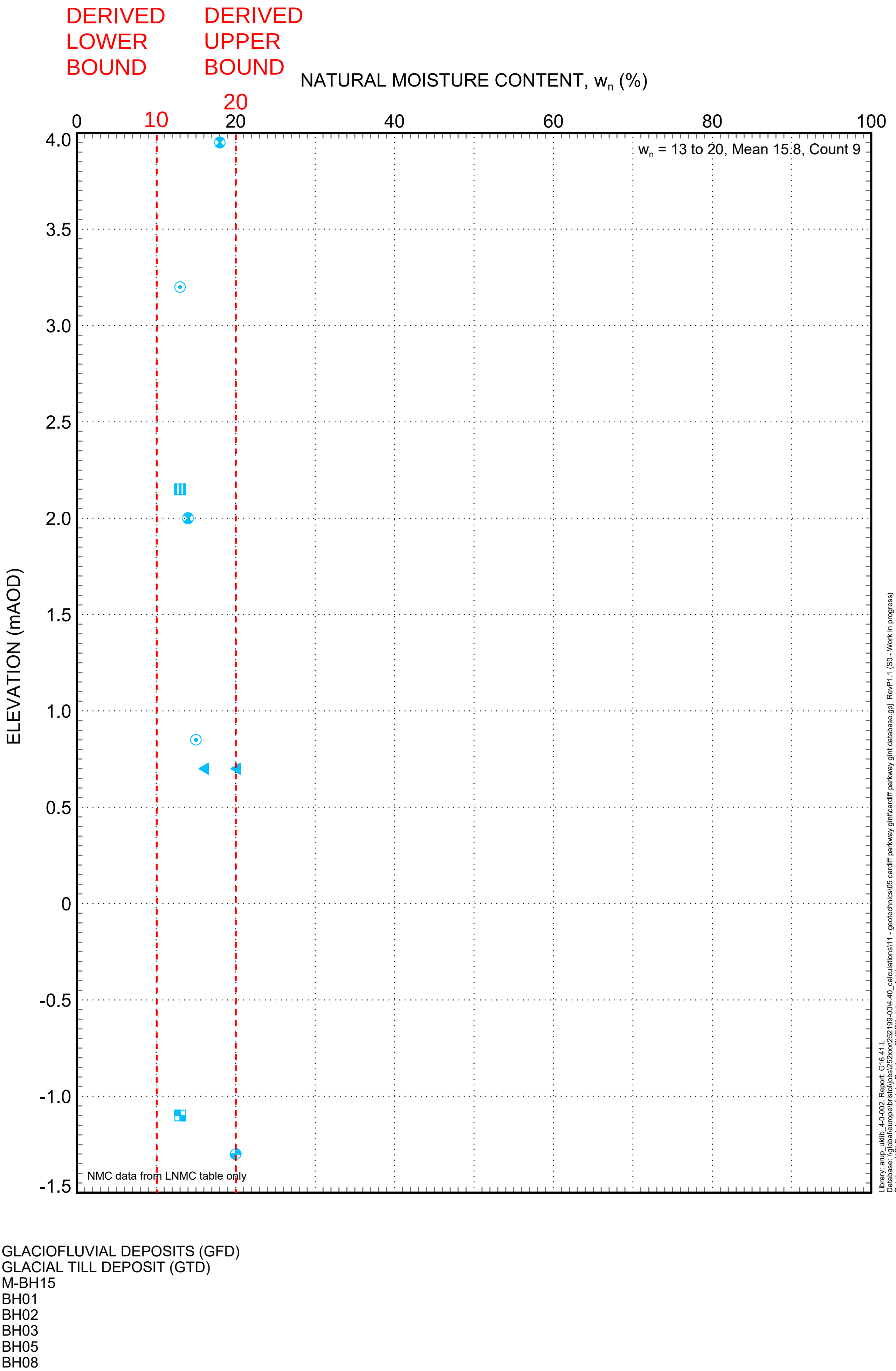


CARDIFF PARKWAY

SHEAR MODULUS - CPTs

TFD-PEAT 252199 - Plot B.3.14

B4 Glacial Till Deposit



Library: arup_uklib_4-0-002. Report: G16.41.L
Database: \\global\europe\bristol\jobs\252xxx\252199-00\4.40_calculations\11 - geotechnics\05 cardiff parkway gint\cardiff parkway gint database.gpj RevP1.1 (S0 - Work in progress)
Database HOLE status = of data; Database CHECK status = of data
Zone filter: None (all keys) + Output Keys: (Data not currently available)
Filter: None.
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], (([GEOL].[GEOL_GEOL] = 'GTD')Or([GEOL].[GEOL_GEOL] = 'GFD'))
Script: C:\USERS\PUBLIC\DOCUMENTS\BENTLEY\GINT\TEMP\GSC60592.GSC

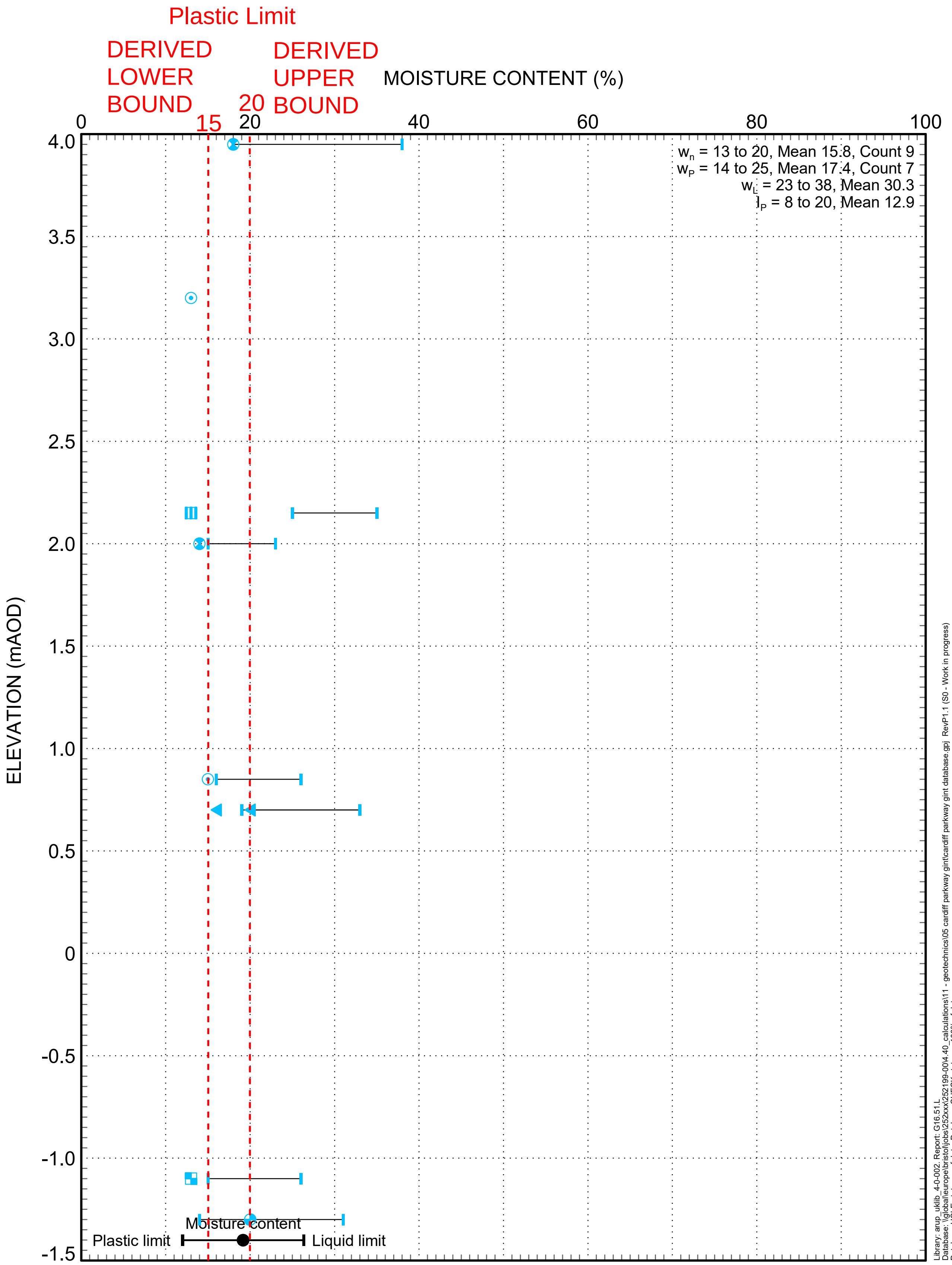
ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY

MOISTURE CONTENT

GTD

252199 - Plot B.4.1



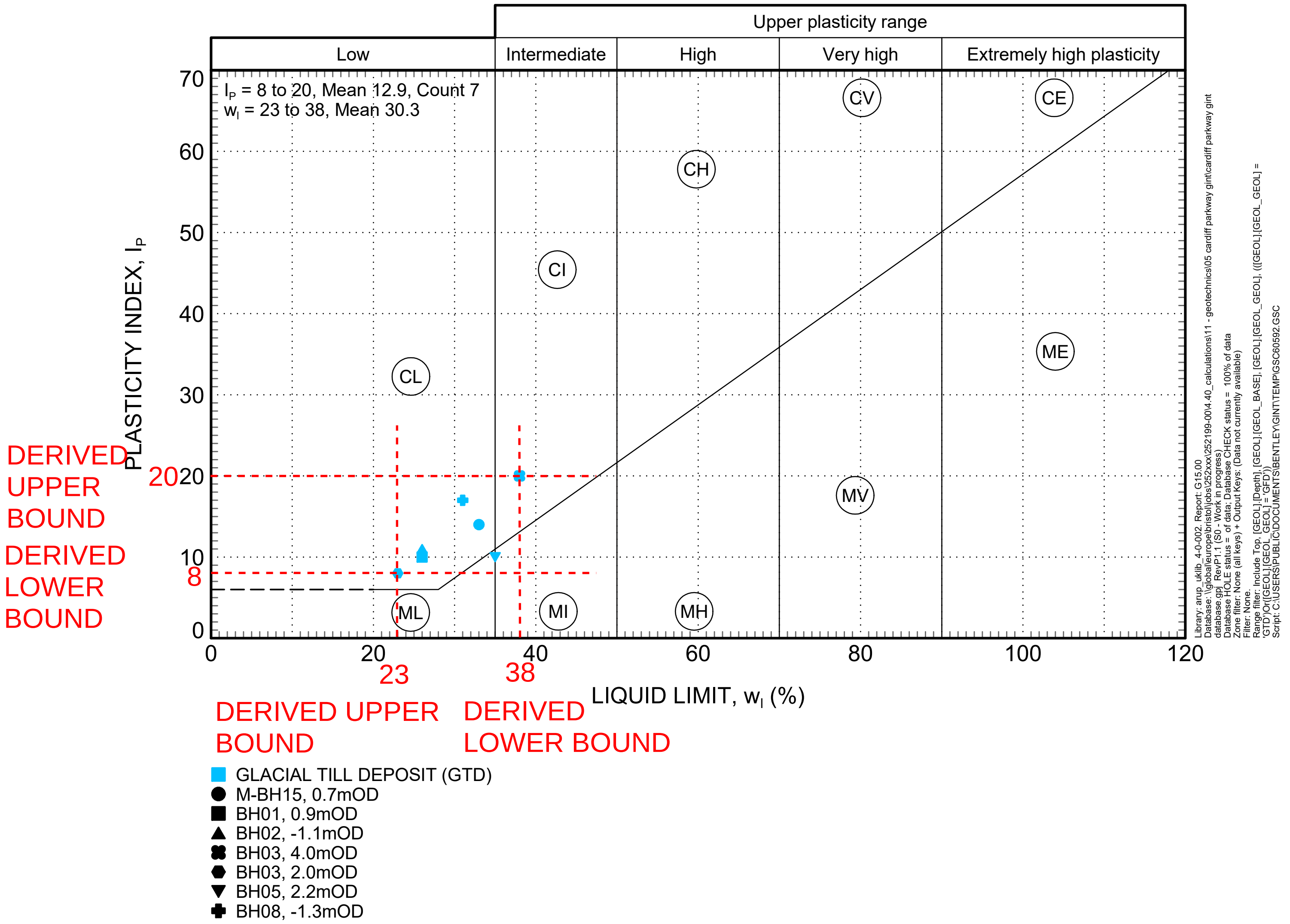
Library: arup_uklib_4-0-002. Report: G16.51.L
Database: \\global\europe\bristol\jobs\252xxx\252199-00\4.40_calculations\11 - geotechnics\05 cardiff parkway gint\cardiff parkway gint database.gpj RevP1.1 (S0 - Work in progress)
Database HOLE status = of data; Database CHECK status = 100% of data
Zone filter: None (all keys) + Output Keys: (Data not currently available)
Filter: None.
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], (([GEOL].[GEOL_GEOL] = 'GTD')Or([GEOL].[GEOL_GEOL] = 'GFD'))

- ■ GLACIAL TILL DEPOSIT (GTD)
- ◀ M-BH15
- ⊙ BH01
- BH02
- BH03
- BH05
- BH08

ARUP. gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY
ATTERBERG LIMITS
GTD

252199 - Plot B.4.2



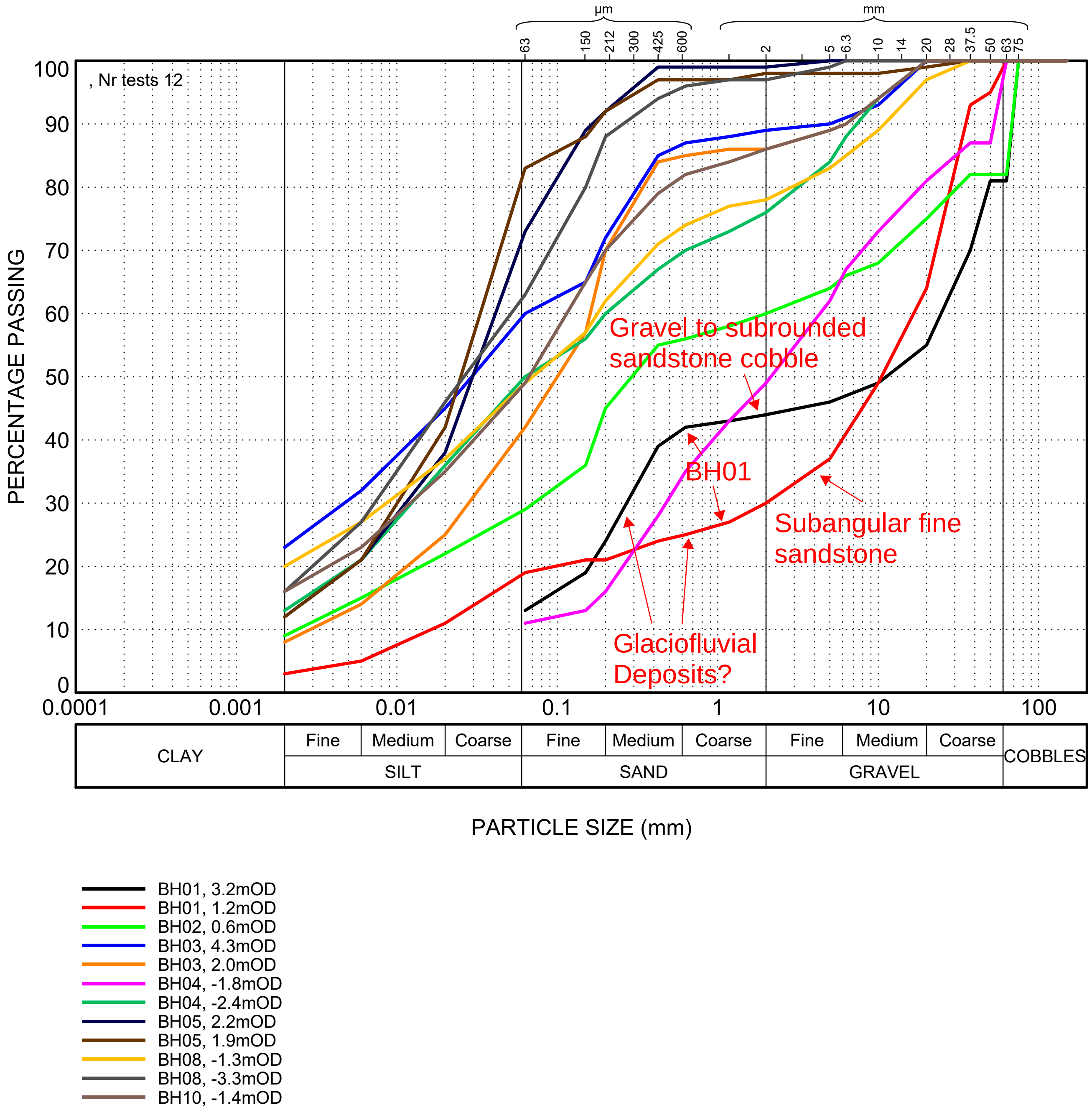
ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY

PLASTICITY CHART

GTD

252199 - Plot B.4.3



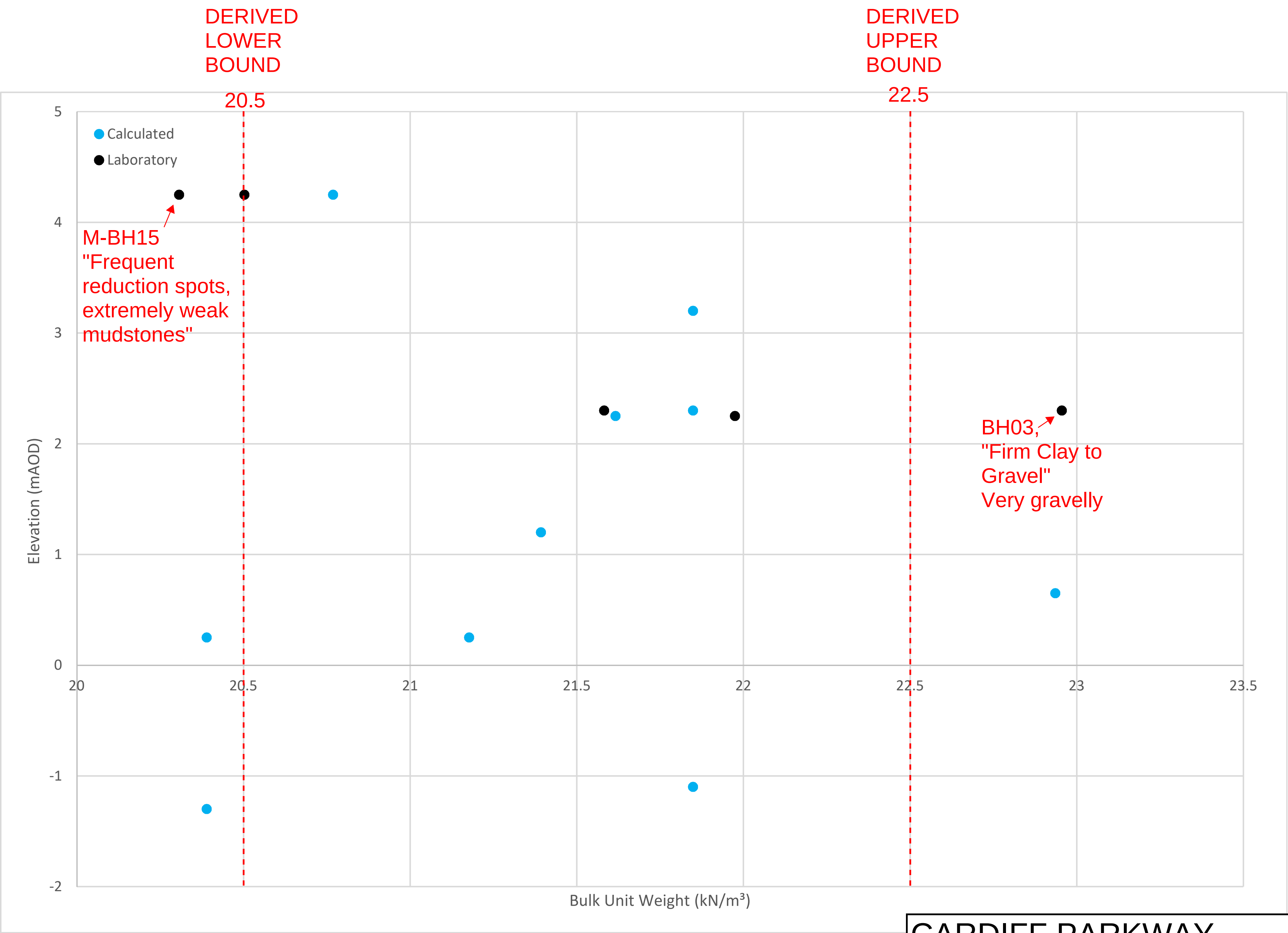
ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY

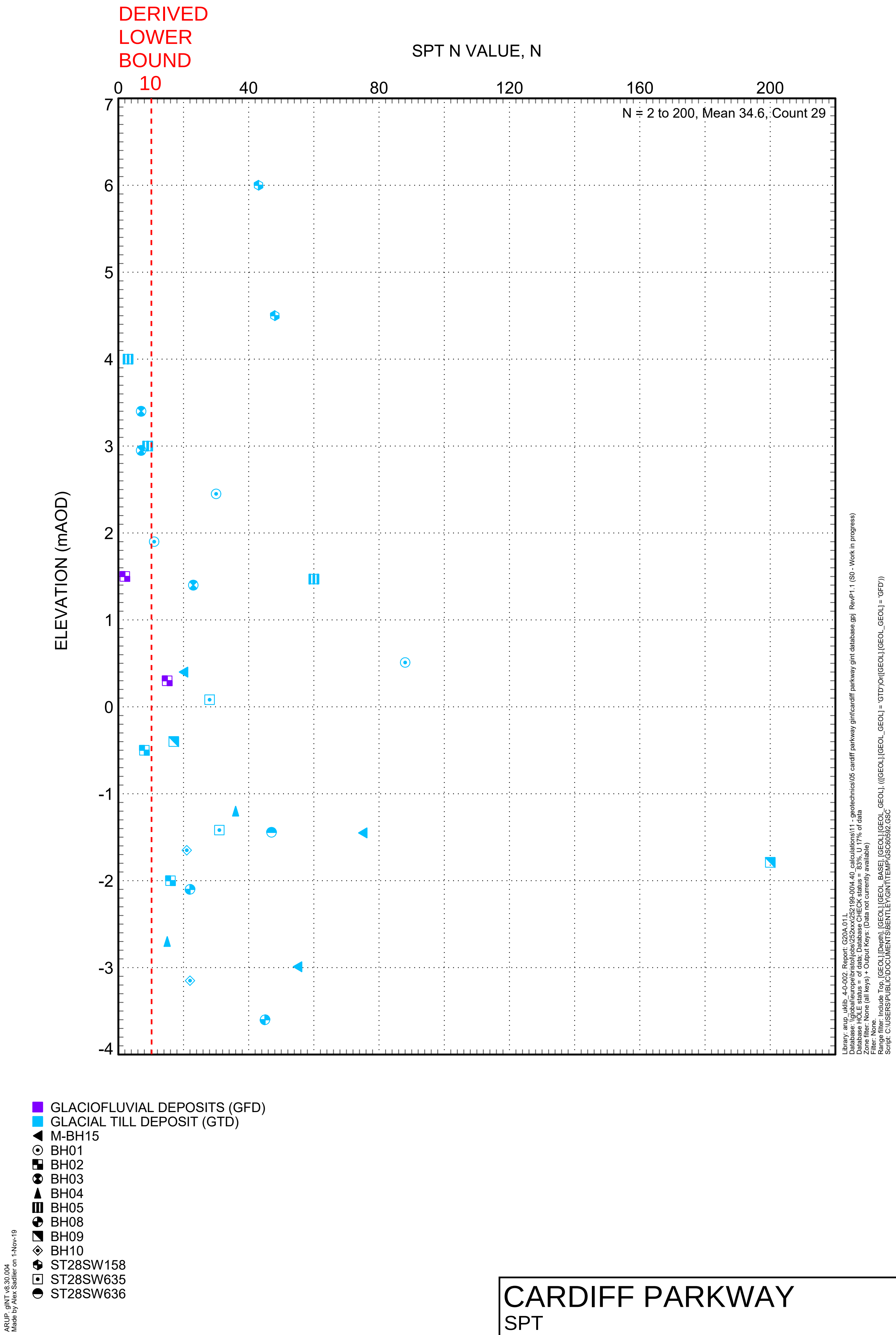
PSD

GTD

252199 - Plot B.4.4



CARDIFF PARKWAY
BULK UNIT WEIGHT
GTD
252199 - Plot B.4.5



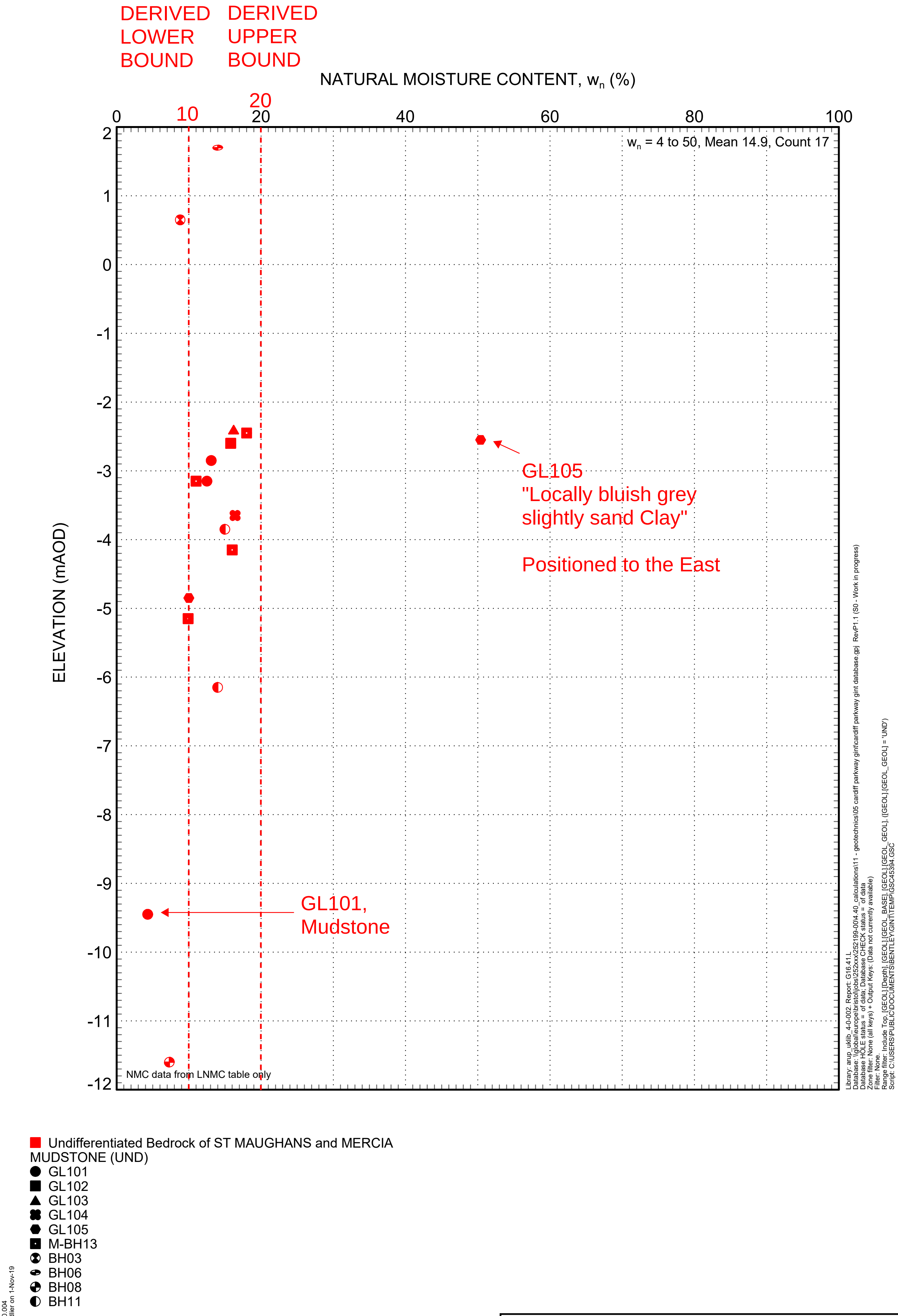
CARDIFF PARKWAY

SPT

GTD

252199 - Plot B.4.6

B5 Undifferentiated Bedrock of St Maughan's and Mercia Mudstone

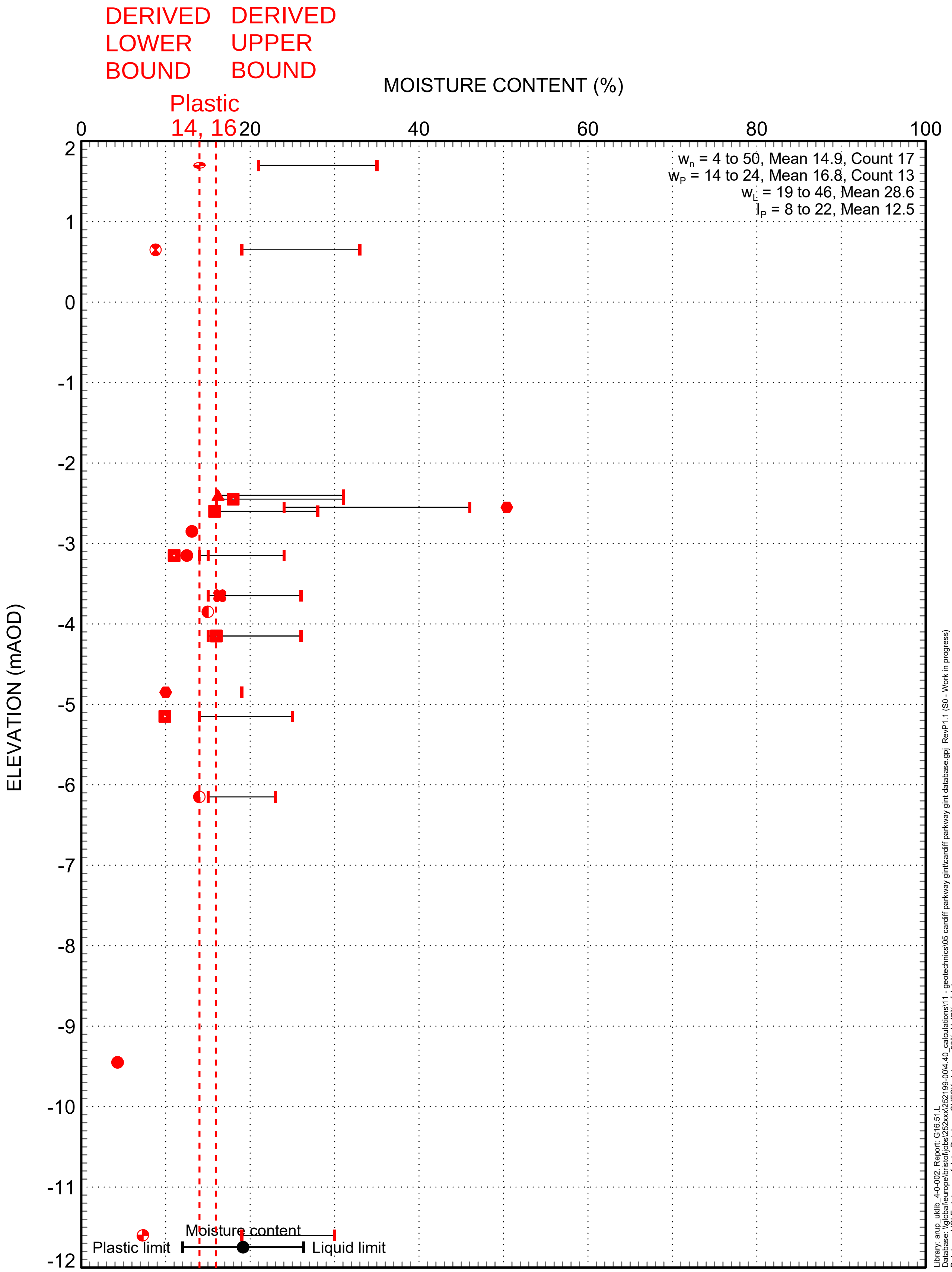


CARDIFF PARKWAY

MOISTURE CONTENT

MMG & SMF

252199 - Plot B.5.1



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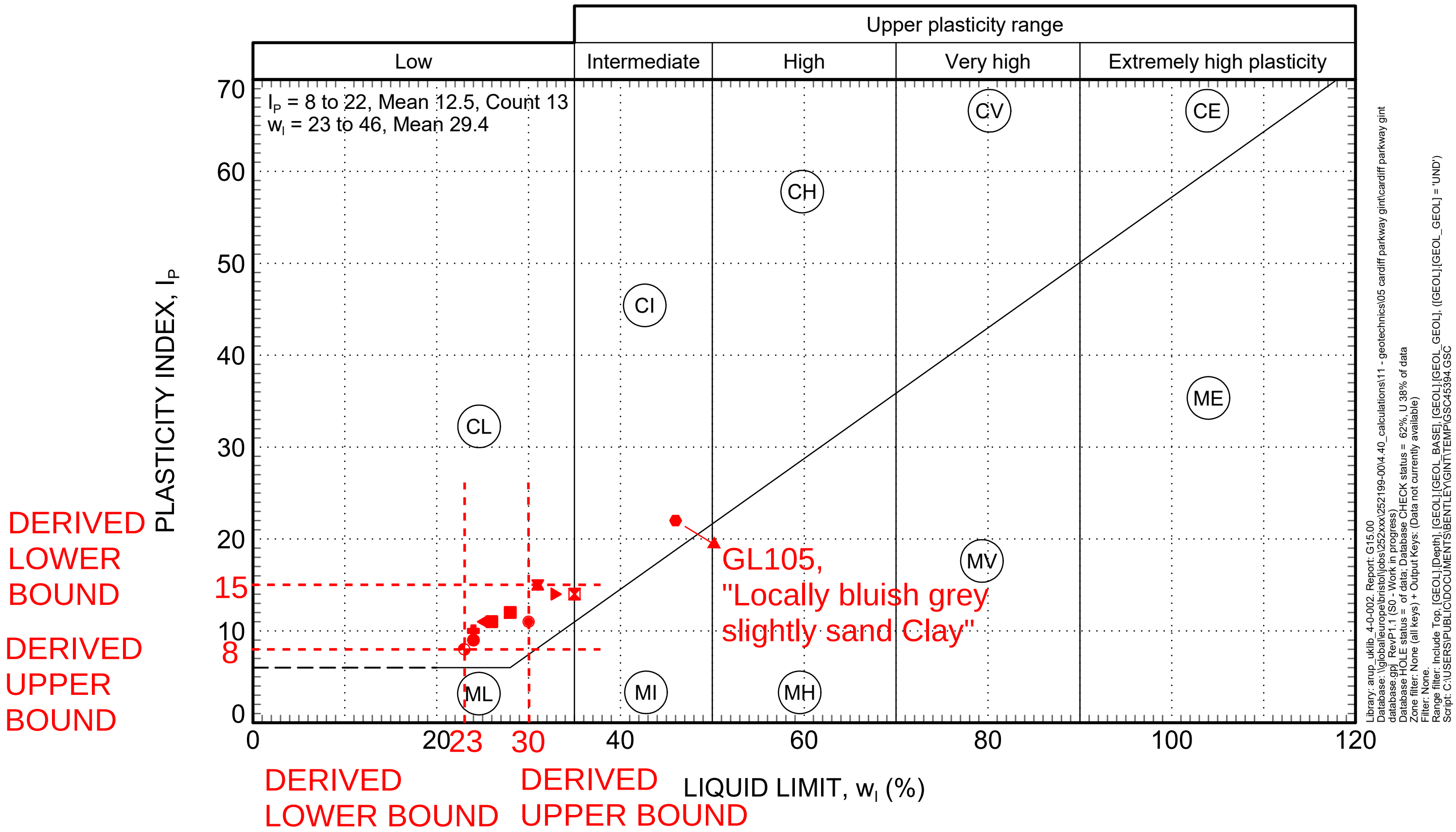
Database HOLE status = of data; Database CHECK status = 53%, U 47% of data
Zone filter: None (all keys) + Output Keys: (Data not currently available)
Filter: None.
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], ([GEOL].[GEOL_GEOL] = 'UND')

■ Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE (UND)
- ● GL101
- ■ GL102
- ▲ GL103
- GL104
- ⬢ GL105
- M-BH13
- BH03
- BH06
- BH08
- ◐ BH11

ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY
ATTERBERG LIMITS
MMG & SMF

252199 - Plot B.5.2



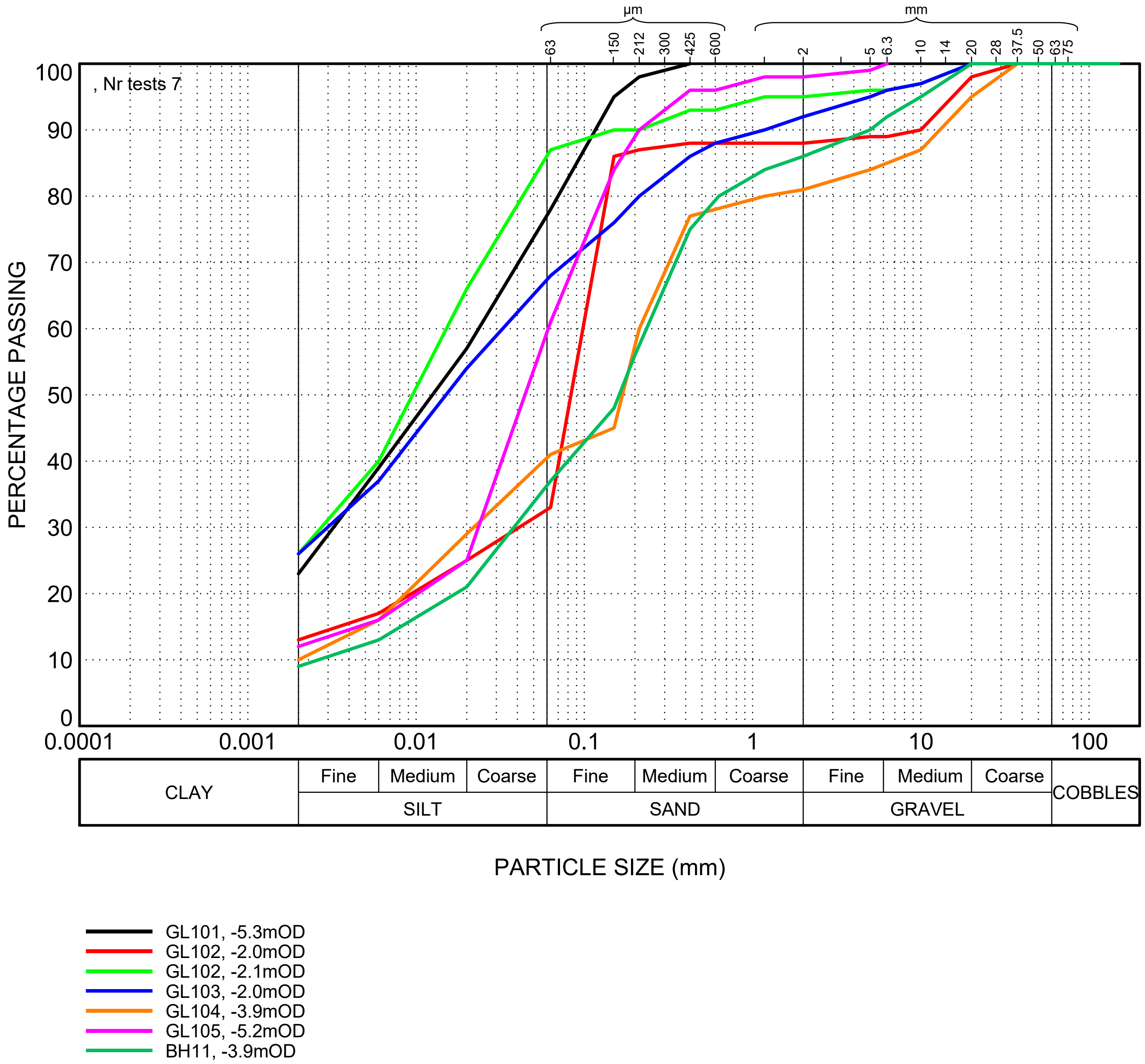
- Undifferentiated Bedrock of ST MAUGHANS and MERCIA MUDSTONE (UND)
- GL101, -3.2mOD
- GL102, -2.6mOD
- GL103, -2.4mOD
- GL104, -3.7mOD
- GL105, -2.6mOD
- M-BH13, -2.5mOD
- M-BH13, -3.2mOD
- M-BH13, -4.2mOD
- M-BH13, -5.2mOD
- BH03, 0.7mOD
- BH06, 1.7mOD
- BH08, -11.6mOD
- BH11, -6.2mOD

ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY

PLASTICITY CHART

MMG & SMF 252199 - Plot B.5.3



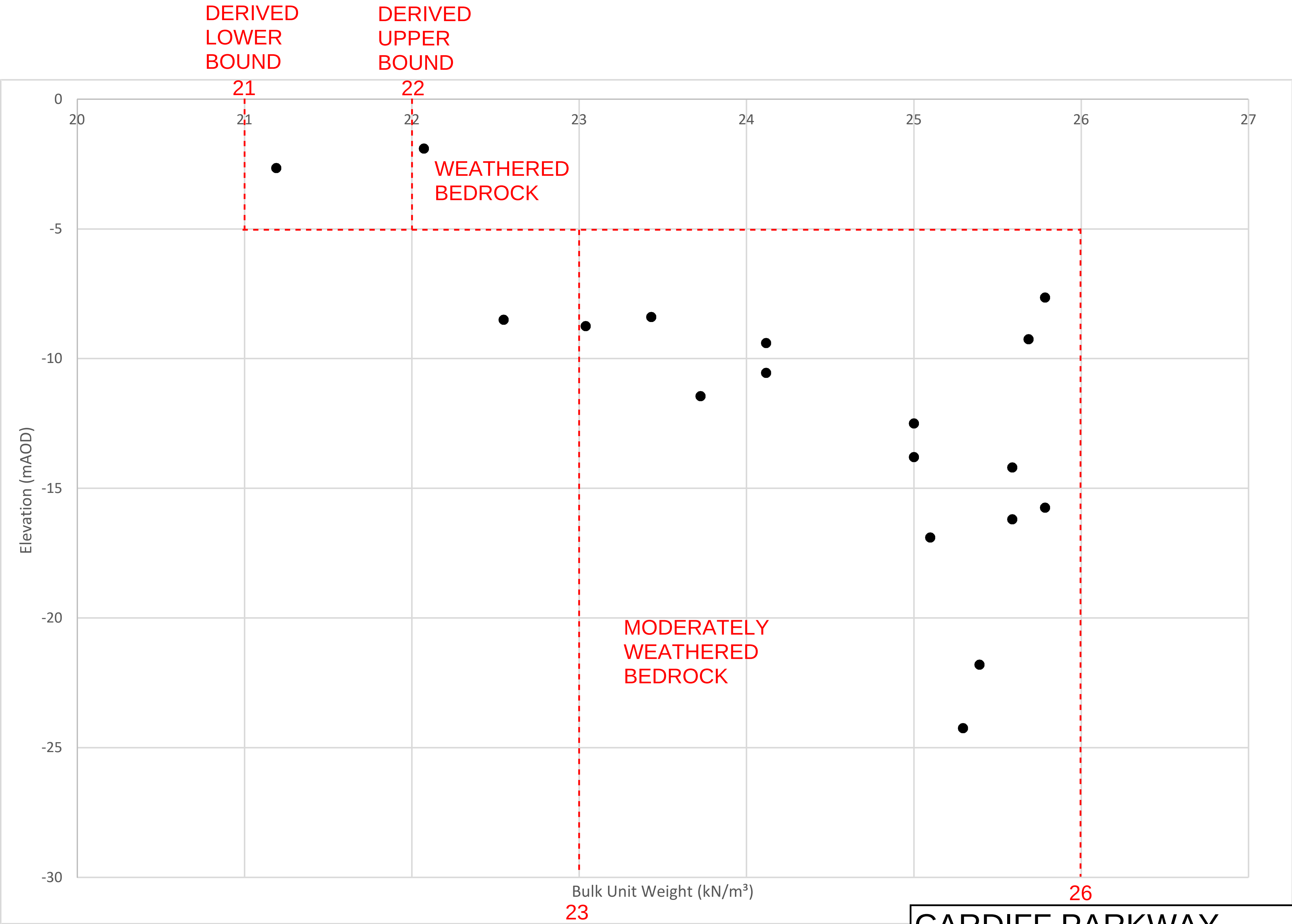
ARUP_gINT v8.30.004
Made by Alex Sadlier on 1-Nov-19

CARDIFF PARKWAY

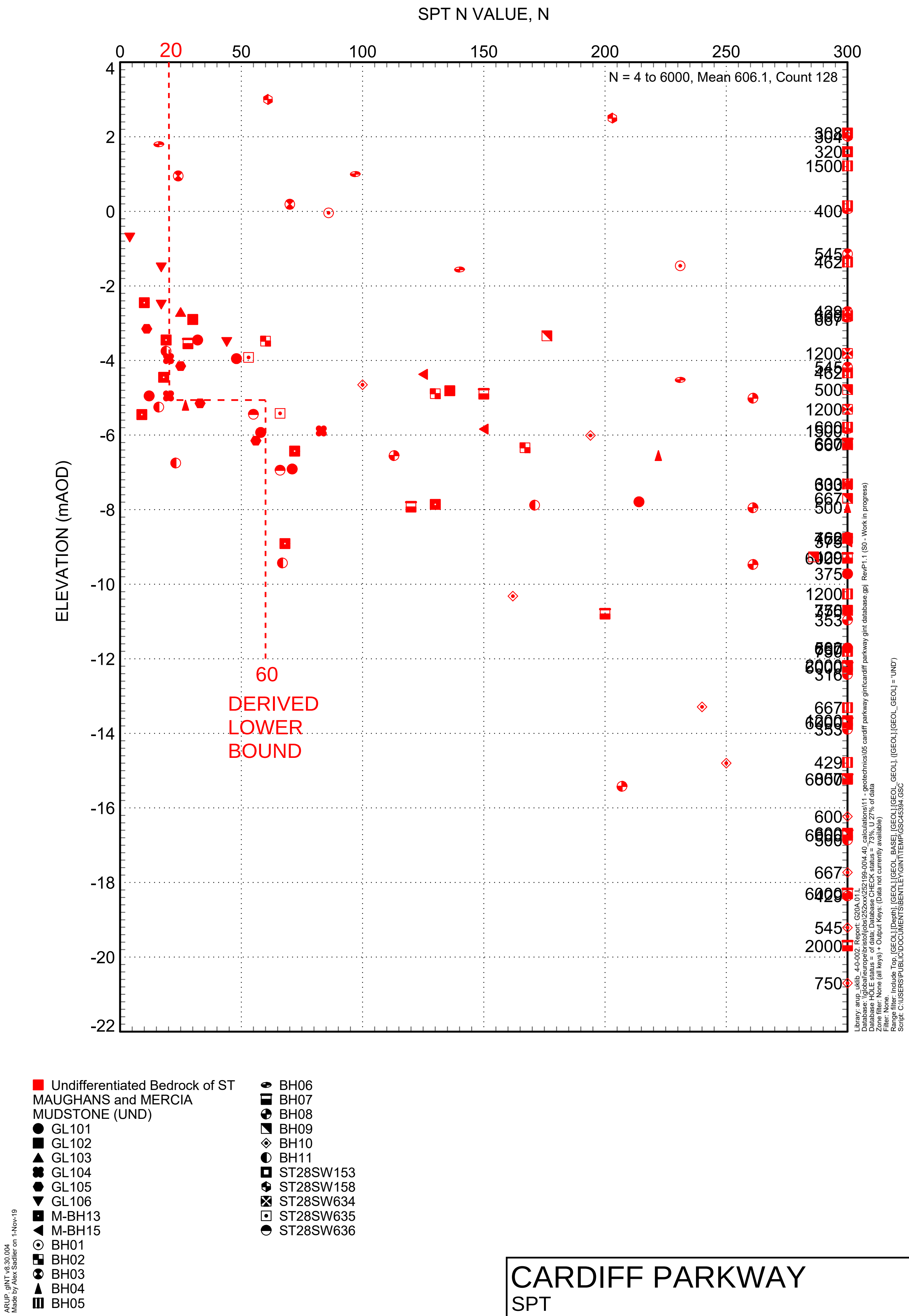
PSD

MMG & SMF

252199 - Plot B.5.4



CARDIFF PARKWAY
BULK UNIT WEIGHT
MMG & SMF
252199 - Plot B.5.5



CARDIFF PARKWAY

SPT

MMG & SMF 252199 - Plot B.5.6

Appendix C

Groundwater

Groundwater Testing Results

Sample Reference		AA-EQS Inland surface waters	1282924	1302759	1315976	1281935	1302760	1315162	1281936	1282925	1302761	1315977	1281937	1282926	1302762	1315163	1281938	1282927	1302763	1315164	1282928	1302764	1315978	1293700	1302765	1315165	1302766	1315166	1302767	1315167	1282929	1302768	1315979
Excavation			BH01	BH01	BH01	BH02	BH02	BH02	BH03	BH03	BH03	BH03	BH04	BH04	BH04	BH04	BH05	BH05	BH05	BH05	BH06	BH06	BH06	BH07	BH07	BH07	BH08	BH08	BH09	BH09	BH10	BH10	BH10
Sample Depth			1.14	1	0.97	0.88	0.58	0.64	1.03	1.6	1.37	1.5	1.13	0.91	0.79	0.88	1.22	1.21	1.1	1.2	1.42	1.01	1.06	1.05	1.02	1.08	1.12	1.18	0.76	0.89	0.9	0.7	1.1
Date			01/08/2019	28/08/2019	12/09/2019	30/07/2019	17/08/2019	12/09/2019	30/07/2019	01/08/2019	28/08/2019	12/09/2019	30/07/2019	01/08/2019	17/08/2019	12/09/2019	30/07/2019	01/08/2019	17/08/2019	12/09/2019	01/08/2019	28/08/2019	12/09/2019	15/08/2019	17/08/2019	12/09/2019	27/08/2019	12/09/2019	27/08/2019	12/09/2019	01/08/2019	27/08/2019	12/09/2019
Round			1	2	3	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	1	2	1	2	3
Stratigraphy			SMF	SMF	SMF	TFD	TFD	TFD	GTD	GTD	GTD	GTD	SMF	SMF	SMF	SMF	GTD	GTD	GTD	GTD	GTD/SMF	GTD/SMF	GTD/SMF	SMF	SMF	SMF	GTD	GTD	SMF	SMF	TFD	TFD	TFD
General Inorganics																																	
pH	pH Units		7.5	7.6	7.6	7.5	7.5	7.4	7.6	7.7	7.8	7.8	7.6	7.6	7.7	7.8	7.7	8.0	7.3	7.5	7.1	7.1	7.1	6.9	7.3	7.4	7.2	7.5	7.6	7.6	8.0	7.3	8.0
Total Cyanide	µg/l	1	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Ammoniacal Nitrogen as N	µg/l		97	340	93	110	200	68	830	22	< 15	< 15	1500	1200	1400	1200	330	410	280	74	44	210	62	800	1000	1000	1900	2100	100	170	430	48	85
Dissolved Organic Carbon (DOC)	mg/l		2.77	2.40	2.13	3.85	2.91	3.58	8.08	5.21	3.78	3.28	12.40	1.18	4.42	2.00	10.50	7.26	8.36	9.87	9.02	9.75	10.50	11.70	11.00	9.18	17.90	26.20	18.60	15.10	6.81	37.40	10.90
Nitrate as N	mg/l		0.11	0.49	0.35	0.35	0.37	0.65	0.24	0.13	0.10	0.07	0.27	0.10	0.30	0.45	0.57	0.10	0.35	0.30	0.10	0.76	0.64	0.07	0.19	0.36	0.60	0.39	0.16	0.34	0.11	0.08	0.11
Nitrite as N	µg/l		25.0	24.0	14.0	15.0	14.0	18.0	14.0	16.0	24.0	14.0	11.0	16.0	14.0	11.0	14.0	14.0	16.0	12.0	16.0	26.0	23.0	4.3	5.6	2.3	21.0	16.0	46.0	11.0	11.0	5.3	32.0
Chemical Oxygen Demand (Total)	mg/l		28.0	6.3	16.0	1700.0	11.0	100.0	50.0	74.0	46.0	610.0	74.0	26.0	20.0	53.0	1900.0	730.0	25.0	1700.0	210.0	200.0	110.0	27.0	32.0	34.0	50.0	140.0	270.0	1500.0	270.0	120.0	180.0
BOD (Biochemical Oxygen Demand) (Total) - PL	mg/l		3.10	< 1.0	< 1.0	2.40	< 1.0	< 1.0	< 1.0	8.50	< 1.0	1.20	1.00	2.50	1.40	< 1.0	2.90	62.00	5.80	1.20	3.50	1.10	< 1.0	15.00	2.30	8.40	9.20	1.80	8.70	1.60	16.00	85.00	1.90
Total Oxidised Nitrogen (TON)	mg/l		< 0.3	0.50	0.40	0.40	0.40	0.70	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	0.30	0.50	0.60	< 0.3	0.40	0.30	< 0.3	0.80	0.70	< 0.3	< 0.3	0.40	0.60	0.40	< 0.3	0.30	< 0.3	< 0.3	< 0.3
Hardness - Total	mgCaCO3/l		279	209	250	255	239	302	159	214	201	244	362	170	130	186	291	126	295	299	228	319	379	434	182	205	205	231	275	326	413	175	315
Total Phenols																																	
Total Phenols (monohydric)	µg/l	7.7	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	48.00	< 10
Speciated PAHs																																	
Naphthalene	µg/l	2	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Acenaphthylene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Acenaphthene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fluorene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Phenanthrene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Anthracene	µg/l	0.1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fluoranthene	µg/l	0.0063	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Pyrene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(a)anthracene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chrysene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(b)fluoranthene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(k)fluoranthene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(a)pyrene	µg/l	0.00017	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Indeno(1,2,3-cd)pyrene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Dibenz(a,h)anthracene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(ghi)perylene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Total PAH																																	
Total EPA-16 PAHs	µg/l		< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16
Heavy Metals / Metalloids																																	
Arsenic (dissolved)	µg/l	50	0.66	0.63	0.36	0.68	1.32	0.82	1.16	1.22	1.18	0.82	0.82	1.71	1.21	1.77	1.09	1.12	1.04	1.27	1.14	1.35	0.90	4.70	0.86	1.05	1.64	3.36	0.75	1.16	2.89	3.16	1.47
Cadmium (dissolved) [1]	µg/l	0.15	0.03	< 0.02	< 0.02	0.04	0.11	0.17	< 0.02	< 0.02	< 0.02	0.03	< 0.02	0.02	< 0.02	< 0.02	< 0.02	0.04	< 0.02	< 0.02	0.16	0.08	0.06	< 0.02	< 0.02	0.04	< 0.02	0.03	< 0.02	< 0.02	0.12	< 0.02	0.04
Calcium (dissolved)	mg/l		71	49	60	66	62	76	28	51	50	58	83	38	31	44	44	25	66	55	30	47	50	110	40	38	47	29	56	61	94	55	44
Chromium (dissolved)	µg/l		0.50	< 0.2	< 0.2	0.20	< 0.2	< 0.2	0.50	0.60	0.20	< 0.2	0.40	0.40	0.40	0.80	0.20	1.20	< 0.2	0.40	2.10	0.20	< 0.2	0.80	0.30	0.40	1.20	0.50	0.30	0.30	2.30	< 0.2	0.60
Copper (dissolved)	µg/l		18	3	8	6	3	6	7	10	2	2	7	4	2	1	3	6	2	1	14	9	7	16	6	3	5	3	3	4	16	1	13
Bioavailable Copper	µg/l	1	1.60	0.27	1.03	0.37	0.26	0.38	0.20	0.48	0.16	0.15	0.13	0.84	0.10	0.14	0.06	0.25	0.05	0.03	0.37	0.22	0.16	0.37	0.11	0.06	0.08	0.05	0.05	0.07	0.72	0.01	0.40
Lead (dissolved)	µg/l		0.40	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.20	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.20	< 0.2	< 0.2	1.90	< 0.2	< 0.2	1.30	< 0.2	< 0.2	0.60	< 0.2	0.60	0.60	0.30	< 0.2	< 0.2	6.90	< 0.2	< 0.2
Bioavailable lead	µg/l	1.2	0.14	0.08	0.09	0.05	0.07	0.06	0.02	0.04	0.05	0.06	0.02	0.17	0.05	0.10	0.02	0.26	0.02	0.02	0.14	0.02	0.02	0.05	0.02	0.07	0.03	0.02	0.01	0.01	1.01	0.01	0.02
Magnesium (dissolved)	mg/l		25	21	24	22	20	28	22	21	18	24	37	18	13	19	44	16	32	40	38	49	62	41	20	27	21	38	33	42	43	9	50
Mercury (dissolved)	µg/l		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.19	0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.64	0.07	< 0.05	0.12	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.14	0.15	0.12	0.11	< 0.05
Nickel (dissolved)	µg/l		1.40	< 0.5	< 0.5	3.10	2.00	2.40	3.10	2.70	1.60	1.30	3.00	1.40	1.90	1.20	4.30	3.10	3.70	3.70	3.80	1.70	1.40	5.60	2.40	2.40	7.10	2.70	2.90	4.10	7.90	1.90	1.90
Bioavailable Nickel	µg/l	4	0.40	0.19	0.17	0.83	0.59	0.61	0.84	0.84	0.61	0.48	0.48	0.74	0.78	0.60	1.00	1.16	0.68	0.75	0.80	0.31	0.24	0.71	0.46	0.53	0.97	0.36	0.42	0.66	2.45	0.24	0.54
Phosphorus (dissolved)	µg/l		< 20.0	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0	30.20	< 20.0	< 20.0	< 20.0	< 20.0	25.40	< 20.0	25.50	23.50	< 20.0	21.30	< 20.0	46.80	38.20	22.40	155.00	30.40	20.80	27.50	39.70	< 20.0	< 20.0	1010.00	193.00	55.60
Selenium (dissolved)	µg/l		1.20	1.10	1.30	1.50	0.90	0.90	3.90	1.70	1.30	1.10	3.90	2.80	3.10	3.80	17.00	2.20	1.70	8.70	2.20	2.30	1.20	2.00	2.50	3.90	3.50	9.40	12.00	20.00	4.00	< 0.6	1.60
Zinc (dissolved)	µg/l		0.60	0.70	2.90	2.10	1.60	4.70	4.70	2.20	2.40	0.60	1.30	2.70	1.40	2.10	0.50	15.00	6.90	2.90	1.40	1.70	0.80	10.00	1.70	3.40	2.60	2.30	0.50	9.50	26.00	1.00	0.60
Bioavailable zinc	µg/l	13.1	0.32	0.40	1.70	0.97	0.84	2.25	1.37	0.85	1.10	0.29	0.28	2.03	0.61	1.32	0.12	4.33	2.18	0.76	0.43	0.51	0.23	3.06	0.43	0.96	0.46	0.31	0.07	1.71	7.95	0.16	0.12
Monoaromatics & Oxygenates																																	
Benzene	µg/l	10	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	µg/l	74	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	5.40
Ethylbenzene	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
p & m-xylene	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-xylene	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
MTBE (Methyl Tertiary Butyl Ether)	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Petroleum Hydrocarbons																																	
TPH-CWG - Aliphatic >C5 - C6	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aliphatic >C6 - C8	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aliphatic >C8 - C10	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aliphatic >C10 - C12	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C12 - C16	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	24	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C16 - C21	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	95	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C21 - C35	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	1700	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C35 - C44	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	300	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic (C5 - C35)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	1800	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic (C5 - C44)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	2100	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C5 - C7	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C7 - C8	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	5.40
TPH-CWG - Aromatic >C8 - C10	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C10 - C12	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C12 - C16	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C16 - C21	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C21 - C35	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C35 - C44	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic (C5 - C35)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic (C5 - C44)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10

Notes:
1.) Class 4 EQS based on recorded hardness values

Exceedance of EQS

Appendix D

Surface Water

Surface Water Testing Results

Sample Reference		AA-EQS Inland surface waters (mg/l)	1244139	1244140	1244141	1244142	1244143	1253977	1253978	1253979	1253980	1253981	1270398	1270399	1270400	1270401	1270402	1279524	1279525	1279526	1279527	1279528	1293663	1293664	1293665	1293666	1293667	1302779	1302780	1302781	1302782	1302783	1315154	1315155	1315156	1315157	1315158	12687	12688
Sample location			SW1	SW2	SW3	SW4	SW5	SW1	SW2	SW3	SW4	SW5	SW1	SW2	SW3	SW4	SW5	SW1	SW2	SW3	SW4	SW5	SW1	SW2	SW3	SW4	SW5	SW1	SW2	SW3	SW4	SW5	SW1	SW2	SW3	SW4	SW5	SW1	SW2
Sample Depth			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Date			12/06/2019	12/06/2019	12/06/2019	12/06/2019	12/06/2019	26/06/2019	26/06/2019	26/06/2019	26/06/2019	26/06/2019	17/07/2019	17/07/2019	17/07/2019	17/07/2019	17/07/2019	30/07/2019	30/07/2019	30/07/2019	30/07/2019	30/07/2019	15/08/2019	15/08/2019	15/08/2019	15/08/2019	15/08/2019	28/08/2019	28/08/2019	28/08/2019	28/08/2019	28/08/2019	12/09/2019	12/09/2019	12/09/2019	12/09/2019	12/09/2019	24/09/2019	24/09/2019
Round			1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8
General Inorganics																																							
pH	pH Units		7.7	7.6	8.0	7.4	7.9	7.3	7.5	7.6	7.4	7.5	7.6	7.5	7.8	7.5	7.5	7.7	7.4	7.4	7.4	7.4	7.5	7.5	7.4	7.5	7.3	7.8	7.5	7.3	7.3	7.5	7.7	7.5	7.3	7.3	7.5	8.0	7.5
Total Cyanide	µg/l	1	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Ammoniacal Nitrogen as N	µg/l		280	< 15	52	36	16	920	89	370	37	34	22	17	43	< 15	15	110	150	1000	86	910	430	700	430	130	370	490	120	290	47	< 15	350	33	62	270	39	150	93
Dissolved Organic Carbon (DOC)	mg/l		3.96	7.89	5.10	4.86	6.91	8.29	7.92	7.13	8.58	7.70	7.17	9.60	6.70	6.28	11.80	7.36	7.31	7.14	7.75	6.47	6.43	6.63	3.76	3.88	5.80	5.23	7.09	7.45	4.95	5.14	6.37	5.89	5.69	4.95	5.59	6.84	5.32
Nitrate as N	mg/l		1.45	0.04	0.99	0.01	0.02	0.21	0.11	0.59	0.14	0.11	0.17	0.21	0.18	0.16	0.17	2.01	0.48	0.38	0.45	0.56	0.31	0.37	0.34	0.39	0.02	0.26	0.10	0.11	0.13	0.10	0.77	0.29	0.30	0.30	0.26	1.76	0.35
Nitrite as N	µg/l		80.0	6.4	78.0	8.1	9.2	19.0	15.0	170.0	6.2	6.6	< 1.0	4.9	< 1.0	< 1.0	2.8	55.0	13.0	7.9	8.2	4.5	110.0	130.0	53.0	78.0	15.0	53.0	9.4	5.7	16.0	9.3	93.0	6.1	5.1	46.0	7.4	60.0	65.0
Chemical Oxygen Demand (Total)	mg/l		12.0	13.0	8.0	13.0	9.3	200.0	23.0	25.0	52.0	21.0	38.0	38.0	40.0	120.0	76.0	31.0	21.0	20.0	26.0	22.0	23.0	26.0	20.0	13.0	35.0	17.0	25.0	28.0	21.0	17.0	25.0	24.0	31.0	20.0	23.0	25.0	36.0
BOD (Biochemical Oxygen Demand) (Total) - PL	mg/l							21.00	5.30	4.80	3.70	3.40	11.00	8.90	4.20	6.10	12.00	2.80	3.20	5.00	7.60	3.70	8.70	10.00	8.70	8.40	11.00	4.90	7.60	9.80	4.10	7.20	2.30	1.40	6.90	1.40	1.40	3.70	2.10
Total Oxidised Nitrogen (TON)	mg/l		1.50	< 0.3	1.10	< 0.3	< 0.3	< 0.3	< 0.3	0.80	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	2.10	0.50	0.40	0.50	0.60	0.40	0.50	0.40	0.50	< 0.3	0.30	< 0.3	< 0.3	< 0.3	< 0.3	0.90	< 0.3	0.30	0.30	< 0.3	1.80	0.40
Hardness - Total	mgCaCO3/l		137	111	142	84	111	168	103	161	200	146	277	177	243	248	167	154	125	148	160	180	148	130	73	96	119	241	202	139	140	189	163	192	189	192	167	168	198
Total Phenols																																							
Total Phenols (monohydric)	µg/l	7.7	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Speciated PAHs																																							
Naphthalene	µg/l	2	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Acenaphthylene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Acenaphthene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fluorene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Phenanthrene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Anthracene	µg/l	0.1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fluoranthene	µg/l	0.0063	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Pyrene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(a)anthracene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chrysene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(b)fluoranthene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(k)fluoranthene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(a)pyrene	µg/l	0.00017	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Indeno(1,2,3-cd)pyrene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Dibenz(a,h)anthracene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(ghi)perylene	µg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Total PAH																																							
Total EPA-16 PAHs	µg/l		< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16	< 0.16
Heavy Metals / Metalloids																																							
Arsenic (dissolved)	µg/l	50	1.20	1.30	1.11	1.01	1.94	1.99	3.38	1.02	0.82	1.13	4.40	3.45	1.26	1.29	2.52	0.78	3.88	1.20	4.63	1.34	4.96	2.91	0.86	0.53	1.65	2.47	2.62	0.69	0.95	1.09	2.11	1.75	0.82	0.82	1.60	1.06	1.57
Boron (dissolved)	µg/l																																					15.00	< 10
Cadmium (dissolved) [1]	µg/l	0.15	0.04	< 0.02	0.02	< 0.02	< 0.02	0.10	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.05	0.02	0.03	0.04	< 0.02	0.05	0.07	0.02	< 0.02	< 0.02	< 0.02	0.04	0.02	< 0.02	< 0.02	0.02	< 0.02	0.03	< 0.02	0.06	0.03	0.02
Calcium (dissolved)	mg/l		29	24	31	21	23	46	25	39	52	37	74	44	63	64	39	45	35	42	45	51	43	37	22	28	35	68	59	41	40	56	43	53	51	51	46	51	58
Chromium (dissolved)	µg/l		0.50	0.40	0.40	0.50	0.40	0.70	0.50	0.40	0.40	0.40	< 0.2	0.20	0.50	0.60	0.30	2.40	0.40	0.30	0.70	0.50	0.60	0.60	0.80	0.90	0.40	0.50	0.40	0.30	0.30	0.30	1.00	0.50	0.50	0.50	0.80	2.30	0.90
Copper (dissolved)	µg/l		5	5	6	3	9	8	5	3	5	3	2	2	10	3	4	13	5	16	5	7	11	10	7	6	4	4	6	5	3	4	6	5	4	3	8	12	9
Bioavailable Copper	µg/l	1	0.31	0.14	0.36	0.16	0.35	0.20	0.13	0.10	0.12	0.09	0.05	0.06	0.38	0.12	0.08	0.42	0.14	0.49	0.13	0.23	0.38	0.34	0.41	0.37	0.16	0.22	0.19	0.14	0.16	0.19	0.24	0.18	0.14	0.15	0.34	0.54	0.36
Lead (dissolved)	µg/l		1.20	0.30	0.60	0.20	< 0.2	2.10	0.60	0.50	< 0.2	0.40	< 0.2	3.80	0.60	0.40	0.60	1.70	0.50	1.50	1.80	0.30	2.10	2.30	1.20	0.30	< 0.2	< 0.2	0.50	0.20	< 0.2	0.20	0.80	< 0.2	6.20	0.60	< 0.2	1.90	0.80
Bioavailable lead	µg/l	1.2	0.30	0.04	0.12	0.04	0.03	0.25	0.08	0.07	0.02	0.05	0.03	0.40	0.09	0.06	0.05	0.23	0.07	0.21	0.23	0.05	0.33	0.35	0.32	0.08	0.03	0.04	0.07	0.03	0.04	0.04	0.13	0.03	1.09	0.12	0.04	0.28	0.15
Magnesium (dissolved)	mg/l		16	12	16	8	13	13	10	15	17	13	22	16	21	21	17	10	9	10	12	13	10	9	5	6	8	17	13	9	10	12	14	15	15	16	13	10	13
Mercury (dissolved)	µg/l		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nickel (dissolved)	µg/l		0.50	< 0.5	0.70	0.60	0.60	0.80	< 0.5	< 0.5	< 0.5	< 0.5	1.30	1.30	1.20	0.80	1.90	1.00	1.00	1.00	1.30	1.00	1.00	1.50	1.00	0.70	1.20	0.90	0.80	0.60	< 0.5	< 0.5	0.70	0.80	0.90	0.70	0.90	1.20	0.80
Bioavailable Nickel	µg/l	4	0.22	0.14	0.34	0.21	0.21	0.17	0.13	0.14	0.11	0.13	0.29	0.29	0.33	0.19	0.38	0.28	0.26	0.25	0.30	0.24	0.27	0.42	0.40	0.28	0.33	0.26	0.18	0.14	0.14	0.13	0.22	0.21	0.22	0.18	0.25	0.42	0.21
Phosphorus (dissolved)	µg/l		205.00	56.40	118.00	93.30	46.10	280.00	35.20	206.00	35.30	34.30	191.00	158.00	605.00	269.00	201.00	156.00	131.00	477.00	143.00	340.00	242.00	135.00	141.00	125.00	123.00	135.00	104.00	93.70	75.60	58.40	174.00	110.00	119.00	174.00	146.00	259.00	174.00
Selenium (dissolved)	µg/l		0.80	< 0.6	0.80	< 0.6	< 0.6	0.70	< 0.6	0.60	0.70	< 0.6	0.70	< 0.6	< 0.6	< 0.6	1.30	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	0.70	< 0.6	< 0.6	< 0.6	< 0.6	0.70	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	0.60	< 0.6	< 0.6	< 0.6	< 0.6
Zinc (dissolved)	µg/l		10.00	1.80	6.00	2.40	3.40	20.00	5.60	8.00	0.90	2.50	1.60	7.30	14.00	4.50	8.90	16.00	2.10	12.00	21.00	5.10	56.00	99.00	12.00	8.90	2.90	3.00	8.00	6.40	1.50	5.70	5.90	4.80	6.70	11.00	1.70	20.00	18.00
Bioavailable zinc	µg/l	13.1	4.68	0.53	2.27	1.05	1.04	6.27	1.70	2.57	0.27	0.78	0.52	1.94	4.51	1.61	1.99	4.92	0.70	4.05	6.71	1.83	19.78	34.26	6.13	4.34	1.14	1.13	2.66	2.15	0.65	2.30	2.01	1.79	2.66	4.70	0.66	6.08	7.11
Monoaromatics & Oxygenates																																							
Benzene	µg/l	10	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	µg/l	74	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
p & m-xylene	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-xylene	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
MTBE (Methyl Tertiary Butyl Ether)	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Petroleum Hydrocarbons																																							
TPH-CWG - Aliphatic >C5 - C6	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aliphatic >C6 - C8	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aliphatic >C8 - C10	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aliphatic >C10 - C12	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C12 - C16	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C16 - C21	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C21 - C35	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C35 - C44	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic (C5 - C35)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic (C5 - C44)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C5 - C7	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C7 - C8	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C8 - C10	µg/l		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C10 - C12	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C12 - C16	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C16 - C21	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C21 - C35	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C35 - C44	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic (C5 - C35)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic (C5 - C44)	µg/l		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10

Notes:
1.) Class 4 EQS based on recorded hardness values

Exceedance of EQS

Appendix E

Gas

Ground gas monitoring results

Shallow Installations

	BH01					
	0.3 - 2.0 (19mm)					
	TFD					
	16-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	0.2	0.1	0	0	0	0
Methane (%)	0	0	0	0	0	0
Oxygen (%)	7.7	21.1	20	21.4	20.6	21.1
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	0	0	0.5	0	0.8	0
Gas flow ltr/hr	0	0	0	0	0	0
Groundwater level, m bgl	1.39	1.12	0.83	0.99	0.96	0.92
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH02					
	0.5 – 2.0 (19mm)					
	TFD					
	16-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	-	0.1	0	0	0	0.1
Methane (%)	-	0	0	0	0	0
Oxygen (%)	-	21	20.3	21.5	20.7	20.9
LEL (%)	-	0	0	0	0	0
Hydrogen sulphide (ppm)	-	0	0	0	0	0
Carbon monoxide (ppm)	-	0	0	0	0	0
VOC (ppm)	-	0.1	0	0	0	0
Gas flow ltr/hr	-	0	0	0	0	0
Groundwater level, m bgl	1.24	0.88	0.65	0.53	0.66	0.65
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH03					
	0.3 – 2.0 (19mm)					
	TFD/GTD					
	16-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	4	4.7	5.6	3.1	0	4.3
Methane (%)	0	0	0	0	0	0
Oxygen (%)	0.9	1.2	0	8.6	5.5	6.4
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	63.1	51.4	0.9	0	0	0
Gas flow ltr/hr	0	0	15.4	0	0	0
Groundwater level, m bgl	1.39	1.45	1.14	0.11	1.01	1.11
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH06					
	0.3 – 2.5 (19mm)					
	TFD					
	18-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	1.1	2.2	2.2	0	3.7	0
Methane (%)	0	0	0	0	0	0
Oxygen (%)	18.8	11.4	12.2	21.7	14.5	20.9
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	0.8	0.5	0	0	0	0
Gas flow ltr/hr	0	0	3	0	0	0
Groundwater level, m bgl	-	1.39	0.9	0.63	0.84	0.58
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH09					
	0.4 – 2.0 (19mm)					
	TFD					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	9.8	4.8	0	0	11.1	3.4
Methane (%)	0	0	0	0	0	0
Oxygen (%)	0.3	6.7	20.4	21.4	4.4	13.3
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	18.4	4	0.2	0	0	0
Gas flow ltr/hr	0	0	0	1.5	0	0
Groundwater level, m bgl	1.22	0.72	0.45	0.58	0.89	0.91
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH05					
	0.5 – 1.5 (19mm)					
	TFD with peat					
	18-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	6.5	0	0	0.1	0	0
Methane (%)	0	0	0	0	0	0
Oxygen (%)	3.3	21.3	20.3	21.3	20.7	20.9
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	9	0.3	0.3	0	0	0
Gas flow ltr/hr	0	0	0	1.5	0	0
Groundwater level, m bgl	1.29	1.1	0.4	0.43	1.06	1.13
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH10					
	0.5 – 2.5 (50mm)					
	TFD with peat					
	18-Jul	30-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	3.2	3.4	2.6	0.8	5.5	5.1
Methane (%)	0	0	0	0	0	0
Oxygen (%)	8.8	5.3	15.4	18.9	8.5	12.1
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	105.1	5.9	4.4	52.1	0	0
Gas flow ltr/hr	0	0	0	0	0	0
Groundwater level, m bgl	1.29	0.9	0.68	0.5	1.1	1.16
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

Long Installations - Band Drain Representative Installations

	BH07					
	0.5 – 7.0 (19mm)					
	TFD					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	1.8	2	2.7	0	3.8	3.8
Methane (%)	0	0	0	0	0	0
Oxygen (%)	18.7	19.1	17.2	21.3	17.2	18.4
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0		0	0	0
VOC (ppm)	0.5	0.2	0.1	0	0	0
Gas flow ltr/hr	0	0	0	0	0	0
Groundwater level, m bgl	1.35	1.13	0.75	0.88	1.03	1.04
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH08					
	0.5 – 6.0 (19mm)					
	TFD with peat					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	0	2.6	0	0	0	0.4
Methane (%)	0	0	0	0	0	0
Oxygen (%)	20.2	18.3	20.4	21.2	20.8	20.8
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)		0	0	0	0	0
VOC (ppm)	23.4	2.2	0.3	0	0	0
Gas flow ltr/hr	0	0	0	0.9	0	0
Groundwater level, m bgl	1.39	0.85	1.17	1.11	1.18	1.21
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH04					
	0.5 – 6.0 (19mm)					
	TFD/GTD					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	3	5.1	0	0.6	4.8	4.6
Methane (%)	0	0	0	0	0	0
Oxygen (%)	16.2	12.1	20.4	19.2	10.3	10.4
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	4.3	1	0.3	0	0	0
Gas flow ltr/hr	0	0	0	0	0	0
Groundwater level, m bgl	1.25	1.22	0.78	0.7	0.86	0.64
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

Deep installations

	BH02					
	4 – 5 (50mm)					
	TFD					
	16-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	0	0	0	0	0	0.1
Methane (%)	0	0	0	0	0	0
Oxygen (%)	20.3	21.4	20.4	21.5	20.7	21
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	2.2	11.2	0.8	0	0	0
Gas flow ltr/hr	0	0	0	0	-0.6	0
Groundwater level, m bgl	1.09	0.8	0.55	0.53	0.64	0.61
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH03					
	4.7 -6.0 (50mm)					
	GTD					
	16-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	0.1	0.2	0	0.1	0.6	0
Methane (%)	0	0	0	0	0	0
Oxygen (%)	20	21.1	20	21.5	19.6	21
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	10.2	10	0.9	0	0	0
Gas flow ltr/hr	0	0	0	0	0	0
Groundwater level, m bgl	1.72	1.6	1.37	1.27	1.5	1.5
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH05					
	2.7 – 4.0 (50mm)					
	GTD					
	18-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	0	0	0	0	0	0
Methane (%)	0	0	0	0	0	0
Oxygen (%)	19.9	21.1	20.4	21.4	20.7	20.8
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0		0	0	0
VOC (ppm)	51.1	6.2	1.4	0.4	0.2	0
Gas flow ltr/hr	0	0	0	1.9	0	0
Groundwater level, m bgl	1.4	1.21	1.06	0.93	1.2	1.25
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH08					
	8.5-9.5 (50mm)					
	GTD					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	0.1	0	0	0	0	0
Methane (%)	0	0	0	0	0	
Oxygen (%)	19.8	21.2	20.4	21.3	20.9	21.1
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	8.1	1.7	0.9	2.4	0	0
Gas flow ltr/hr	-6	0	-3.5	0	0	-0.6
Groundwater level, m bgl	1.42	1.29	1.2	1.09	1.18	1.21
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH06					
	3.7 – 5.0 (50mm)					
	GTD/SMF					
	18-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	0.3	0.6	0	0	0	0.2
Methane (%)	0	0	0	0	0	0
Oxygen (%)	19.9	20.4	20.4	21.3	20.7	20.9
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	15.7	18.8	0.6	0.4	0.1	0.5
Gas flow ltr/hr	0	0	3	0	0	0
Groundwater level, m bgl	1.63	1.42	1.21	0.91	1.06	0.93
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH01					
	6.7 – 8.0 (50mm)					
	SMF					
	16-Jul	01-Aug	14-Aug	23-Aug	11-Sep	24-Sep
Carbon Dioxide (%)	0	0	0	0	0.3	0.1
Methane (%)	0	0.1	0	0	0	0
Oxygen (%)	20.4	20.9	20.3	21.4	20.2	20.3
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	0	0	0.4	0	0.8	0
Gas flow ltr/hr	0	0	0	0	0	0
Groundwater level, m bgl	1.43	1.14	0.93	0.95	0.97	0.96
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH04					
	11 – 12 (50mm)					
	SMF					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	0	0.1	0	0	0	0
Methane (%)	0	0	0	0	0	0
Oxygen (%)	20	20.9	20.3	21.2	20.6	20.9
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	42.3	117.9	0.3	0	0.1	0
Gas flow ltr/hr	0	0	0	0	0	0
Groundwater level, m bgl	1.3	0.91	0.8	0.7	0.88	0.87
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH07					
	10.5 – 11.5 (50mm)					
	SMF					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	0.5	0.2	0.4	0.1	0.5	0
Methane (%)	0	0	0	0	0	0
Oxygen (%)	19.3	20.9	20	21.2	20.6	21.1
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	11.9	112.3	0.8	0	0.2	0
Gas flow ltr/hr	-9.4	0	-3.9	0	-9.1	0
Groundwater level, m bgl	1.29	1.03	1.05	1	1.08	1.06
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

	BH09					
	9.7 – 11.0 (50mm)					
	SMF					
	17-Jul	31-Jul	14-Aug	23-Aug	10-Sep	23-Sep
Carbon Dioxide (%)	0.1	0.1	0	0.1	0.1	0.1
Methane (%)	0	0	0	0	0	0
Oxygen (%)	19.8	21.1	20.4	21.4	20.8	21
LEL (%)	0	0	0	0	0	0
Hydrogen sulphide (ppm)	0	0	0	0	0	0
Carbon monoxide (ppm)	0	0	0	0	0	0
VOC (ppm)	113.5	1.3	0.5	0	0	0
Gas flow ltr/hr	0	0	0	1.5	0	0
Groundwater level, m bgl	1.42	1.22	0.5	0.57	0.89	0.91
Atmospheric pressure	1017.667	1019.25	1008.368	1024.368	1018.5	1001.444

Note: gas monitoring results are based on the final reading taken from a set of results collected over a 2 minute period for gas concentration and 3 minute period for gas flow.