Cambois Data Centre Campus

Ground Investigation Report

Document Ref: 30226657-AUK-XX-XX-RP-ZZ-0017-01

Revision: 01

January 2025

Cambois Data Centre Campus

Ground Investigation Report

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Document Ref.	30226657-AUK-XX-XX-RP-ZZ-0017-01
Date	January 2025

Revision Control

Revision	Date	Author	Checker	Reviewer	Approver	Changes
01	**Jan 25**	**DF**	**JA**	**AH**	**SC**	**N/A – Initial Issue**

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List of Abbreviations used in this report

ACM	Asbestos Containing Material
AMP	Asbestos Management Plan
BGS	British Geological Survey
CA	Coal Authority
CBR	California Bearing Ratio
CoC	Contaminants of Concern
CPT	Cone Penetration Test
DHRA	Development High Risk Area
GI	Ground Investigation
GW	Groundwater
HDP	High Pressure Dilatometer
LCRM	Land Contamination Risk Management
LPA	Local Planning Authority
m AOD	Metres Above Ordnance Datum
m bgl	Metres Below Ground Level
MCertS	Monitoring Certification Scheme
MMP	Materials Management Plan
NAPL	Non-aqueous Phase Liquid
NPPF	National Planning Policy Framework
NSL	North Sea Link
PFA	Pulverised Fuel Ash
PLT	Plate Load Test
PMCM	Pennine Middle Coal Measures
PPE	Personal Protective Equipment
ppm	Parts per million
QTS	Quality Technology Services
SOM	Soil Organic Matter
SPZ	Source Protection Zone
SPA	Special Protection Area
SPT	Standard Penetration Test
UCS	Uniaxial Compressive Strength
UKAS	United Kingdom Accreditation Service
UXO	Unexploded Ordnance

1 Introduction

1.1 Appointment

1.1.1 Arcadis (UK) Limited (Arcadis) was appointed by Renaissance Land Limited to undertake further site investigations at the former coal stocking yard associated with the Blyth Power Station in Cambois, Northumberland (the site).

1.1.2 The investigations comprised a Phase 1B Geoenvironmental desk-based study [1], completion of several phases of supplementary intrusive ground investigation [2] [3], the preparation of a Phase 2 Geoenvironmental Assessment Report [4] and this Ground Investigation Report with geotechnical appraisal.

1.2 Proposed Development

1.2.1 For the purposes of planning, the Proposed Development is for the development of a data centre campus comprising up to 10 data centres of Class B8 use totalling up to 540,000 square metres (sqm) gross internal area (GIA), in addition to ancillary structures, substation, emergency generators and other associated works.

1.2.2 It is anticipated that an earthworks programme will be required to establish the development platform for the site. The proposed masterplan is included in Appendix A.

1.2.3 The Proposed Development will be developed and operated by Quality Technology Services (QTS).

1.3 Existing Information

1.3.1 Multiple phases of desk-based and intrusive investigation have been completed at the site by others. Rolton Group completed several phases of ground investigation and subsequent monitoring on the site between 2020 and 2024 in support of a previously proposed scheme. Information from the following Rolton Group documents have been used in this report:

- Rolton Group Limited, 2022, Geotechnical & Geo-Environmental Report [5];
- Rolton Group Limited, 2022, Burnt Shale Trial Pit Investigations [6];
- Rolton Group Limited, 2022, Phase 1 & Preliminary Geo-Environmental Summary for Rail Head Land, Cambois [7]; and,
- Rolton Group Limited, 2024, Gas and Groundwater Monitoring Summary Report [8].

1.3.2 Arcadis has previously produced a Phase 1B Desk Study to support the Proposed Development and completed two stages of supplementary ground investigation at the site. Details of the investigations are presented within the following reports:

- Arcadis (UK) Limited, 2024, Phase 1B Geoenvironmental Desk Study [1] – Planning document ref 4.6;
- Arcadis (UK) Limited, 2024. Ground Investigation Factual Report – Stage 1 [2] – Planning document ref 4.9;
- Arcadis (UK) Limited, 2024. Ground Investigation Factual Report – Stage 2 [3] – Planning document ref 4.10, and,
- Arcadis (UK) Limited, 2024. Phase 2 Geoenvironmental Assessment [4] – Planning document ref 4.11.

1.4 Objectives and Scope of Work

1.4.1 This ground investigation report (GIR) is to review and interpret the ground conditions, engineering geology and geotechnical data from the 2 stages of 2024 Arcadis ground investigations, to provide a geotechnical appraisal for the proposed development. The previous available ground investigations have been reviewed. The geotechnical appraisal will include the following based on the preliminary design at the time of writing:

- Excavations and Earthworks
- Recommended foundation and floor slab solutions
- A summary of geotechnical parameters to inform detailed design
- Concrete design sulphate classification
- PFA Stockpiles (unloading and Reuse)
- Pavement design based on California Bearing Ratio (CBR)
- Infiltration drainage feasibility
- Summary of Coal Mining Risk assessment

1.4.2 The works have been completed in general accordance with recommended guidance including LCRM [9], BS10175 [10], BS5930 [11], EN 1997-2:2007 [12] and other relevant guidance and good practice.

1.5 Reliability of Information/Limitations

1.5.1 Arcadis warrants that the services performed were conducted in a competent and professional manner in accordance with sound consulting practices and procedures.

1.5.2 Arcadis cannot warrant the actual property conditions described in this report beyond matters amenable to confirmation within the limits of this report.

1.5.3 This report has been completed using information from a number of sources which Arcadis deems to be trustworthy, however Arcadis are unable to guarantee the accuracy of information provided by others. Arcadis cannot accept any responsibility for any use of or reliance on the contents of the report by any third party.

1.5.4 Several constraints were identified onsite during the intrusive investigations which restricted exploratory work in some locations. Reference should be made to the constraints plan included in Appendix B.

1.5.5 Ground investigations by nature only reveal a small percentage of the ground conditions present beneath the site. The possibility of significant variation in ground conditions existing between sampling locations cannot be discounted. Soil borne gas and groundwater conditions are based on observations made at the time of the investigation and during subsequent monitoring visits and may be subject to significant variation due to atmospheric, seasonal or other effects.

1.5.6 If any additional investigation is undertaken at the site there is potential for further information to become available which may alter the conclusions of this document, for which Arcadis cannot be held responsible.

1.5.7 Arcadis' liability, pursuant to the terms of the appointment of Arcadis by Renaissance Land Limited, is strictly limited to the work undertaken and the matters contained and specifically referred to in this report.

1.5.8 A copy of Arcadis' Study Limitations is presented in Section 10 of this report.

1.6 Reliance

1.6.1 It is understood that the current report will be prepared for the use of Renaissance Land Limited. The contents of this report may not be used or relied upon by any person other than this part without the express consent and authorisation of Arcadis.

2 Summary of Desk Study Information

2.1.1 The following section provides a summary of the key findings of the Phase 1B Desk Study previously completed by Arcadis [1]. For further information please refer to this document.

2.2 General site Information

Site Location

2.2.1 The site is located to the south-west of the village of Cambois, approximately 1km to the north of the Northumberland town of Blyth, with indicative postcode NE22 7BL. The approximate centre of the site is at National Grid Reference NZ 29821 84126.

2.2.2 The site lies roughly 175m west of the North Sea and sits between the Blyth Estuary to the south and the Wansbeck Estuary to the north.



Figure 2-1: site Location

Topography

2.2.3 Ground levels across the site are relatively flat with local undulations, falling from approximately 10m Above Ordnance Datum (AOD) in the north to 5m AOD in the south-east. There are localised areas of higher ground across the site associated with material stockpiles and two large Pulverised Fuel Ash (PFA) mounds located in the eastern area of the site (rising to approximately 15m AOD on the northern mound and 24m AOD on the southern mound).

Current site Conditions

2.2.4 The site is currently vacant brownfield land, with onsite structures limited to a multi-storey modular office/welfare unit in the south. The site is partially covered by concrete or asphalt hardstanding (predominantly in the west), with gravel scrubland to the northern central area, and vegetated areas to the east and south.

2.2.5 Some site preparatory works for a previously proposed development have been undertaken on the site, including works for the diversion of watercourses crossing the site, the construction of several piling mats, test piles and shallow foundations, and the installation of service ducts within the main access road and around the temporary cabins.

2.2.6 Two large stockpiles of PFA material are present in the east of the site, partly covered in grasses, shrubs, and semi-mature trees. It is understood that this material was placed under a waste management licence.

2.2.7 Concrete lined lagoon features covering a total area of approximately 200m x 100m are present in the south-east of the site and are relics of the former site use as a coal stocking pad for the adjacent former power station. In addition, multiple concrete lined open drains and channels can be seen across the central areas of the site, which would have been used to divert water away from the stockpiles of coal.

2.2.8 One pond feature was also noted in the central-northern area of the site; however, it appears to have been partly backfilled during site preparatory works undertaken as part of the previously proposed development.

2.2.9 A bridge crosses the route of a former railway line in the east of the site. Although no remaining railway infrastructure remains in this area, areas of railway embankments and surface ballast can be seen. This north-eastern site area is referred to within the report as the railhead area.

Surrounding Land Uses

2.2.10 The northern site boundary is formed by the Cambois Branch railway line. The land beyond is generally undeveloped, with the exception of a sewage treatment works located approximately 100m to the north-west and residential properties approximately 100m to the north-east.

2.2.11 A large industrial development is currently under construction to the south in the location of the former Blyth Power Station. A National Grid substation is located beyond this development.

2.2.12 The land to the east of the site is occupied by residential housing, Cambois Primary School, and the Cambois Branch railway line which wraps around the northern boundary of the site. The North Sea is located approximately 175m to the east.

2.2.13 Land west of the site hosts an industrial estate (Fergusson's Business Park) and agricultural land. The North Sea Link (NSL) UK Converter Station is also situated to the south-west.

Historical site Use

2.2.14 Earliest historical maps dating from 1865 show the site to be agricultural land. Mapping shows a football pitch, pavilion and embankment have been constructed on the site by 1924. By 1940 a railway line and sidings have been constructed in the north and east of the site, with other areas noted as allotments and welfare grounds.

2.2.15 By 1966 the site has been developed for use as a coal storage pad for the Blyth Power Station. A mineral railway with sidings has been developed through the centre of the site, and infrastructure including pylons, floodlighting, conveyors, reservoirs, and other ancillary buildings.

2.2.16 Mapping from 1992 shows much of the site infrastructure to have been demolished, and two large mounds of PFA material have been deposited in the eastern site area.

2.2.17 Aerial imagery from 2021 onwards shows evidence of surface scarring likely associated with ground investigation and earthworks, as well as the construction of working platforms and haul roads. It is understood that this was in relation to works completed for a previously proposed scheme.

2.3 Environmental Setting

Published Geology

2.3.1 The published geology [13] [14] [15] indicates the site is underlain by superficial deposits comprising Glacial Till (Boulder Clay - clay, sand, gravel, and boulders), which in turn overlies bedrock of the Pennine Middle Coal Measures (PMCM – sandstone, mudstone, siltstone and coal). A mafic igneous intrusion, the West Sleekburn Dyke, is indicated to transect the northern site area.

2.3.2 One coal seam is mapped to subcrop beneath the site. The Moorland seam is shown in the north-western corner trending south-west to north-east, beneath the superficial deposits. Two geological normal faults are shown to extend beneath the site within the bedrock in the south-east. These trend north-west to south-east with the downthrown block between.

Mining Activity

2.3.3 The north-western site area lies within a Coal Authority (CA) Development High Risk Area (DHRA), relating to ‘probable’ shallow working of the coal seam which is mapped to subcrop beneath this area of the site.

2.3.4 Records show multiple underground workings on several deep coal seams beneath the site at depths from 104m bgl. No mine entries or other associated mining hazards are recorded within 100m of the site.

2.3.5 Previous site investigations on the site did not identify any mining related voids, however one instance of broken ground was recorded in a drillers log as a possible working.

Site Specific Geology – Previous Investigation

2.3.6 Multiple phases of intrusive ground investigation have been completed at the site by others. A summary of the encountered geology is listed below:

Table 2-1 Summary of Previous Investigation Encountered Geology

Geology	Description
Artificial Ground	Hardstanding was predominantly found in the central and south-eastern areas of the site comprising of either a thin layer of macadam or concrete.

Geology	Description
	Made Ground was generally recorded between 0.2 to 3.5m (although locally deeper) with an average depth of 2.0m. This was generally encountered as a granular layer of subbase or capping overlying a reworked natural clay. The Made Ground was generally found to be variable comprising both granular and cohesive Made Ground with anthropogenic materials, however, some distinct material types were identified across the site, including: • A silty sandy gravel with frequent cobbles comprising of predominantly of burnt red shale material. This material was found to a maximum recorded depth of >4.5m bgl and was generally identified as a basal layer in the south of the site. • A reworked natural clay encountered across the site overlying natural Glacial Till deposits to a maximum depth of between 4.0 to 5.0m; typically described as a firm to stiff dark brown sandy gravelly clay containing sandstone, limestone, coal and burnt shale fragments. • A thin layer of organic clay with rootlets was encountered beneath Made Ground with an average thickness of 0.3m. This layer can be interpreted as a relic topsoil. • Railway track ballast found across the eastern site area along the route of former railway sidings. • PFA material predominantly within the two large mounds to the east of the site, but also as localised pockets within the general Made Ground. The thickness of PFA in the mounds was recorded as between 7.2 to 9.5m in the northern mound and 15.9 to 16.4m in the southern mound. The PFA was generally described as light grey silty sandy gravel and cobbles of solidified PFA material.
Superficial Deposits	Isolated deposits of Alluvium were identified in several locations across the site at shallow depths, likely relating to the former positions of Cow Gut and Maw Burn prior to their diversion and culverting. Soft to firm organic clays with localised pockets of fibrous peat were observed up to 1.0m in thickness, at depths between 0.2 to 3.8m bgl. Glacial Till, encountered beneath the Made Ground and alluvial soils, was recorded to a depth of between 18.5 and 33.15m. The thickness of the Glacial Till appears to increase the towards the north-west, with the thinnest deposits identified in the south-eastern site area; this correlates with the British Geological Survey (BGS) buried valley modelling [16]. The Glacial Till comprised predominantly firm becoming stiff, brown becoming bluish grey sandy gravelly clay with occasional cobbles. Softer laminated clays and bands of sand were also recorded, frequently with groundwater strikes. Deposits were generally found to increase in strength with depth, with Glacial Till below 5m recording Standard Penetration Test (SPT) N values of between 10 and 50+, and Glacial Till at around 25m frequently recording SPT refusals.
Bedrock	Solid geology was recorded as interbedded layers of weak, dark grey, slightly weathered sandstone, siltstone and mudstone. Thin layers of coal were identified in two locations (up to 0.3m thick) in the north-west corner and central northern site area. No further coal seams were encountered to the maximum drilled depth of 60m bgl. The West Sleekburn Dyke was identified through targeted drilling and a magnetometer survey. The dyke was estimated to be 15m wide, and crosses the northern area of the site, trending north-west to north-east.

Hydrogeology

2.3.7 Published data indicates the superficial Glacial Till deposits are classified as a Secondary (undifferentiated) aquifer and the Pennine Middle Coal Measures are classified as a Secondary A aquifer. Localised Alluvium was identified at the site, however it is not mapped in the area on published geological records, so does not have an aquifer designation.

2.3.8 During previous ground investigations by others, groundwater was encountered in three main strata: shallow perched water in the Made Ground (recorded at 5.56m AOD – 9.98m AOD); discontinuous groundwater within granular lenses in the Glacial Till (recorded at 1.14m AOD – 9.32m AOD), and groundwater within the bedrock. No wells were previously installed within the bedrock, however groundwater in the bedrock was noted to be confined by the overlying Glacial Till.

2.3.9 One groundwater abstraction licence is active within 1km of the site. This relates to a pump and treat pollution remediation abstraction from the “Bates No. 3 Mineshaft”, approximately 900m south. There are no potable abstraction licenses within 2km of the site.

2.3.10 The site does not lie within 1km of a groundwater Source Protection Zone (SPZ).

Hydrology

2.3.11 Two named watercourses are present onsite, Maw Burn in the north and Cow Gut in the south. Both of these watercourses have been culverted for most of their length across the site. They run from west to east, with Maw Burn entering in the north-western corner of the site, exiting along the eastern boundary and out falling into the North Sea. Cow Gut enters along the western site boundary, exits along the southern boundary and outfalls into the Blyth Estuary.

2.3.12 It is understood that diversion works for both watercourses were undertaken under a previous scheme, however, it is not clear if these were made active before works were ceased. Maw Burn was diverted into an open channel along the northern site boundary before rejoining existing site drainage and the original outfall. The Cow Gut diversion works diverted the channel to the south-east, before joining the existing outfall in the south-west.

2.3.13 Several open concrete lined drainage channels are present across the site around the former coal stock areas and PFA mounds; these appear to drain into the original routes of Maw Burn and Cow Gut.

2.3.14 Beyond the site, the North Sea is located roughly 175m east at its nearest point. The Wansbeck Estuary is located approximately 650m north and the Blyth Estuary is located approximately 300m south.

Environmental Designations

2.3.15 Several sensitive land uses are recorded in areas surrounding the site. The Coquet to St Marys and Berwick to St Marys Marine Nature Reserves are approximately 150m east, the Northumberland Marins Special Protection Area (SPA) is located approximately 80m south-east and the Northumbria Coast SPA and Ramsar site is located approximately 700m south-east.

Landfill Land Waste Management Activities

2.3.16 No active landfills are recorded within 1km of the site. The two large mounds of PFA material located in the central area of the site are recorded as historical landfills and were constructed under a former Waste Management Licence. The licence allowed for the deposition of waste, including industrial waste, equal to or greater than 75,000 tonnes per year, and was surrendered on 20 July 2004. The area noted in the licence extends significantly beyond the current PFA stockpiles, however, there is no evidence to suggest additional material deposition.

Radon

2.3.17 The site is within a lower probability radon area. Therefore, radon protection measures will not be required for new development on the site.

Unexploded Ordnance

2.3.18 Detailed Unexploded Ordnance (UXO) Threat and Risk Assessments previously completed for the site concluded that the UXO risk rating across part of the site is medium. These areas can be seen on the constraints drawing included in Appendix B. The reports state that, whilst there is a residual UXO risk, there is not a significant pathway to warrant proactive on-site UXO risk mitigation measures, and recommended a UXO safety and awareness briefing, an emergency response plan and on-call disposal engineer for any intrusive works. Additional measures may be required if large scale earthworks are to be undertaken.

Preliminary Conceptual Engineering Geological Model

2.3.19 Within the Arcadis, 2024 desk study [1], the above information was reviewed and compiled to produce a conceptual engineering geological model which is presented below.

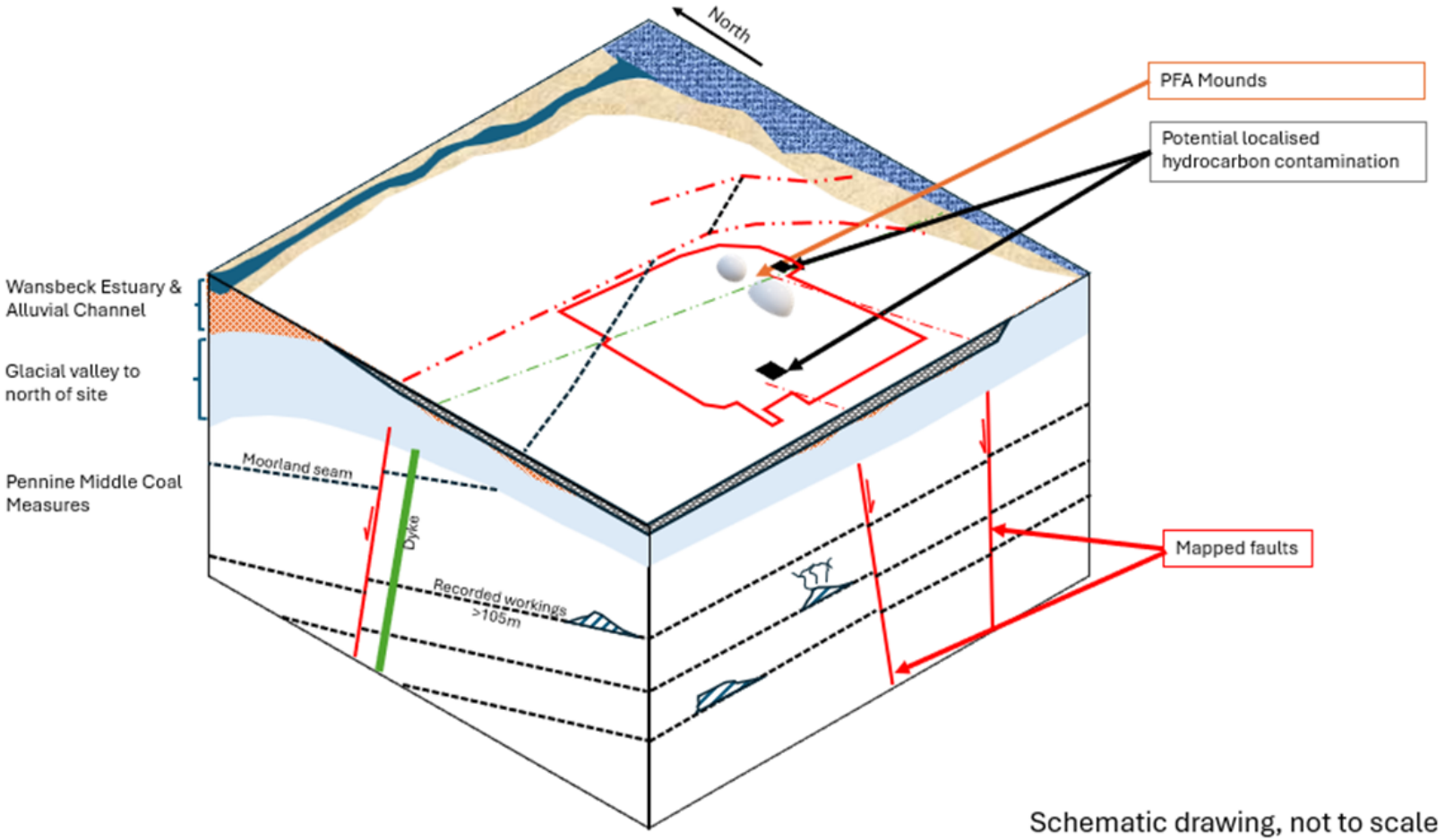


Figure 2-2 - Preliminary Conceptual Engineering Geological Model

3 Ground Investigation Scope & Methodology

3.1.1 The ground investigation was designed and managed by Arcadis in agreement with the Client to support the Proposed Development and meet any data gaps identified within the previous investigations and reporting. The Phase 1B Desk Study produced by Arcadis provides a summary of the previous works, a data gap assessment and a preliminary conceptual site model on which the supplementary investigations were based. The works were carried out between May and October 2024 by Arcadis and were completed across two stages owing to ecological constraints restricting movement to parts of the site during Stage 1 of the works. Further details relating to the ecological constraints can be seen within the Stage 1 Factual Report [2].

3.1.2 Factual reports have been prepared for each stage of the Arcadis ground investigation [2] [3]. The reports include full details of the ground investigation methodology, monitoring programme and laboratory testing completed. In addition, the reports contain exploratory hole location plans and exploratory logs, including full details of the ground conditions encountered, samples obtained, and in-situ testing completed. Laboratory certificates, ground gas and groundwater monitoring and sampling records are also included.

3.1.3 The table below presents a summary of the rationale for the ground investigation scope and the works completed during the Arcadis ground investigations.

Table 3-1 Summary of Ground Investigation Scope and Rationale

Investigation Type	No. advanced (maximum depth)	Investigation rationale	Designation
Machine excavated trial pits	95 (4.6m bgl)	Investigate shallow ground conditions (Made Ground and superficial deposits) across the site and in areas not previously investigated.	TP102-TP111 TP114-TP128 TP401-TP414
		Investigate the composition of large stockpiles and mounds across the site.	TP201-TP205
		Targeting an area of strong hydrocarbon odour identified during the Arcadis Stage 1 of investigation (and within previous investigation by others), and to delineate its extent.	TP301-TP304
		Investigate shallow conditions within the PFA stockpiles and collect representative samples for chemical and geotechnical analysis.	TP501-TP512
		Investigate possible in-ground obstructions identified both visually on the site and during previous investigations.	TP601-TP602, TP604-TP605, TP607, TP610, TP613, TP616
		Investigate composition and thickness of piling mats constructed to enable a pile test programme for a previously proposed development.	TP617-TP623
		Trial pits excavated in locations following completion of a Plate Load Test (PLT).	CBR115, CBR117, CBR124, CBR127, CBR130, CBR133, CBR135-CBR138, CBR140,

Investigation Type	No. advanced (maximum depth)	Investigation rationale	Designation
			CBR146- CBR147, CBR154, CBR156, CBR158, CBR164, CBR166, CBR168, CBR169
Hand excavated observation pits	39 (1.2m bgl)	Completed prior to Cone Penetration Tests (CPT) to investigate shallow ground conditions and to confirm absence of shallow buried utilities.	CPT102-CPT103, CPT111-CPT113, CPT116-CPT117, CPT119-CPT120, CPT122, CPT124-CPT127, CPT129-CPT141, CPT144-CPT146, CPT148-CPT151
		Investigate the composition of mounds and stockpiles on the site.	SP-G–SP-K
Windowless sampling boreholes	21 (5.45m bgl)	Investigate shallow ground conditions across the site and within areas not previously investigated and allow the installation of shallow ground gas and groundwater monitoring wells.	WS101, WS103-WS104, WS107, WS110-WS114, WS116-WS123 WS201-WS204
Cone Penetration Testing (CPT)	31 (24.54m bgl)	Investigate the competency of the shallow soils and to undertake specialist in-situ testing.	CPT102-CPT103, CPT111-CPT113, CPT116-CPT117, CPT119-CPT120, CPT122, CPT124-CPT127, CPT129-CPT141, CPT144-CPT146, CPT148-CPT151 CPT501-CPT504
Cable percussive boreholes	19 (27.0m bgl)	Investigate shallow ground conditions, provide information on depth to bedrock (in selected locations), and install groundwater and gas monitoring wells.	BH403 BH505-BH513 BH601
		Investigate the composition of the PFA mounds and obtain deeper samples of the PFA material.	BH701-BH708
Rotary wireline drilling / sonic drilling	27 (101m bgl)	Investigate shallow ground conditions as well as deeper bedrock geology. Additionally, these boreholes were to investigate the presence of intact or worked coal seams to a target depth of 100m bgl.	BH101, BH103A-BH108
		As above, to a target depth of 75m bgl.	BH201-BH203, BH205
		Investigate shallow and deep ground conditions at proposed column locations for Buildings 1 and 2 (as per early test fit applicable at time of investigation – the location of this structure has been amended following the investigation).	BH307, BH309-BH311B, BH325-BH326, BH328, BH333-BH336

Investigation Type	No. advanced (maximum depth)	Investigation rationale	Designation
		Investigate shallow and deep ground conditions following on from CPT testing.	BH501-BH504
Rotary follow on – in selected cable percussive boreholes	9 (46m bgl)	Investigate the composition and competency of the bedrock geology.	BH505-BH513
Downhole geophysical testing	11	Specialist geophysical testing using density gamma probe, optical televiewer and acoustic televiewer techniques in deeper boreholes to aid in identification of any intact or worked coal seams.	BH101, BH103A-BH108 BH201-BH203, BH205
Plate load testing (PLT)	26	To provide California Bearing Ratio (CBR) values of the shallow ground.	CBR111, CBR115, CBR117, CBR121, CBR124, CBR126-CBR127, CBR130, CBR133, CBR135-CBR138, CBR140, CBR142, CBR145-CBR147, CBR154, CBR156, CBR158, CBR164-CBR166, CBR168-CBR169
Resistivity testing	3	Specialist geophysical/geotechnical testing in the area of the proposed electrical substation.	RS101-103
High pressure dilatometer testing (HDP)	7	Specialist geotechnical testing in the superficial deposits.	BH328 T01-T03 BH333 T01-T04
Groundwater monitoring and sampling	N/A	Eight rounds of ground gas and ground water level monitoring and one round of groundwater sampling (select locations) have been undertaken for contamination and ground gas assessment. Visits were conducted between 8th July – 17th October 2024.	*
Ground gas monitoring	N/A		
Surface water sampling	N/A	Two rounds of surface water sampling from Cow Gut and Maw Burn for contamination assessment.	SW-MB-UP and SW-BB-DOWN SW-CG-UP and SW-CG-DOWN

* Full details of locations included in the monitoring programme presented in the data tables within the Factual Reports.

3.1.4 Plans showing all completed exploratory locations are presented in Appendix B.

3.1.5 Several constraints were identified on-site during the investigation. A plan showing the constraints to the ground investigation is included in Appendix B. Resulting limitations to the investigation are covered within the respective Factual Reports [2] [3].

3.1.6 All factual information relating to the Arcadis ground investigations, including logs, sample information, general site procedures, and Quality Assurance and Control, can be found within the Factual Reports produced for each stage of intrusive works [2] [3].

4 Ground Conditions

4.1 Stratigraphy

4.1.1 The stratigraphy recorded during the Arcadis investigations includes variable Made Ground, underlain by Alluvial soils (locally), Glacial Till, and the Pennine Middle Coal Measures. The ground conditions identified during the Arcadis investigation are generally in accordance with previous site investigations completed by others, and the published BGS data.

4.1.2 A detailed description of the ground conditions encountered during the intrusive investigation is included on the exploratory hole logs included within the Factual Reports [2] [3]. The tables below present a summary of the ground conditions encountered. Table 4-1 presents a summary of the general ground conditions excluding the PFA mounds.

4.1.3 An exploratory hole location plan is presented in Appendix B.

Table 4-1 Summary of In-ground Conditions (Excluding PFA Mounds and Stockpiled Materials)

Stratum	General Description	Depth Range of Top-Level m bgl (m AOD)	Thickness (m)
Made Ground (Topsoil like properties)	**Made Ground with Topsoil-like properties [TOP] –** Grey or brown sandy gravelly CLAY. Gravels generally noted to be anthropogenic in origin, comprising brick, burnt red shale, slag, coal, and clinker. Recorded in a small number of locations, primarily in the north of the site.	0.00 (4.88 – 10.11)	0.05 – 0.70
Made Ground	**Granular Made Ground [MG-G] –** Found to be variable across the site. Hardstanding at the site includes both macadam material (0.1 – 0.2m in thickness) and concrete (0.3 – 0.5m in thickness), often underlain by sub-base material comprising yellowish brown sandy gravels of sandstone, limestone, or anthropogenic materials. Other sands and gravels across the site were found to be variable in colour and composition. Anthropogenic inclusions include sandstone, mudstone, burnt red shale, brick, concrete, slag, coal, and clinker, with rare inclusions of plastic, metal, and ceramics.	0.00 – 2.30 (4.35 – 11.96)	0.05 – 2.95
	Cohesive Made Ground [MG-C] – Found as both a general cohesive Made Ground and reworked natural deposits. General cohesive Made Ground was variable in colour and composition and was found with abundant anthropogenic inclusions. Reworked natural deposits were generally found to comprise greyish brown sandy gravelly CLAY, with gravels consisting of sandstone, mudstone, and coal.	0.00 – 2.50 (3.76 – 11.58)	0.05 – 4.35
	Burnt Red Shale [MG-BS50] – Predominantly found through the central and north-western site area as a reddish brown or orangish brown silty sandy GRAVEL with regular cobbles, with both gravels and cobbles comprising burnt red shale, and minor inclusions of slag, clinker, mudstone, sandstone, and plastic.	0.00 – 1.80 (4.16 – 12.63)	0.20 – 1.76

Stratum	General Description	Depth Range of Top-Level m bgl (m AOD)	Thickness (m)
	Also found as a reddish brown clayey gravelly sand, or sandy gravelly clay, with gravels of burnt red shale. Classified as MG-BS50 where logged material is >50% burnt shale.		
	Pulverised Fuel Ash [MG-PFA] – Light or dark grey sandy SILT or silty SAND, often found with gravels or cobbles of cemented PFA. Encountered in-ground in the north-west of the site only.	0.00 – 1.20 (4.86 – 11.81)	0.09 – 2.10
	Relic Topsoil – Found in three locations only within the north-east of the main site area. Recorded as dark brown slightly sandy clay with abundant rootlets.	0.60 – 3.00 (9.82 – 10.09)	0.10 – 0.50
Superficial Deposits	**Alluvium Deposits [AL-ORG] –** Soft to firm, locally stiff, greenish or yellowish brown gravelly sandy CLAY and silty CLAY. Gravels were found to comprise mudstone, sandstone, and coal, with occasional anthropogenic materials identified, likely embedded from Made Ground above. Unit had frequent organic inclusions and organic odours however no peat was encountered. Alluvial material was also found as a yellowish brown clayey gravelly SAND.	0.45 – 2.20 (4.54 – 9.35)	0.10 – 1.35
	Glacial Till [TILL] – Predominantly firm to very stiff brown or greyish brown sandy gravelly CLAY with occasional cobbles throughout. Gravels and cobbles were noted to comprise sandstone, mudstone, siltstone, and coal. Occasional pyrite crystals were noted within clay laminae. Firm to stiff reddish/greyish brown laminated sandy CLAY with silt deposits between laminations. These deposits have been interpreted as Glaciolacustrine Deposits. Medium dense to dense greyish brown SAND or GRAVEL of sandstone, siltstone, mudstone, and coal. These deposits have been interpreted as **Glacial Channel Deposits [G-CD]** and were generally recorded as lenses <1m thick).	0.10 – 4.80 (0.14 – 9.59)	17.50 – 35.97
Bedrock	**Pennine Middle Coal Measures –** Interbedded layers of mudstone, siltstone, sandstone, and coal. **Mudstone [PMCM-MDST]** and **siltstone [PMCM-SLST]** units were generally recorded as weak to moderately strong, dark grey to grey, and heavily fractured. Clay or silt infill within the fractures was common throughout. The **sandstone [PMCM-SST]** units were generally found to be moderately strong to strong and medium to coarse grained. Sandstone was found as both heavily fractured (recovered as non-intact gravel) or massive. Variable **coal deposits [PMCM-COAL]** were recorded, generally comprising very weak to weak, dull to semi bright fusain and clarain coal, with occasional durain and vitrain coal. Plant fossil remnants and pyrite were common throughout.	18.84 – 37.65 (-13.56 – -27.59)	>81.26

Stratum	General Description	Depth Range of Top-Level m bgl (m AOD)	Thickness (m)
	Seatearth deposits recovered as grey very weak to extremely weak grey silty/clayey Mudstone.		

4.1.4 **Table 4-2** below summarises the conditions encountered in exploratory holes completed within the PFA mounds.

Table 4-2 Summary of Ground Conditions Within PFA Mounds

Stratum	General Description	Depth Range of Top Level m bgl (m AOD)	Thickness (m)
Made Ground (Topsoil like properties)	**Made Ground with Topsoil-like properties [TOP] –** Grass over brown gravelly sandy CLAY or SILT with abundant rootlets. Gravels include sandstone, mudstone, ceramics, coal, glass and burnt red shale. Anthropogenic gravels were not found consistently across the PFA mounds.	0.00 (11.85 – 23.52)	0.10 – 0.30
Made Ground	**PFA [MG-PFA] –** Light or dark grey sandy SILT or silty SAND, often found with gravels or cobbles of cemented PFA. Rare inclusions of plastic or brick also noted throughout. The PFA forming the large mounds was generally noted to become sandier in the south of the southern mound.	0.10 – 0.30 (11.75 – 23.22)	6.20 - >13.30
	Cohesive Made Ground [MG-C] – Dark brown slightly sandy gravelly CLAY. Gravels noted to comprise sandstone, mudstone, coal, and brick.	3.30 – 7.40 (7.42 – 12.13)	>0.05 - >0.15

4.1.5 In addition to the above, multiple stockpiles of material are present across the site of variable composition. A plan showing the stockpile locations, and a record of their composition is included in Appendix B.

4.2 Obstructions

4.2.1 The following section provides detail on obstructions identified during the Arcadis investigations.

Table 4-3 Summary of obstructions

Data	Findings
Obstructions	Obstructions were noted in multiple locations across the site both at the surface and in-ground. Plans showing observed obstructions are included in Appendix B, and summarised below: • infrastructure related to the previously proposed development, including existing modular office/welfare unit, and shallow pad foundations for other structures; • relic concrete floor slabs primarily in the north-eastern railhead area, and in the south-west of the site adjacent to the remaining modular office/welfare unit; • hardstanding comprising macadam across large areas of the site, with smaller areas of concrete surfacing. Observed locations of concrete surfacing are shown on the plans in Appendix B;

Data	Findings
	• concrete lined water channels were identified across the site, primarily around the boundaries of the macadam covered areas (former coal stockpiling areas); • multiple concrete bases are present in the southern central area of the site along the route of the former overhead conveyor; and, • several test piles, including haul routes and pile mats, were constructed during early works carried out for a previously proposed development. A plan showing the location of identified piles can be seen in Appendix B. It should be noted that in a previous desk study produced for the site by Parsons Brinkerhoff [17] reference was made to the presence of possible tunnels on the site, although the route and location of these was not clear. Limited investigation was undertaken by Arcadis in the suspected areas of the tunnels, but no evidence to confirm their presence was identified. It is likely that additional in-ground obstructions within the Made Ground across the site are likely considering the site's history, including relic services or infrastructure.

4.3 Hydrogeology

4.3.1 Groundwater elevation has been measured across all wells installed by Arcadis, and in select wells installed by others where accessible and serviceable.

Table 4-4 Summary of Hydrogeological Observations

Data	Findings
Hydrogeological Regime	Analysis of the groundwater data indicates the following groundwater bodies: • shallow perched water within the Made Ground, identified above the contact with the underlying Glacial Till; • water hosted within discrete granular layers within the Glacial Till. Groundwater strikes were not identified during cable percussion borehole progression within the cohesive Glacial Till; and, • groundwater within the Pennine Middle Coal Measures, confined by the predominantly cohesive Glacial Till superficial deposits above.
Groundwater Elevations	During the monitoring undertaken, the elevation of resting groundwater was recorded in each stratum as follows: • Made Ground: 9.973m AOD – 3.937m AOD; • Glacial Till: 9.832m AOD – 0.646m AOD; and, • Pennine Middle Coal Measures: 2.633m AOD – 0.479m AOD* Depth to groundwater in these boreholes was measured as below: • Made Ground: 0.133m bgl** – 6.097m bgl; • Glacial Till: 0.159m bgl – 22.860m bgl; and, • Pennine Middle Coal Measures: 3.383m bgl – 9.520m bgl. There is a general fall in groundwater levels to the northeast as represented by the plots in *Figure 4-1*. Significant short-term fluctuations in water level are not apparent and the groundwater regime does not appear to be tidally influenced. *The above ranges exclude monitoring data obtained from BH203-D. This is the only deep borehole installed within cohesive Glacial Till which was subjected to well development to enable water sampling. The well was developed between the first and

Data	Findings
	second monitoring visits, until almost completely dry. Water levels recorded in this location on subsequent monitoring visits show a gradual rebound to 4.846m AOD during the final monitoring event (initial reading during first visit 5.987m AOD). BH202-D is also installed within Glacial Till and was subjected to well development, however the response zone in this well captures a granular gravel band. Water levels in this borehole remained steady and did not show a similar drop and gradual rebound. ** Monitoring well installed in WS204 was recorded as flooded, with water above the surrounding ground level within the top hat cover.
Groundwater Flow	Groundwater within the granular layers of Glacial Till and within the PMCM was noted to be confined by the overlying cohesive strata, therefore, any flow will be dictated by the confining layers and associated pressures. Well monitoring data for these strata will not provide an accurate representation of any flow. Limited wells have been installed within the Made Ground across the site, and as such there is insufficient monitoring data to accurately characterise any flow within the shallow perched water. However, review of the onsite geology, general topography of the site and surrounding area and local hydrology suggests groundwater flow is likely towards the River Blyth/North Sea to the south-east.

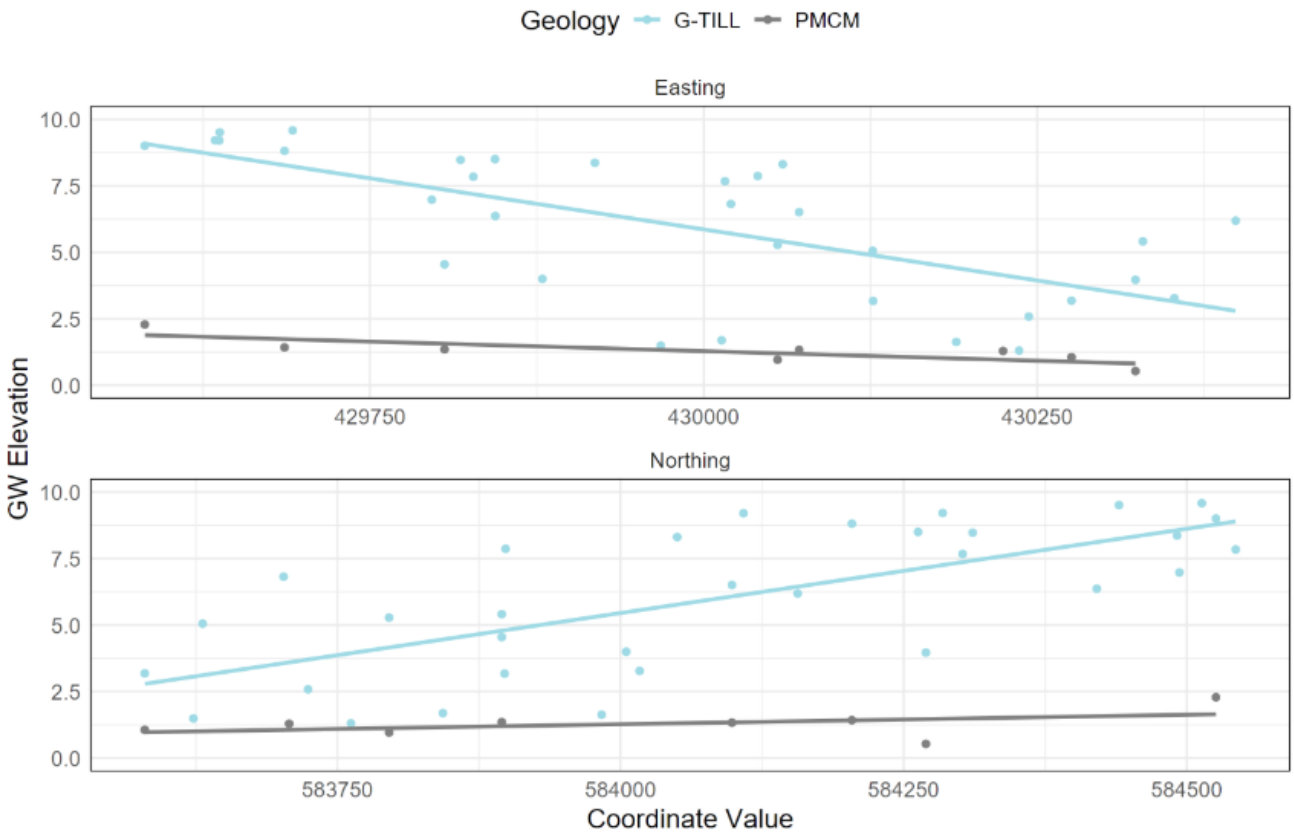


Figure 4-1: Groundwater Elevations (16th October 2024, individual data points and best fit regression line) vs Eastings and Northings by Response Zone Geology.

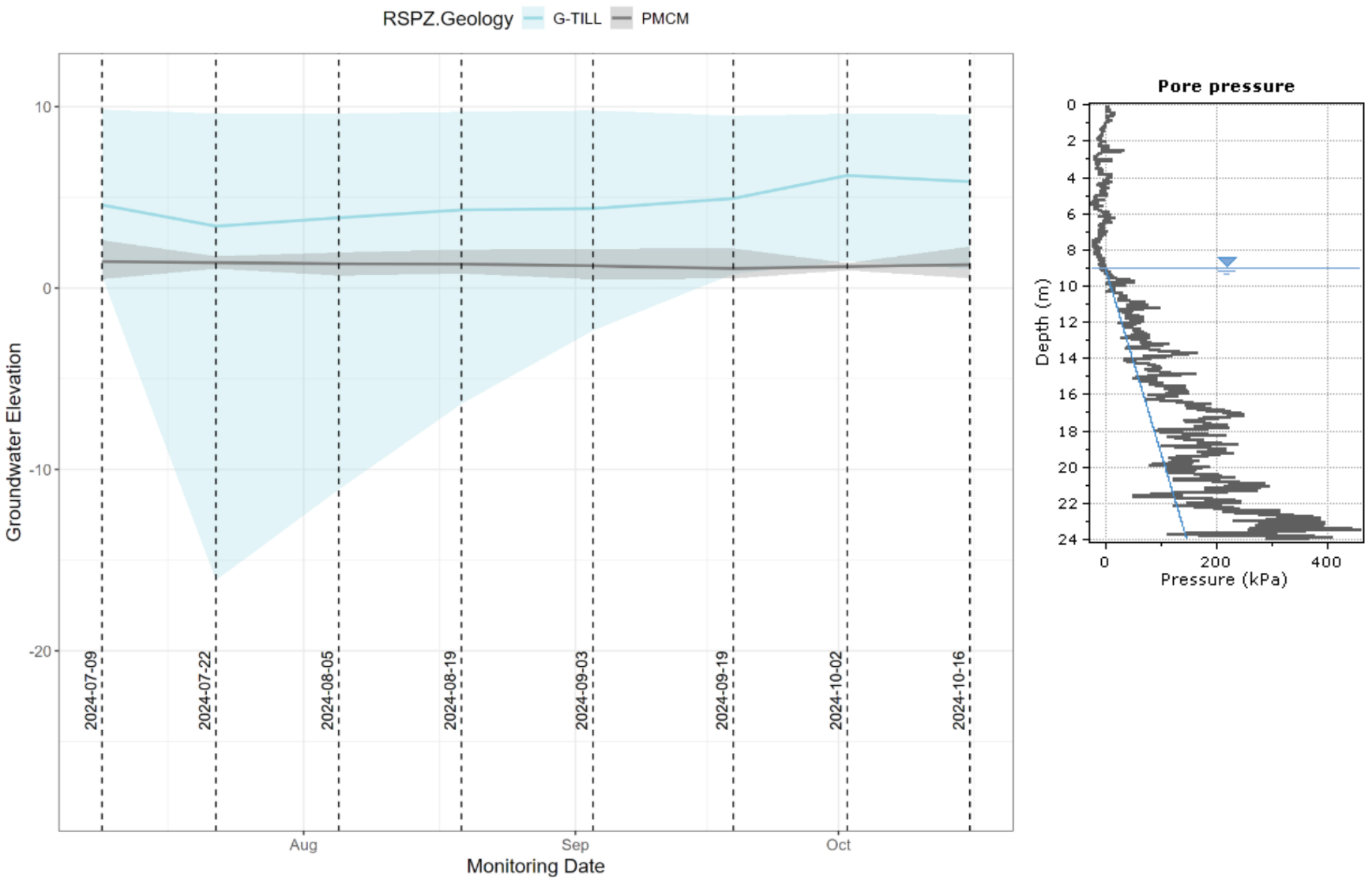


Figure 4-2: Groundwater Elevations: Ribbon Plot – Mean (solid lines), Min and Max (shaded ribbon) Groundwater Levels over Time by Response Zone Geology, alongside calculated Average CPT Porewater Pressure (u2) Profile (depth/elevation aligned).

4.3.2 Figure 4-2 above, shows groundwater levels over time (i.e. by monitoring date). The solid lines show the average elevations across all locations for response zones installed in the Glacial Till and the PMCM on each monitoring event. The corresponding shaded ribbons represent the minimum and maximum elevations to highlight the variation in levels across the site. The average GW level in the PMCM is approximately 1mAOD with a variance of less than ±1m. This level correlates well with the average CPT porewater pressure plot for the site, which shows a consistent rise in porewater pressure from 0kPa at 9m bgl (~1mAOD).

4.3.3 There is a much larger variance in groundwater levels in the Glacial Till. Large dip and rise of the bottom of the ribbon is the development and gradual/slow recovery of BH203-D described Table 4-4 and therefore the natural range of groundwater levels in the Till is expected to be between 1 and 9mAOD.

4.3.4 Groundwater elevation was also monitored using divers which are monitoring probes installed within wells that measure changes in atmospheric pressure and temperature. Data was recorded at 15-minute intervals within BH501 – BH513 and BH601 between dates of 14/10/24 and 22/11/24. This monitoring was undertaken in addition to the manual dipping of wells to assess if the groundwater regime is subject to tidal influence. From review of the data there is no clear trend that would suggest there is tidal influence within the underlying hydrogeology.

4.4 Ground Model

4.4.1 All available geological information obtained during investigations completed by Arcadis and others has been processed within a 3D model using specialist geological modelling software Leapfrog™. The software uses geological principals to interpret the information collected during the intrusive investigations, providing a visual interpretation of the site wide sub-surface conditions. The model below is based on a ‘first-pass’ assessment and the true in-ground conditions may vary from the model. The figures on the following pages show the distribution of different strata across the site as interpreted in the model.

Made Ground

4.4.2 The model shows Made Ground to be prevalent across most of the site, apart from an area to the north-east and limited locations within the east. It should be noted that the area within the south-west of the site (orange dashed circle) was not accessible for investigation. This area includes the main access road to the site, densely vegetated locations, and a site of archaeological interest which was protected during ground investigation. The presence of Made Ground in this area cannot be discounted.



Figure 4-3: Plan Extent of Made Ground Deposits

Made Ground – Granular Deposits

4.4.3 Granular Made Ground [MG- G] is present widely across the site and is generally found above other Made Ground units (except for PFA material). The granular material was generally not found in the north-east of the site.



Figure 4-4 Plan Extent of Granular Made Ground

Made Ground – Cohesive Deposits

4.4.4 Cohesive Made Ground [MG – C] is also widely present across the site; however, it is not as extensive as the granular Made Ground. The cohesive material was generally found beneath granular Made Ground except for areas in the central north-east of the site.

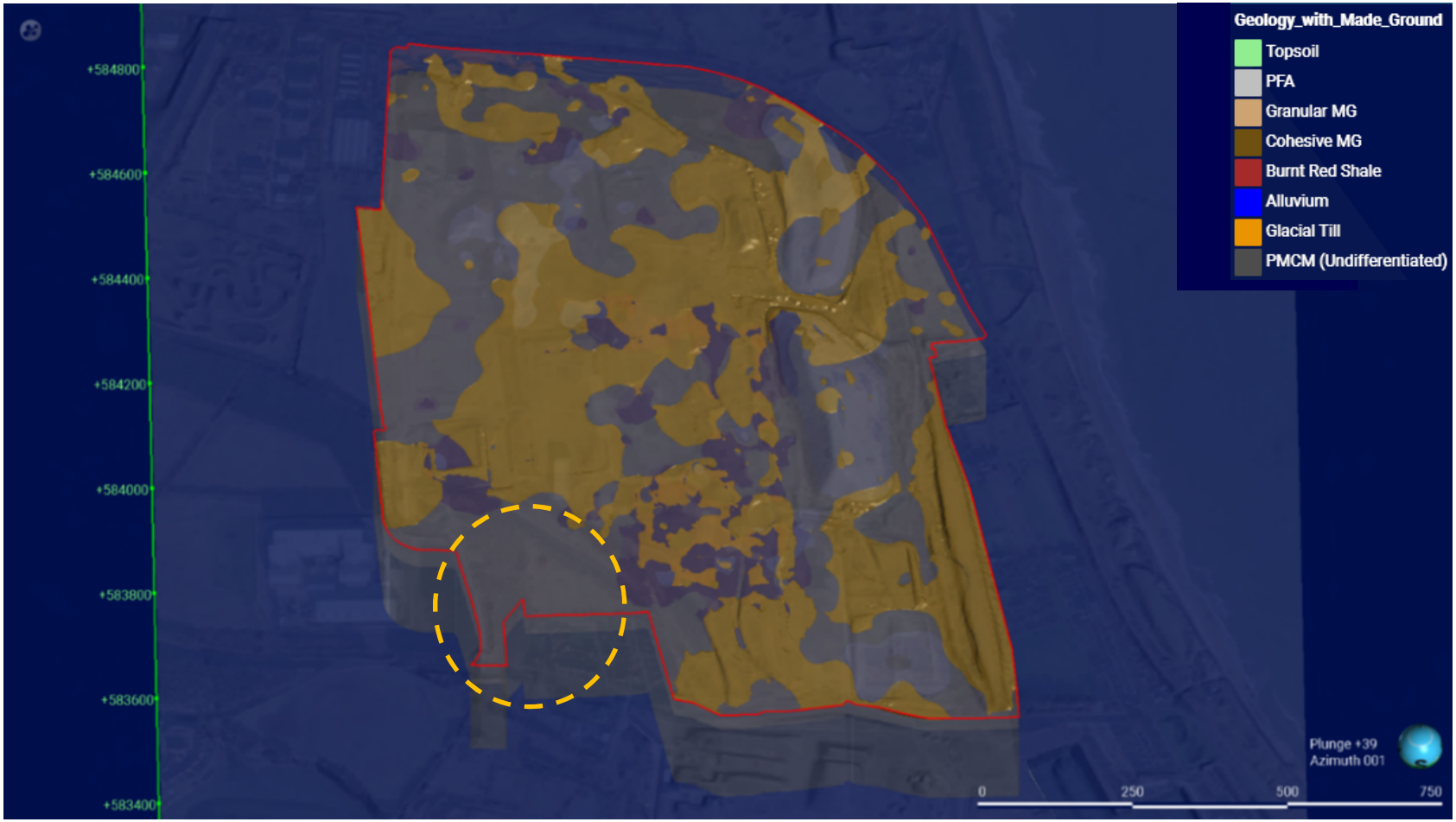


Figure 4-5 Plan Extent of Cohesive Made Ground

Made Ground – Burnt Red Shale

4.4.5 Made Ground comprising predominantly burnt red shale [MG – BS50] was found sporadically across the site, with the largest deposits located in the southern central area of the site. The burnt red shale material was generally found beneath other granular Made Ground.

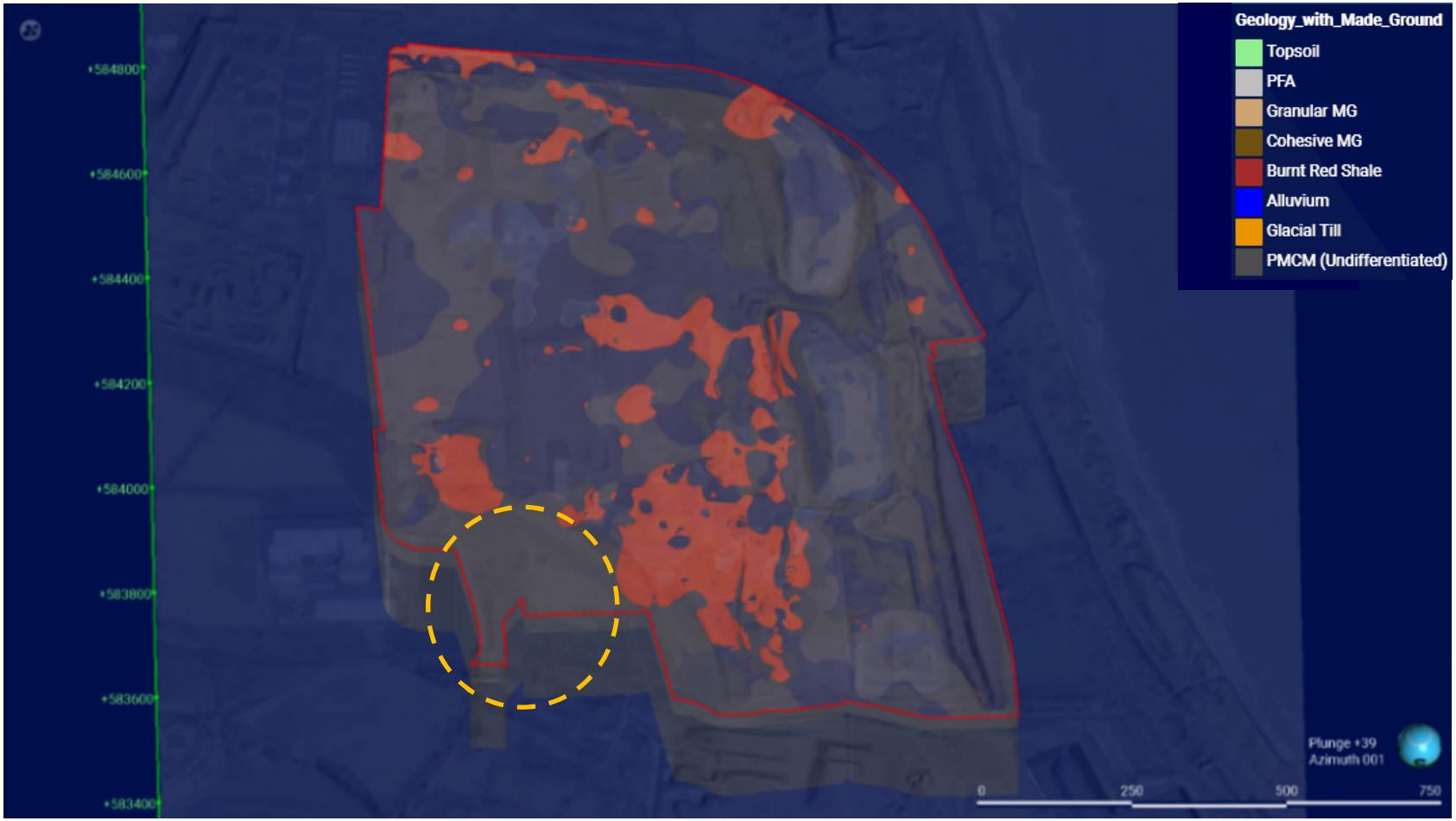


Figure 4-6 Plan Extent of Burnt Red Shale

Made Ground – PFA

4.4.6 Made Ground comprising PFA [MG – PFA] was mainly found in the two large stockpiles in the east of the site but is also present in localised patches in the north-west and south-east. PFA was generally found at the surface, or under surface hardstanding.

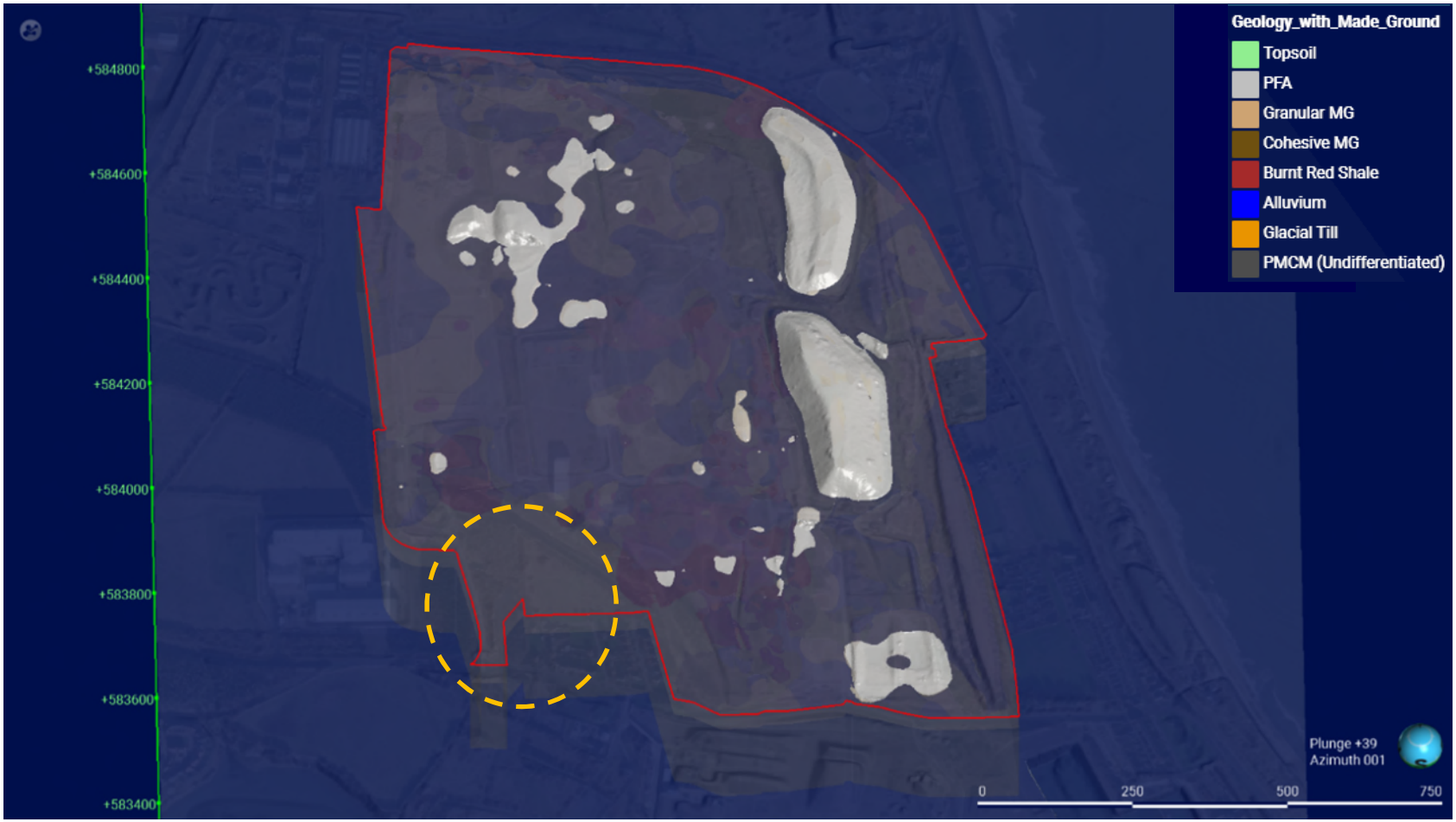


Figure 4-7 Plan Extent of PFA

Superficial Deposits – Alluvium

4.4.7 Alluvium [AL – ORG] was generally identified in shallow discrete deposits across the site, which loosely follow the original route of surface water features prior to their culverting for the coal pad development.

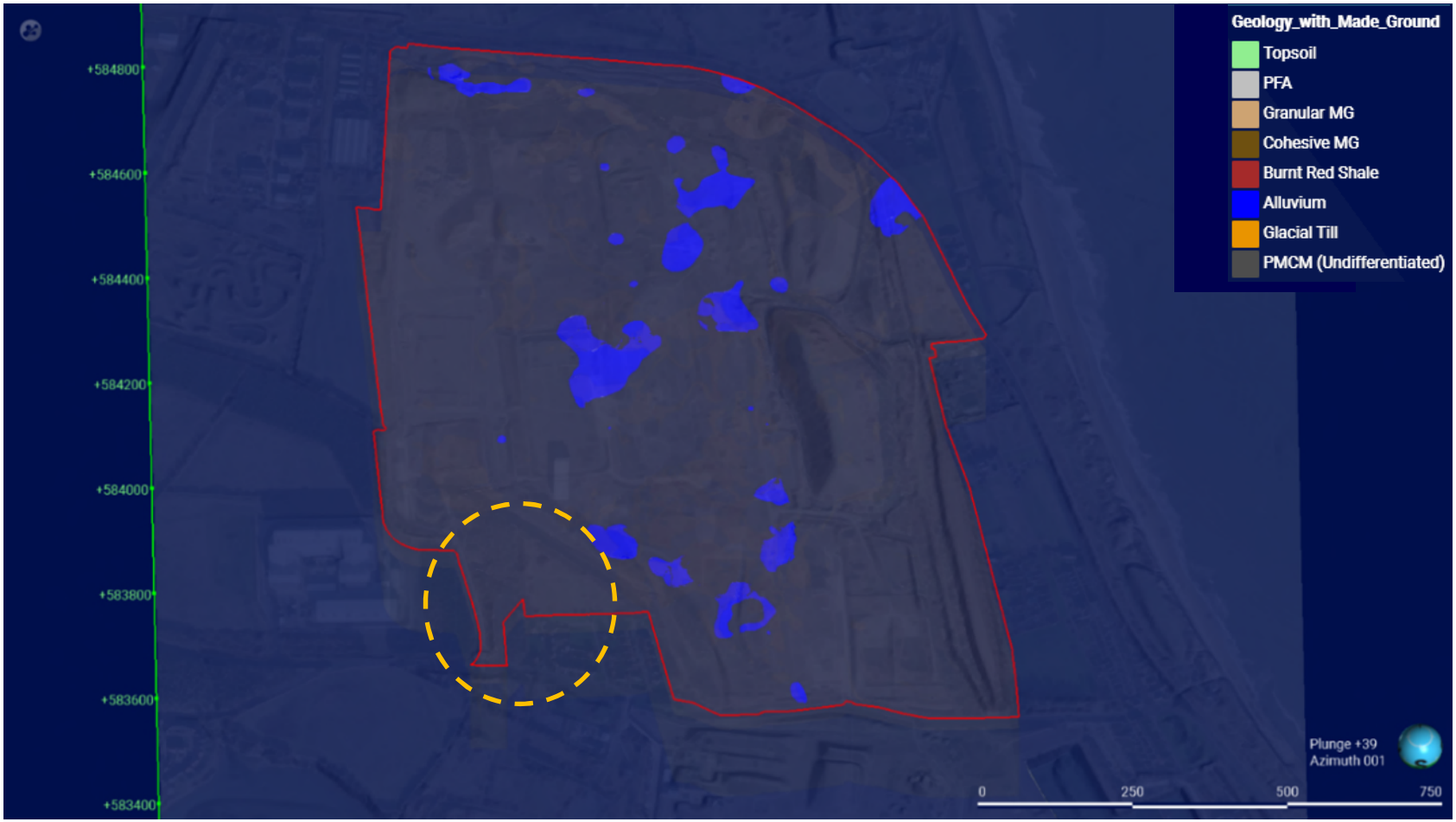


Figure 4-8 Plan Extent of Alluvium

Superficial Deposits (Glacial Till) and Bedrock (Pennine Middle Coal Measures)

4.4.8 Glacial Till [TILL] is present consistently across the site beneath Made Ground deposits and Alluvium. It is thinner in the south/south-east and thickens to the north/north-west. Bedrock of the Pennine Middle Coal Measures [PMCM] is also consistent across the site, beneath the Glacial Till. The depth to bedrock gradually increases from the south-east to the north-west.

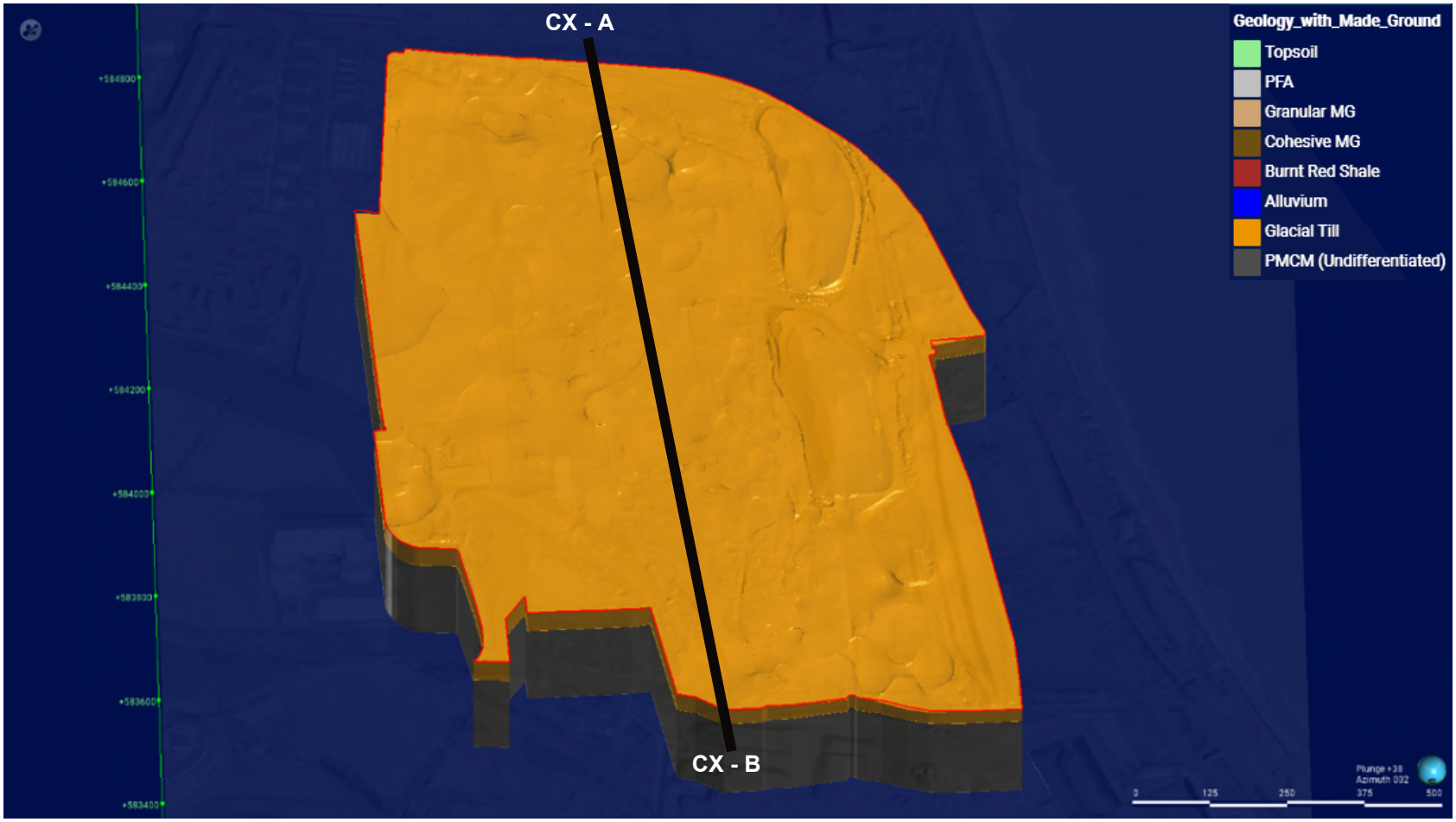


Figure 4-9 Model of Glacial Till and PMCM

4.4.9 Desk study information indicates an igneous intrusion crosses the north-west area of the site. The igneous intrusive was not identified during the intrusive investigation and is therefore not shown within this model.

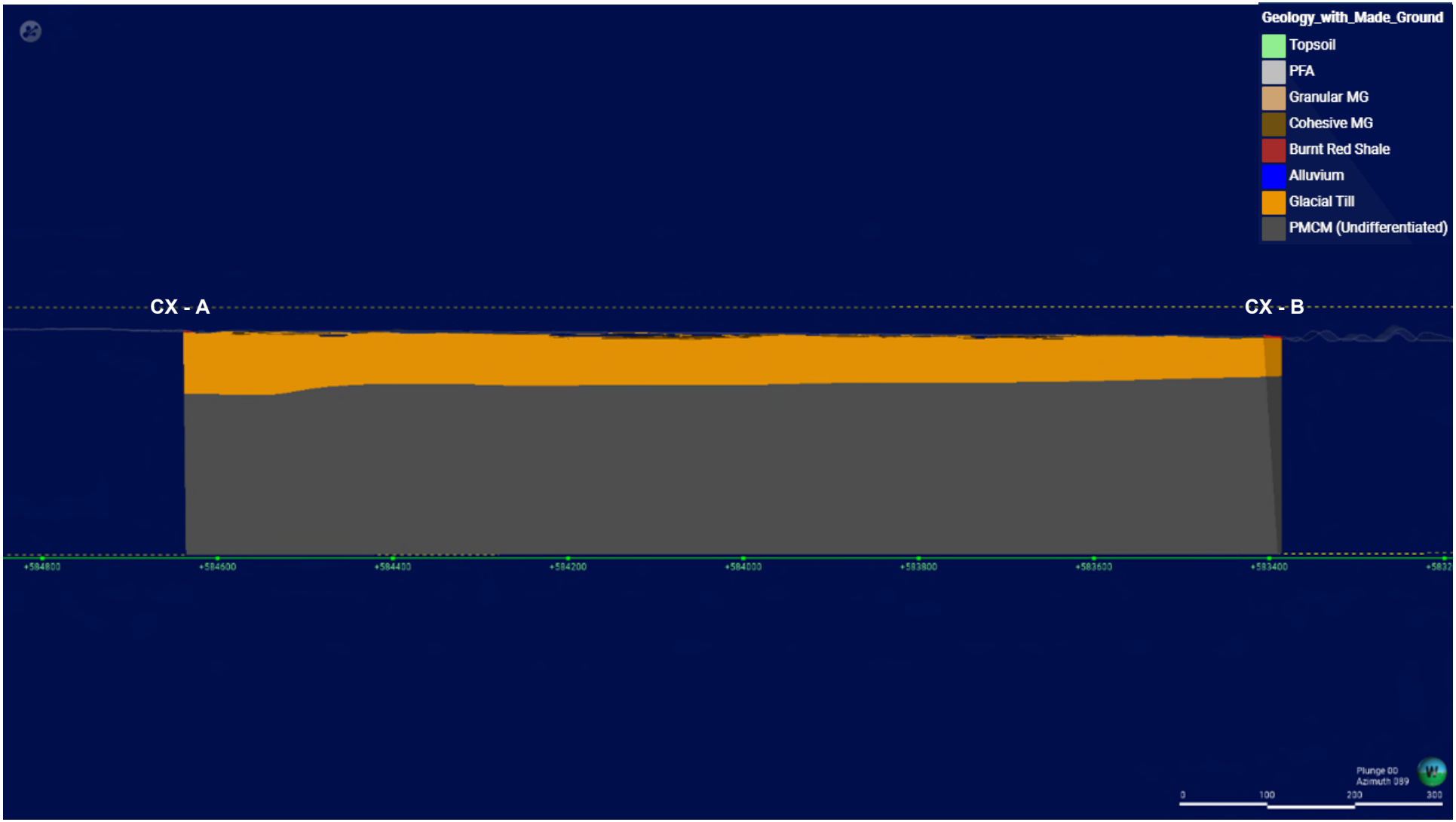


Figure 4-10 Cross Section of Glacial Till and PMCM

5 Engineering Parameters

5.1 Field Tests & In-situ Results

Summary of the 2024 In-situ Testing undertaken in presented in Table 5-1 below.

Table 5-1 Summary of In-situ Tests

Test Type	Test Details	Test Count
Standard Penetration Test (SPTs)	In-situ SPT	604
Variable Head Permeability Testing	Falling Head Test BH513, BH601 and WS118	3
High Pressure Dilatometer (HPD) Testing	BH328	3
	BH333	4
Downhole Geophysics Testing	Undertaken in BH101, BH103A- BH108 (50m bgl) and.BH201-BH203, BH205 (75m bgl).	12
Cone Penetration Testing (CPT)	20.5 tonne track mounted CPT Truck and 13-tonne hybrid crawler CPT unit across stage 1 and stage 2	31
Hand Shear Vane Testing (HSV)	HSV on recovered samples	81
Plate Load Testing (PLT)	PLT with 600mm diameter plate	26
Soil Resistivity Testing	RS101A – RS103A (in both west to east and north to south directions)	3

Standard Penetration Tests (SPT)

5.1.1 SPTs were undertaken at regular depth intervals during borehole progression. SPT N values have been corrected based on the SPT Energy Ratio (E_r) of the specific testing equipment, rod length (m) and diameter of borehole (mm) to calculate the N60 values.

5.1.2 The corrected values are summarised below in Table 5-2 and plotted against elevation in Figure 5-1.

Table 5-2 Summary SPT Data

Geology (code)	N-Value Range	N_{60} Range
Made Ground – Granular (MG – G)	4 – 47	3 – 42
Made Ground – Cohesive (MG – C)	2 - 25	2 – 25
Made Ground – Burnt Red Shale (MG – BS50)	8 - 13	6 – 10
Made Ground – PFA (MG – PFA)	10 – 50	8 – 55
Glacial Channel Deposits (G – CD)	20 – 44	21 – 45

Geology (code)	N-Value Range	N_{60} Range
Glacial Till (TILL)	4 – 50	3 – 56
Pennine Middle Coal Measures – Mudstone (PMCM – MST)	>50	-
Pennine Middle Coal Measures – Siltstone (PMCM – SLT)	>50	-
Pennine Middle Coal Measures -Sandstone (PMCM – SST)	>50	-

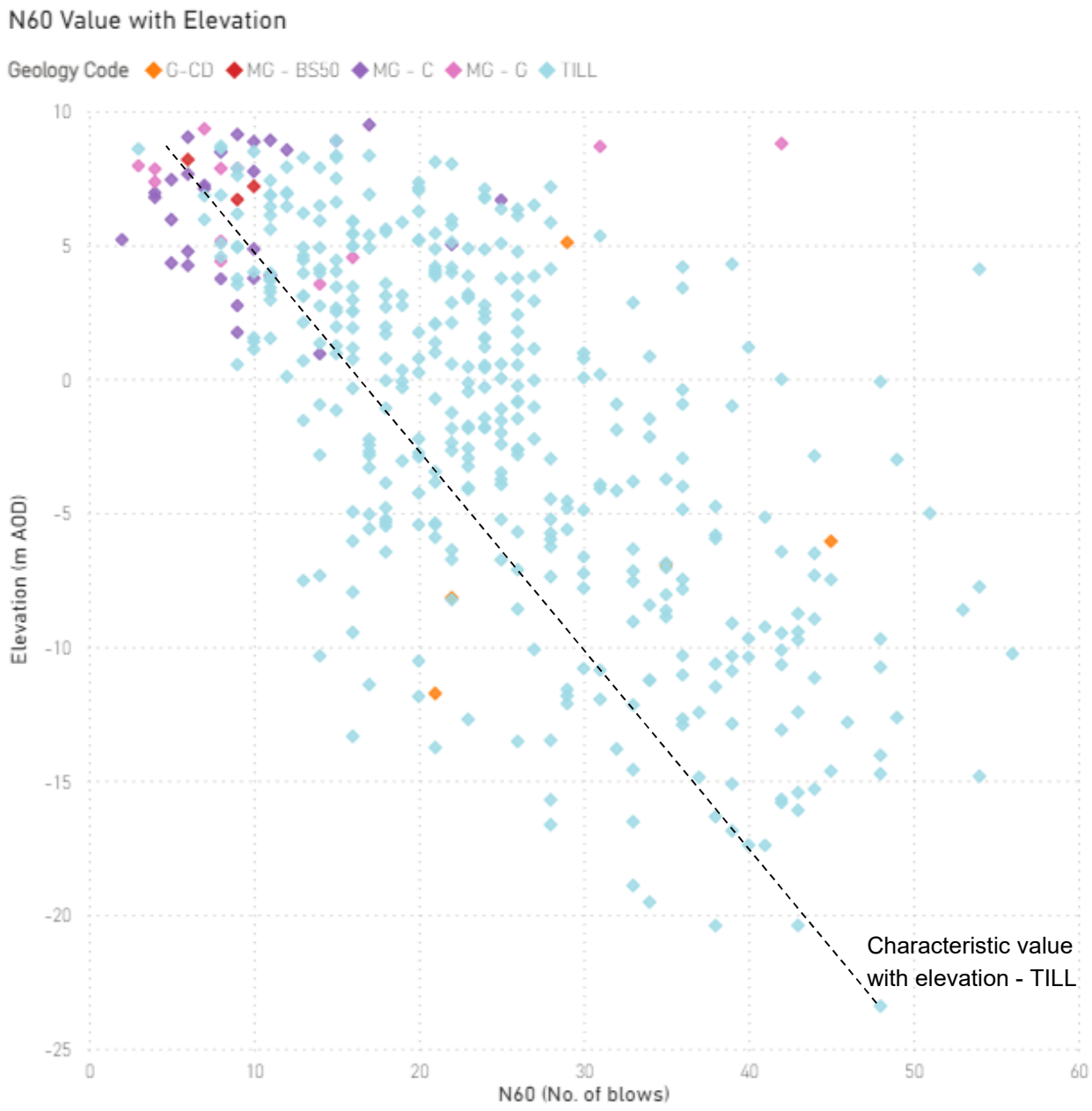


Figure 5-1 SPT N_{60} vs Elevation

Cone Penetration Tests (CPT)

5.1.3 Cone Penetration Testing (CPT) was undertaken by Lankelma on behalf of Arcadis using a 20.5 tonne track mounted CPT Truck and a 13-tonne hybrid crawler CPT unit in twenty-seven locations between 28th May – 13th June 2024. The full results are presented in the Arcadis Stage 1 Factual Report [2]. The full extent of the completed CPT tests included the following:

- Nineteen CPTs with pore pressure measurements,
- Eight seismic cone penetration tests with pore pressure measurements
- Eighty-three dissipation tests

5.1.4 A further four CPTs were undertaken on 30th August 2024 to a target depth of 30m at location CPT501 – CPT504 with results presented in the Arcadis stage 2 factual report [3].

5.1.5 All CPT locations are presented in the exploratory hole plan in Appendix B.

5.1.6 Surface to down-hole seismic shear wave (S-wave) data were collected using a seismic cone penetrometer assembly advanced to the required depths, with the seismic impulse generated at the ground surface adjacent to the CPT rig. Tests were undertaken in the TILL from depths of 7.5m, in ~3m intervals to a maximum depth of 20m. Shear Wave Velocity V_{sh} by linear regression over 4 arrival times (three intervals) was recorded between 220 and 350m/s and values generally increased with increasing depth into the TILL. The range of V_{sh} recorded is characteristic of deep/thick deposits of stiff clay (Ground Type C, Table 3.1 of Eurocode 8 [18]) with v_{s30} in the range of 180-360m/s.

5.1.7 The dissipation tests were undertaken across twelve CPT locations. The Coefficient of Consolidation (Cvh) and the permeability (k1) are summarised in the following plots vs depth. Characteristic values of Cvh = 11m^2/yr and k1 = 6 x10^{-10}m/s (constant with depth) were selected and are annotated on the plots below.

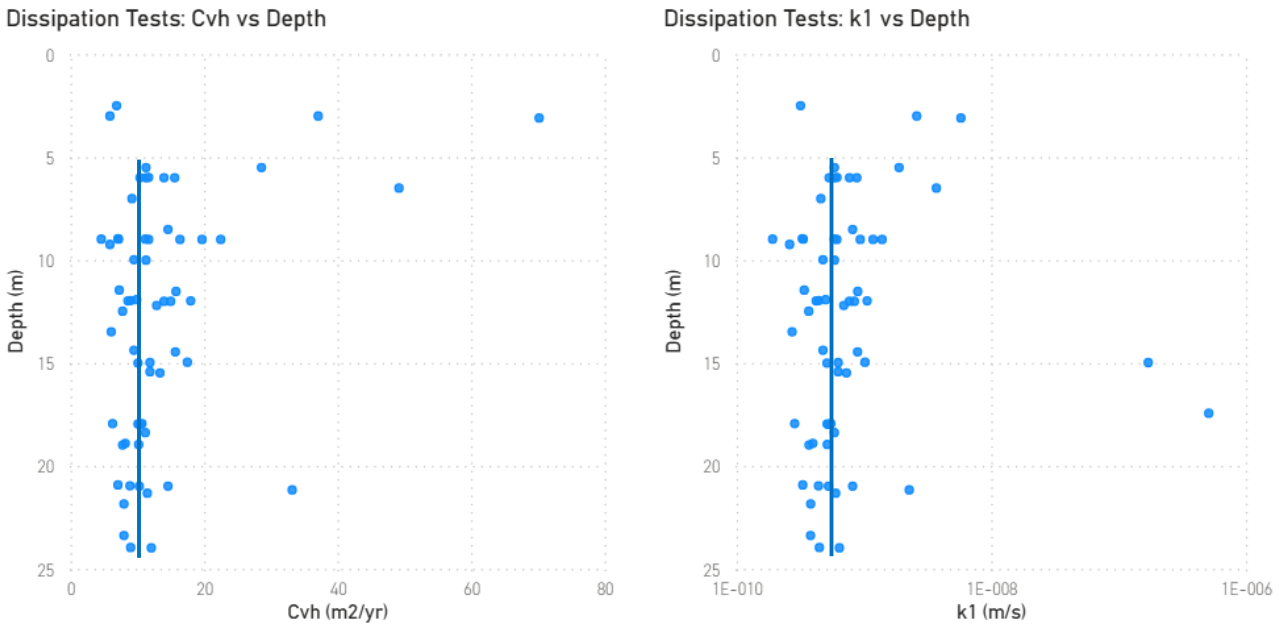


Figure 5-2 Dissipation Test Results and Characteristic Values [Coefficient of Consolidation, Cvh and permeability, k1] vs Depth.

Hand Shear Vane Tests

5.1.8 Hand shear vane tests were undertaken on recovered samples of cohesive Made Ground and Glacial Till. A summary of the results and the tests undertaken is summarised below in Table 5-3.

Table 5-3 Hand Shear Vane Test Summary

Geology (code)	Test Frequency	Shear Strength Range (kPa)	Residual Shear Strength Range (kPa)
Made Ground – Cohesive (MG – C)	6	74 - 150	25 - 54
Glacial Till (TILL)	24	57 - 151	14 - 150

Plate Load Testing

5.1.9 As part of the Stage 1 investigation, plate load testing (PLT) was completed in twenty-six locations across the site. Test locations are presented in the exploratory hole plan in Appendix B.

5.1.10 Testing was undertaken using a 600mm diameter plate and used either a 21-Tonne tracked excavator, or a wheeled backhoe excavator for kentledge. The testing was undertaken in shallow trial pits to a maximum depth of 0.5m bgl, on MG-G. The CBR results ranged from 0 – 279% and a modulus of subgrade reaction from 10 to 375 MPa. Full test results are included in the Stage 1 factual report [2].

Soil Resistivity Testing

5.1.11 Soil resistivity testing was undertaken at the site on 16th August 2024 by subcontractor SUMO as part of the 1st stage of ground investigation to measure soil resistivity for earthing installation. The testing was undertaken in three locations (RS101A – RS103A) within the southwest of the site along both west – east and north – south axes. The Wenner four-pin method was utilised as set out in BS EN 50522 [18] with readings taken at standard electrode spacings of 1, 1.5,2, 3, 4.5, 6, 9, 13.5, 18, 27, 36 and 54 metres. Readings were then obtained by passing a low frequency electrical current across the two outer electrodes, with the potential difference measured across the two inner. This gives the apparent ground resistance of the soil which is then converted using the following equation ($Pa = 2 \pi a R$) which gives the results in ohm-meters. The full results are displayed in the stage 1 factual report [2].

5.1.12 The results of all three tests are within narrow ranges of 49 - 18 Ohm-metres at RS101A; 71 – 21 Ohm-metres at RS102A and 47 - 20 Ohm-metres at RS103A. Generally, the values decrease with depth for the first four – five readings and then fluctuate within a narrow range of 35 – 19 Ohm-metres for the remaining readings. When compared to three nearby boreholes, (BH24, BH25 and BH25a) the low resistivity ranges and decreasing resistivity with depth is are consistent with the ground conditions on of predominantly cohesive Made Ground underlain by glacial till (clay) and coal measures. A soil resistivity testing and borehole location plan is presented in within the Factual Report [3].

5.1.13 It should be noted that ground resistivity is subject to seasonal variation and may vary with new fill material during any future construction works. The techniques utilised were using density gamma probe, optical televiewer and acoustic televiewer techniques.

High Pressure Dilatometer (HPD) Testing

5.1.14 HDP testing was undertaken within BH328 and BH333 during the 2024 Arcadis ground investigation between the 19th to 27th June 2024. A summary of the testing is presented in the table below.

Table 5-4 HPD testing undertaken.

Borehole	Test No	Date	Depth (m bgl)	Geology	Remarks
BH328	T01	26/06/24	2.70	Glacial Till Loose to medium dense SAND over firm to stiff slightly sandy slightly gravelly CLAY.	
	T02	26/06/24	5.70	Glacial Till Firm sandy slightly gravelly CLAY	
	T03	27/06/24	17.60	Glacial Till Firm to stiff sandy gravelly CLAY	
BH333	T01	19/06/24	27.80	Weak thinly laminated MUDSTONE	Membrane burst – no test interpretation
	T02	21/06/24	31.20	Weak thinly to medium bedded fine to medium SANDSTONE	
	T03	24/06/24	34.70	Moderately weak to strong fine to coarse SANDSTONE	No material yield
	T04	25/06/24	37.60	Moderately weak thinly to medium bedded fine to coarse SANDSTONE	

5.1.15 The HDP testing was undertaken to assess the mechanical properties of the soil and rock under high-pressure conditions to determine stiffness, compressibility and shear strength. A summary of the shear strength values are presented below in Table 5-5 with the full results presented in in Appendix D and the Arcadis Factual Report [2]. The secant shear modulus is presented below under different shear strain percentages. This can be used to calculate stiffness at different loading levels and calculate settlement for detailed design.

Table 5-5 Undrained Shear Strength from HDP testing

Borehole	Depth (m bgl)	Geology (code)	Undrained Shear Strength (kPa)	
			$S_{u(M\&R)}$[1]	$S_{u(loading)}$[2]
BH328	2.70	TILL	-	125
	5.70	TILL	103	103
	17.60	TILL	588	588
BH333	27.80	PMCM – MST	-	-
	31.20	PMCM – SST	4040	4040
	34.70	PMCM – SST	-	-
	37.60	PMCM – SST	7838	7838

1 Based on Gibson and Anderson (1961) [19]

2 Based on Marsland and Randolph (1977) [20]

5.1.16 The undrained shear strength parameters presented in Table 5-5 above, have been determined using Gibson and Anderson (1961) [19] for the loading part of the test curves from the HPD testing. This method is based on the assumption of an elastic – perfectly plastic material. Therefore, the test results undertaken in the rock may not be as reliable as it is more likely to exhibit brittle behaviour with little plastic deformation during the testing, compared to soil.

5.1.17 The shear modulus (G) results from the HPD testing can be converted to undrained Youngs modulus (E_u) using the following equation [21].

$$E_u = 2 \times G(1 + \nu)$$

5.1.18 The results are presented below for the testing undertaken in the Glacial Till in BH328.

Table 5-6 Derived Youngs Modulus (undrained) from HDP Testing in BH328

Borehole	Depth (m bgl)	Shear Modulus G_i[1] (MPa)	Assumed Poisson's Ratio (ν)[2]	Eu (MPa)
BH328	2.70	0.7	0.3	1.82
	5.70	8.0	0.3	20.80
	17.60	5.8	0.3	15.08

[1] Initial shear modulus used from HPD testing

[2] Typically published values for Glacial Till

Downhole Geophysics

5.1.19 Downhole Geophysics was undertaken by a specialist third party contractor, Robertson Geo ltd, as part of the 2024 investigation on all rotary boreholes with a target depth of 75m to 100m bgl. This comprised of BH101, BH103A- BH108 (50m bgl) and.BH201-BH203, BH205 (75m bgl). The downhole geophysics was undertaken to look for evidence of borehole instability that may have resulted from historic coal workings or faulting. No obvious signs of instability were observed in any of the logs indicating there are not likely to be any significant instability issues from faulting at depth.

Infiltration Testing

5.1.20 No infiltration testing was performed as part of the Arcadis 2024 ground investigation however, four soakaway tests were undertaken in the Glacial Till in the 2021 Rolton Group Ground Investigation [5] within stiff sandy gravelly clay (Glacial Till) between depths of 1.45m – 3.75m bgl. The testing found no infiltration; therefore, the shallow Glacial Till is not considered suitable to provide natural drainage of stormwater. The overlying Made Ground is also not considered suitable owing to the presence of contaminants and its variable nature.

Permeability Testing

5.1.21 Falling head permeability tests were undertaken in the well installations of WS118, BH513 and BH601 between 26th – 27th November 2024. A test was also attempted in BH504 but was unsuccessful. A known volume of water was added to the wells and fall in groundwater level was recorded manually and by data logger at regular intervals to calculate the permeability (hydraulic conductivity) of the screened geology (of which was slightly sandy slightly gravelly Glacial Till in all wells). The results are presented in Appendix F. To calculate the permeability the Hvorselv Method was used as set out in BS EN ISO 22282-2:2012 B4.2, which gave a range of results of 1.32E-07 ms^{-1} to 3.90E-08 ms^{-1}. The results are consistent with the expected permeability of clay ranging from an almost impermeable to very low permeability. The results suggest that the shallow natural deposits of Glacial Till are not suitable for soakaway drainage. This is also supported by previous soakaway testing undertaken in the Rolton Group investigation [5].

5.2 Geotechnical Lab Results

5.2.1 Geotechnical tests were undertaken on selected disturbed and undisturbed soil samples as well as selected rock core samples obtained from the 2 stages of the Arcadis ground investigation. Full details and testing certificates are presented in the factual reports [2] [3]. Table 5-7 summarises the geotechnical laboratory testing undertaken. A breakdown of the testing in each geological unit is presented in Appendix C.

Table 5-7 Summary of Geotechnical Laboratory Testing – Test Count by Test Type

Test Type	Test Count
Natural Moisture Content (NMC)	319
Atterberg Limits – Liquid Limit/Plastic Limit (LL/PL) (4 points)	234
Particle Size Distribution (PSD)	192
Bulk Density Remoulded	12
Particle Density by Glass Jar	57
Compaction using 2.5kg & 4.5kg Rammer and Vibrating Hammer	53
Quick Undrained Triaxial (QUT)	103
Laboratory Hand Shear Vane (HSV)	22
Consolidated Undrained Multi-Stage Triaxial (CUM)	17
Shear Box Testing (small)	19
Shear Box Testing (large)	2
One-dimensional Consolidation in Oedometer	23
Laboratory California Bearing Ration (CBR) (Recompacted)	60
Moisture Condition Value (MCV)	12
Moisture Condition Calibration (MCC)	41
Los Angeles Coefficient Testing (LA Coeff.)	8
Rock Uniaxial Compressive Strength (UCS)	96
Determination of the Point Load Index Strength	241
Rock Density	96
Rock Natural Water Content	96
Materials testing to BS EN450 (PFA)	8
Accelerated Swell Test with Terminal UCS	4
BRE SD1 Full Suite*	327
TRL 447 Suite*	31

*Results reported and interpreted in 6.5 Concrete Classification.

Natural Moisture Contents & Atterberg Limit

5.2.2 The results of measured Natural Moisture Contents (NMC) and Atterberg Limit tests are summarised in the table below by geology.

Table 5-8 Atterberg Limit Results

	AL - ORG	G – CD	MG – BS50	MG - C	MG – G	MG - PFA	TILL
No. Tests	9	1	4	18	3	26	173
Natural Moisture Content (%)	8.7 – 49	12	12 - 21	11 - 43	3.4 - 33	16 – 52	7.1 – 32
Liquid Limit (%)	42 – 70	28	40 - 48	34 - 61	46	34 - 63	23 – 70
Plastic Limit (%)	20 – 30	15	20 - 23	17 - 28	23	17 - 30	13 – 29
Plasticity Index (%)	22 - 40	13	20 - 25	13 - 35	23	11 - 35	9 – 41
Passing 425mm (%)	89 - 100	91	54 - 70	57 - 93	96	73 - 100	9 – 100
Modified Plasticity Index (%)	20 - 40	12	11 - 18	7 - 33	22	8 - 35	1 - 41

5.2.3 The following figures show NMC and Atterberg Limits plotted by elevation and geological unit (Figure 5-3) and a Casagrande Plot (Figure 5-4) for all samples and parent geological units.

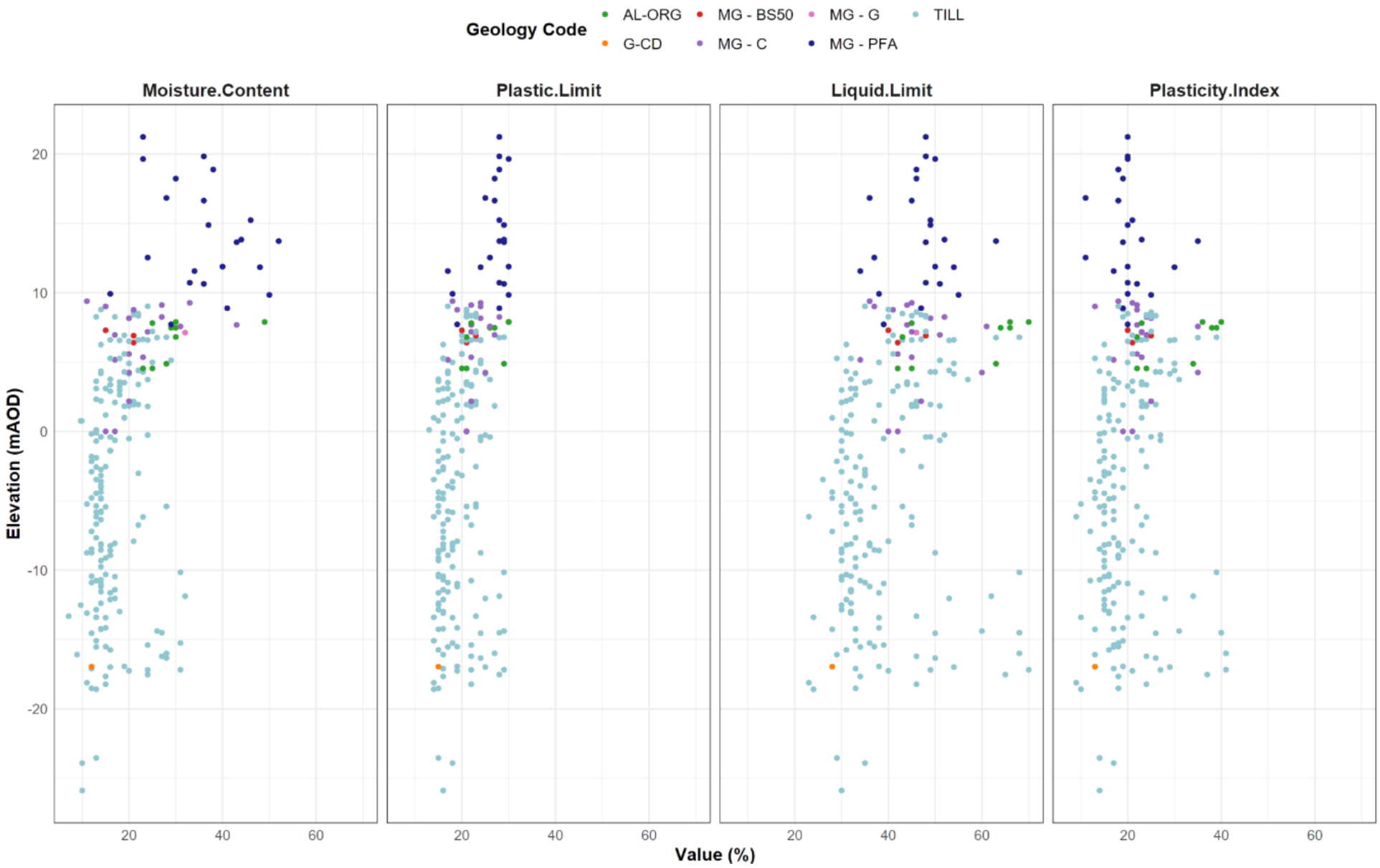


Figure 5-3 Natural Moisture Contents and Atterberg Limits plotted by Elevation and Geology

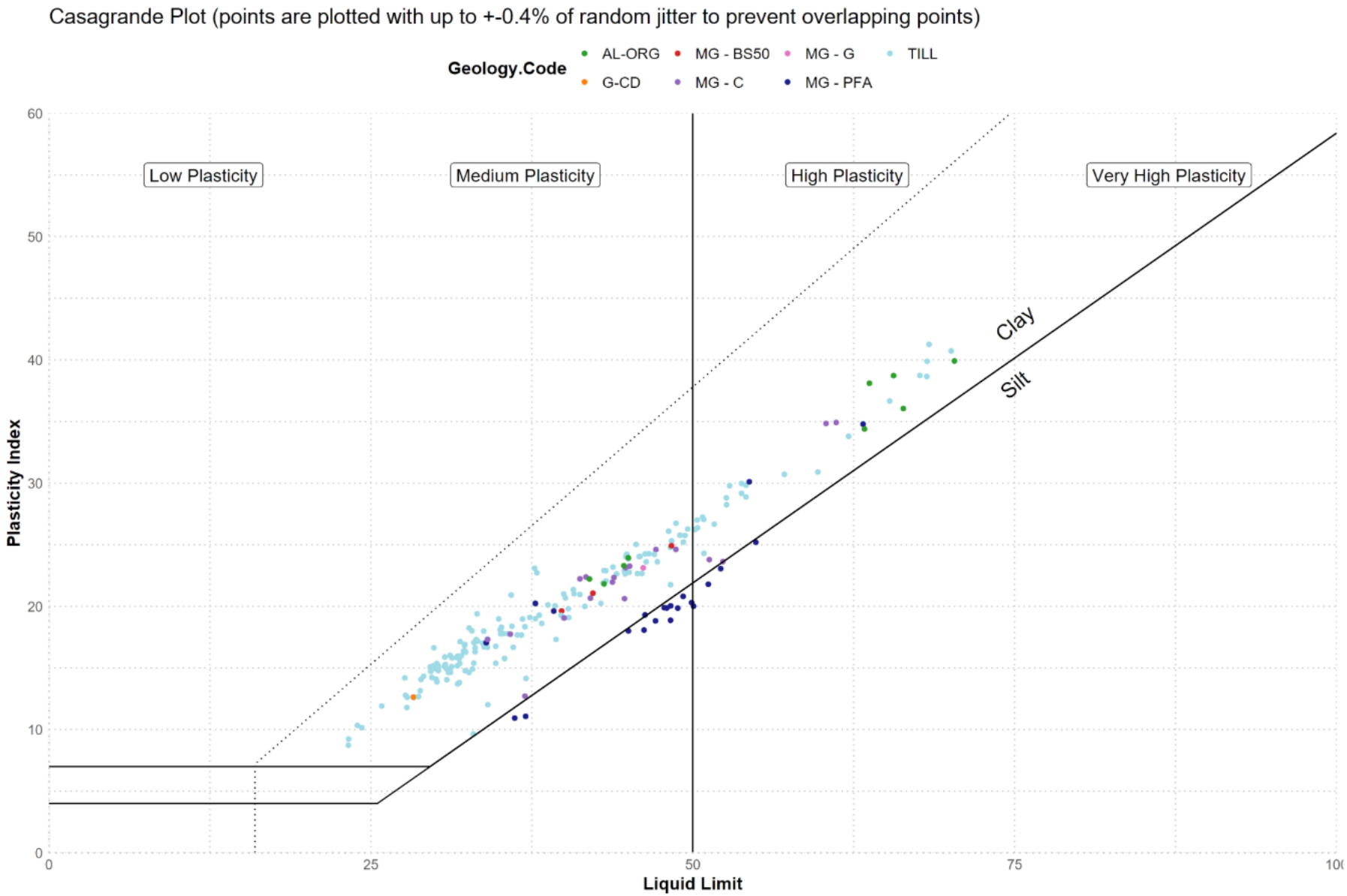


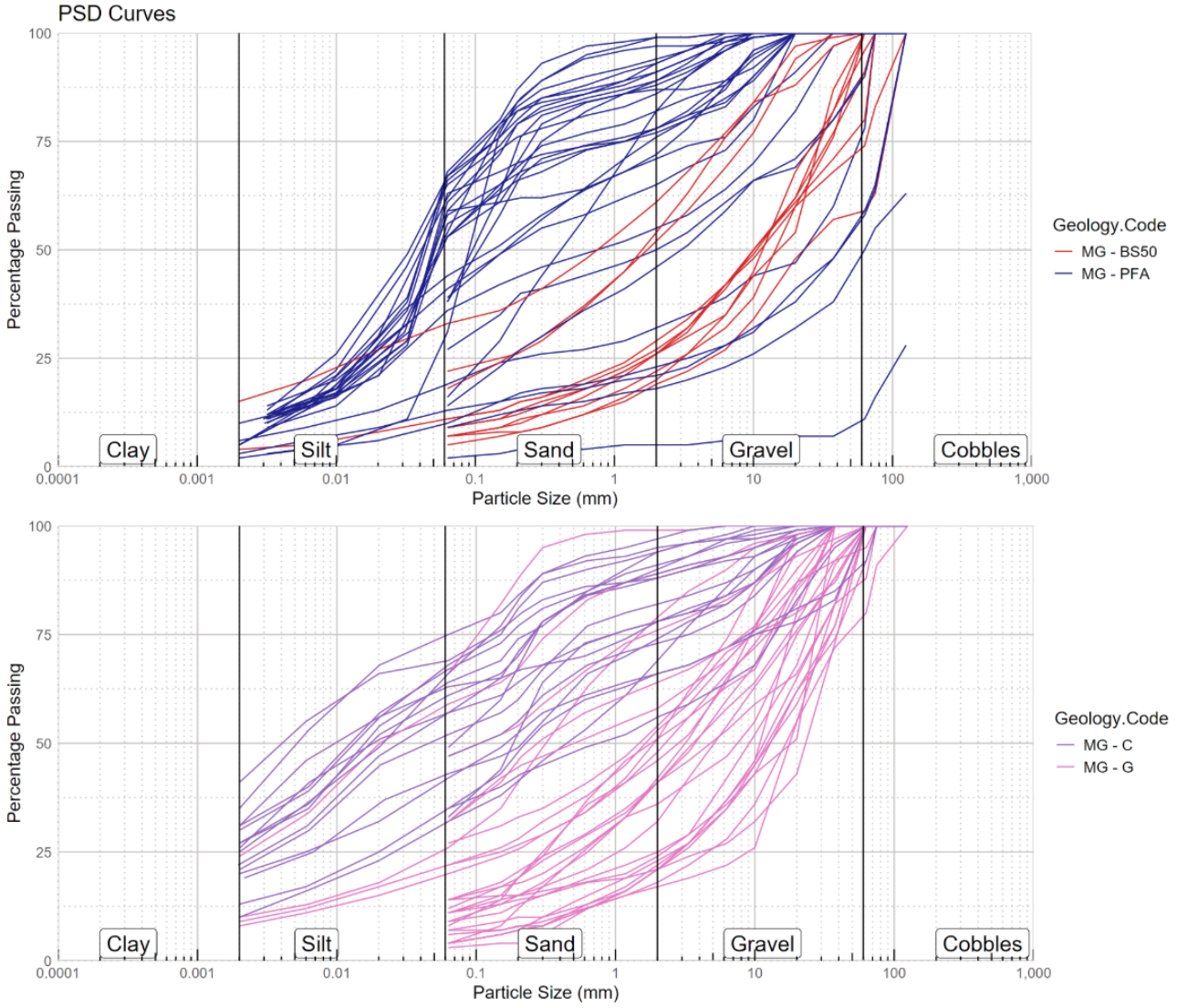
Figure 5-4 Plasticity Chart for Casagrande Classification

5.2.4 The plasticity results generally indicate that the majority of clays are medium to high plasticity when plotted on the Casagrande chart in Figure 5-4. When using the modified plasticity index, the majority of results indicate medium volume-change potential on change of moisture content, With only a few results reaching 40-41% which just fall within 'high volume change potential' classification (MPI>40%).

5.2.5 The Casagrande chart also shows that the majority of the MG – PFA samples tested marginally fall below the A-line indicating they are potentially Non-Plastic, however 5 samples were confirmed as clay, showing the variable nature/grading of the PFA.

Particle Size Distribution

5.2.6 A total of one hundred and ninety-two PSD tests were undertaken. The results are presented below in Figure 5-5 and Table 5-9.



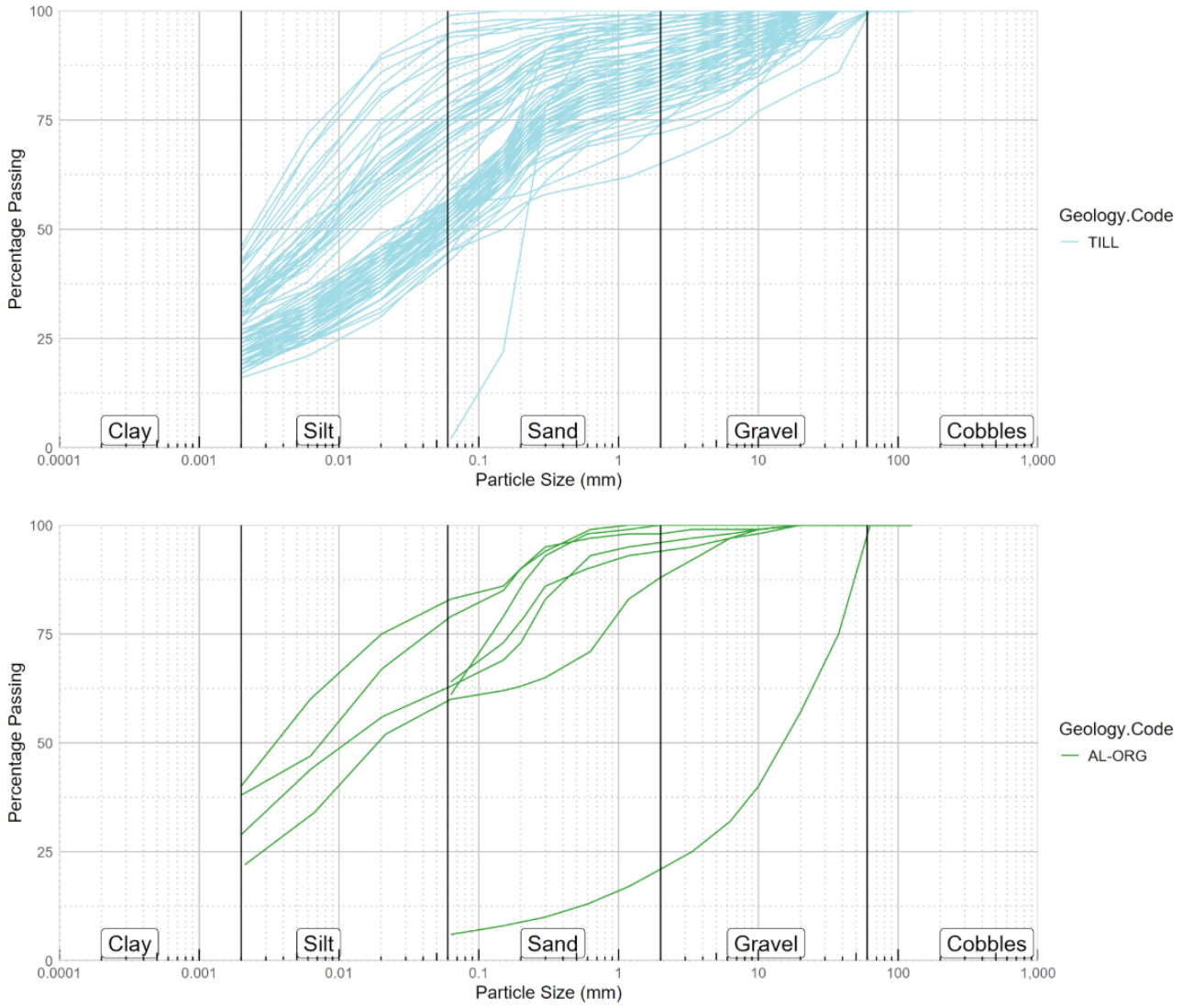


Figure 5-5 Particle Size Distribution Curves

Table 5-9 Summary of all PSD Testing

Geology	Test Count	Comments
AL-ORG	7	The majority of samples are sandy silt with one sample indicated to be a gravel.
G – CD	1	The one sample tested indicated it is indicated to be fine grained of either silt or clay, however the field description of the material was medium to coarse GRAVEL and therefore there was likely an error with sampling/sample labelling and the result should be discarded.
MG – G	28	The results show variability in the distribution of grain size. The majority of results indicate sandy gravel however some samples are predominantly sands with a couple finer samples.
MG – C	19	The samples tested generally had a wide range of grain sizes indicating most samples would be classed as slightly gravelly sandy clay or silt.
MG – BS50	11	The results indicate that all samples have gravel as their principal constituent.
MG – PFA	31	The PSD curves show a wide range in grainsizes and distribution across the PFA samples showing the variability of the material.

TILL	95	The results of the TILL are generally consistent showing the descriptions to be of slightly gravelly slightly sandy silty clays.

Compaction & Density

5.2.7 Twelve samples were submitted for Bulk Density – Linear Measurement tests; seven from the TILL and five from the MG – PFA. The results are summarised in the following table:

Table 5-10 Summary of Bulk Density Testing – Linear Measurement Method

Geology	Test Count	Bulk Density Mg/m^3	Dry Density Mg/m^3	Moisture Content %
MG – PFA	5	0.88 – 1.08	0.66 – 0.82	22 – 35
TILL	7	2.02 – 2.23	1.66 – 1.97	12 – 23

5.2.8 A total of fifty-three compaction tests were undertaken using either a 2.5kg rammer (thirty-two count) or 4.5kg rammer (seventeen count), or vibrating hammer method (four count – MG-G only).

5.2.9 Compaction tests were supplemented with measured Particle Density Tests (thirty-eight count by glass jar method).

5.2.10 A summary of the results by geological unit is presented below in Table 5-11.

Table 5-11 Compaction Testing Results

Geology (code)	No. Tests	Particle Density Range (Mg/m^3)	Optimum Moisture Content Range (%)	Maximum Dry Density Range (Mg/m^3)
MG - PFA	25	1.58 – 2.30	25 – 44	1.06 – 1.24
MG - G	6	2.20 – 2.73	6 – 27	1.33 – 2.24
MG - C	14	2.41 – 2.72	14 – 24	1.48 – 1.90
MG - BS50	13	2.60 – 2.71	13 – 18	1.71 – 1.94
TILL	14	2.62 – 2.69	14 – 21	1.66 – 1.85
AL-ORG	21	2.46 – 2.67	21 – 28	1.47 – 1.55

5.2.11 For the MG – PFA samples there was a consistent grouping of most of the compaction curves in the range of 25 to 29% optimum moisture content (OMC), 1.07 to 1.19Mg/m^3 maximum dry density (MDD) and 1.58 to 1.74g/cm^3 particle density. There were however 3 results which were inconsistent/outliers and for which much higher OMC values of 31 – 44% were recorded, which can be explained by these samples having a much higher particle density ranging from 2.15 – 2.30 Mg/m^3. These samples were all taken from shallow depths of 0.5, 0.7 & 1.0m bgl from the PFA stockpiles, and it is therefore likely that these samples are compositionally different to the majority of PFA with the addition of other materials (e.g. sand, soil etc with higher particle densities). These results are presented below in Figure 5-6.

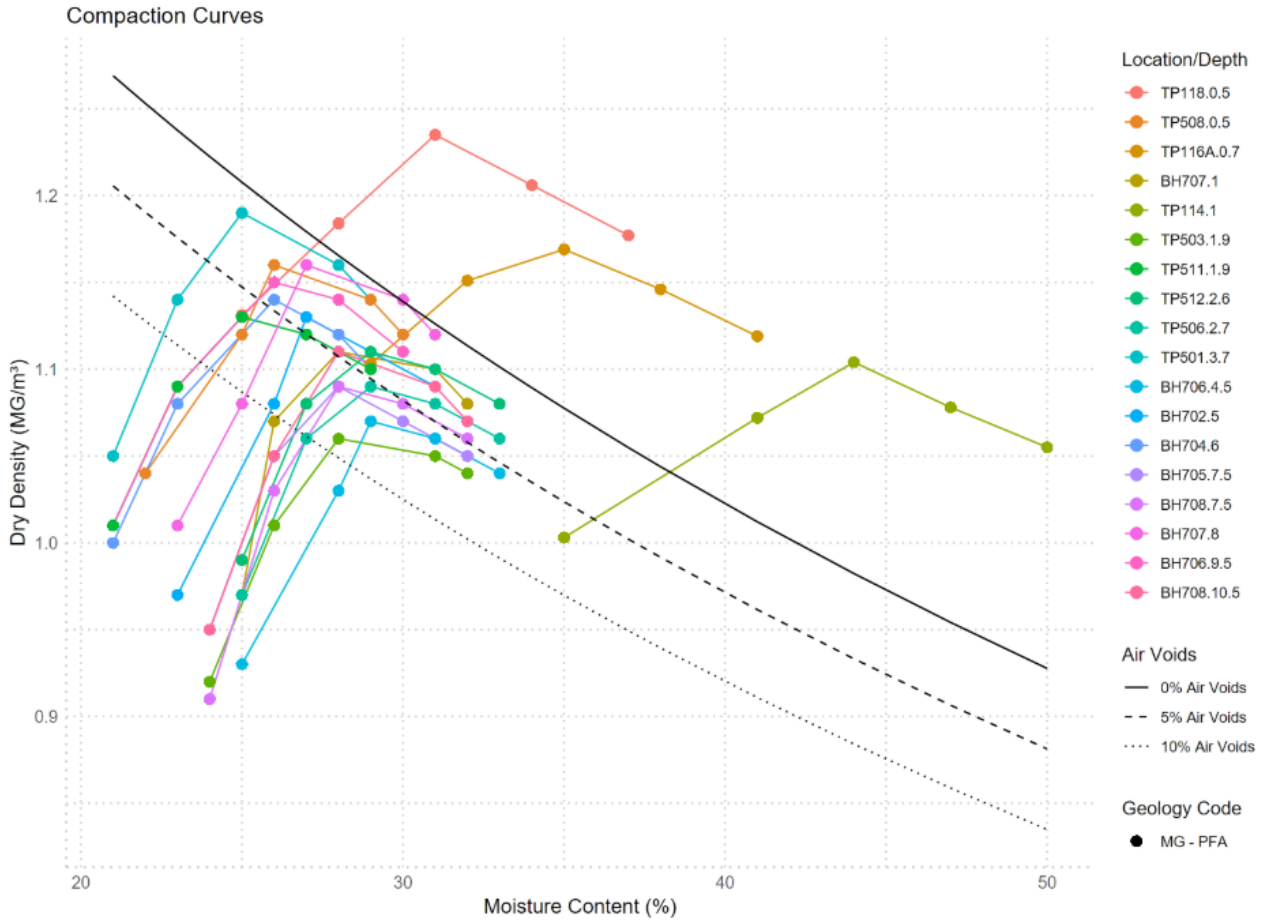


Figure 5-6 Compaction Curves for MG – PFA. Air voids curves plotted for a corresponding particle density of 1.73 mg/m^3

5.2.12 The majority of the samples across all other geologies excluding the PFA had particle densities in the range of 2.60 to 2.73 Mg/m^3, excluding six outliers with PD <2.60 Mg/m^3. The compaction curves for the other geologies tested are presented below in Figure 5-7 with air void curves plotted for a corresponding particle density of 2.73Mg/m^3.

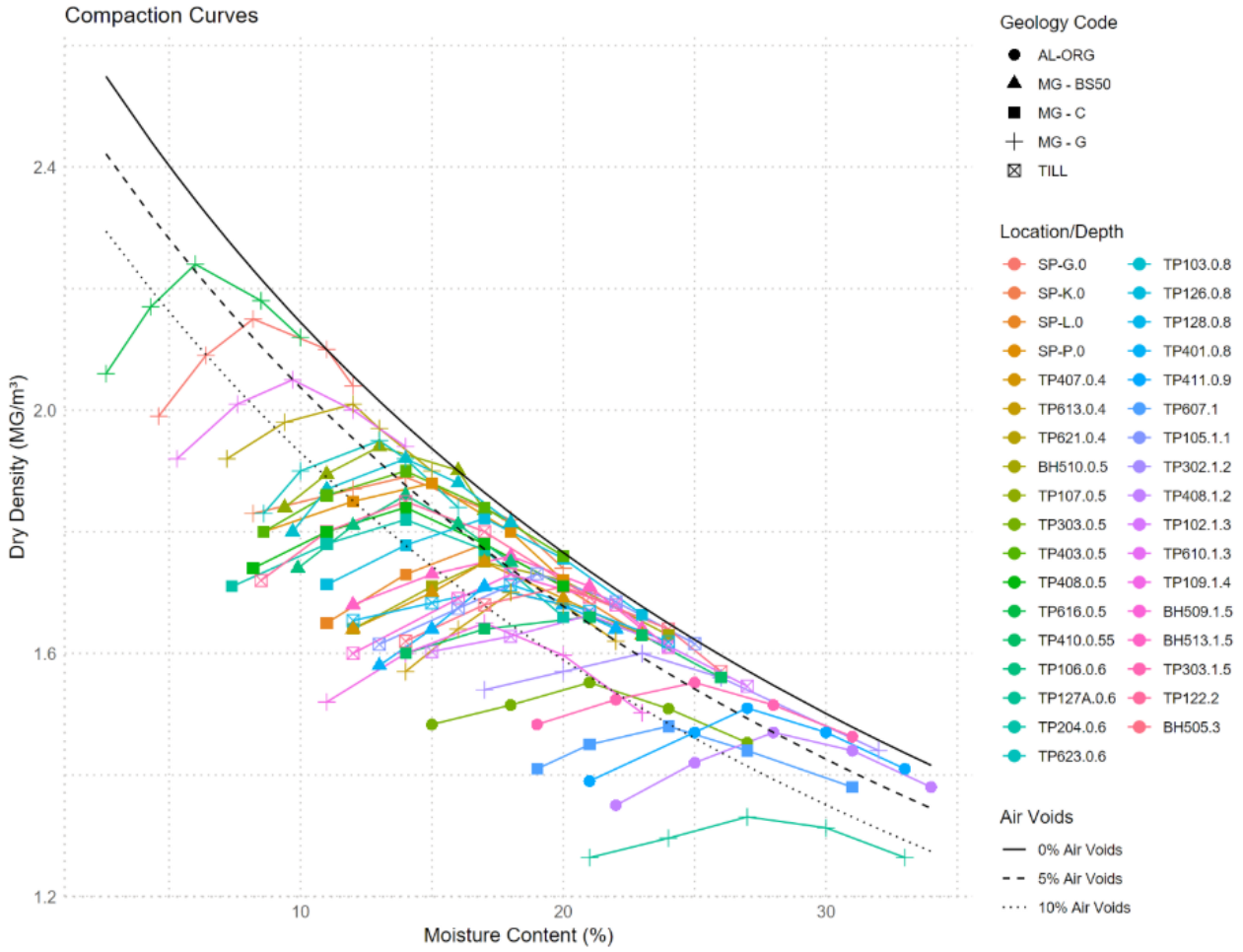


Figure 5-7 Compaction Curves for AL - ORG, MG - BS50, MG - C, MG - G & TILL. Air voids curves plotted for a corresponding particle density of 2.73 mg/m^3

Undrained Shear Strength

5.2.13 Based on quick (unconsolidated) undrained triaxial (QUT) tests (one hundred two undisturbed samples of TILL and one sample of MG-C), failure shear strength (c_u) values were recorded as follows:

- TILL: 17 to 388kPa
- MG-G: 80kPa

5.2.14 Undrained shear strength has also been derived for TILL and MG-C strata using the empirical relationship originally developed by Stroud and Butler [22] , cu = f1*N, where N is the SPT N-value and f1 is a factor dependent upon the Plasticity Index of the material. An f1 factor of 4.5 was obtained for the TILL based on the average PI results.

5.2.15 The direct measurement of undrained shear strength (from QUT) and those derived from the above empirical relationship (f1.N) are plotted vs depth in the chart in Figure 5-8 below.

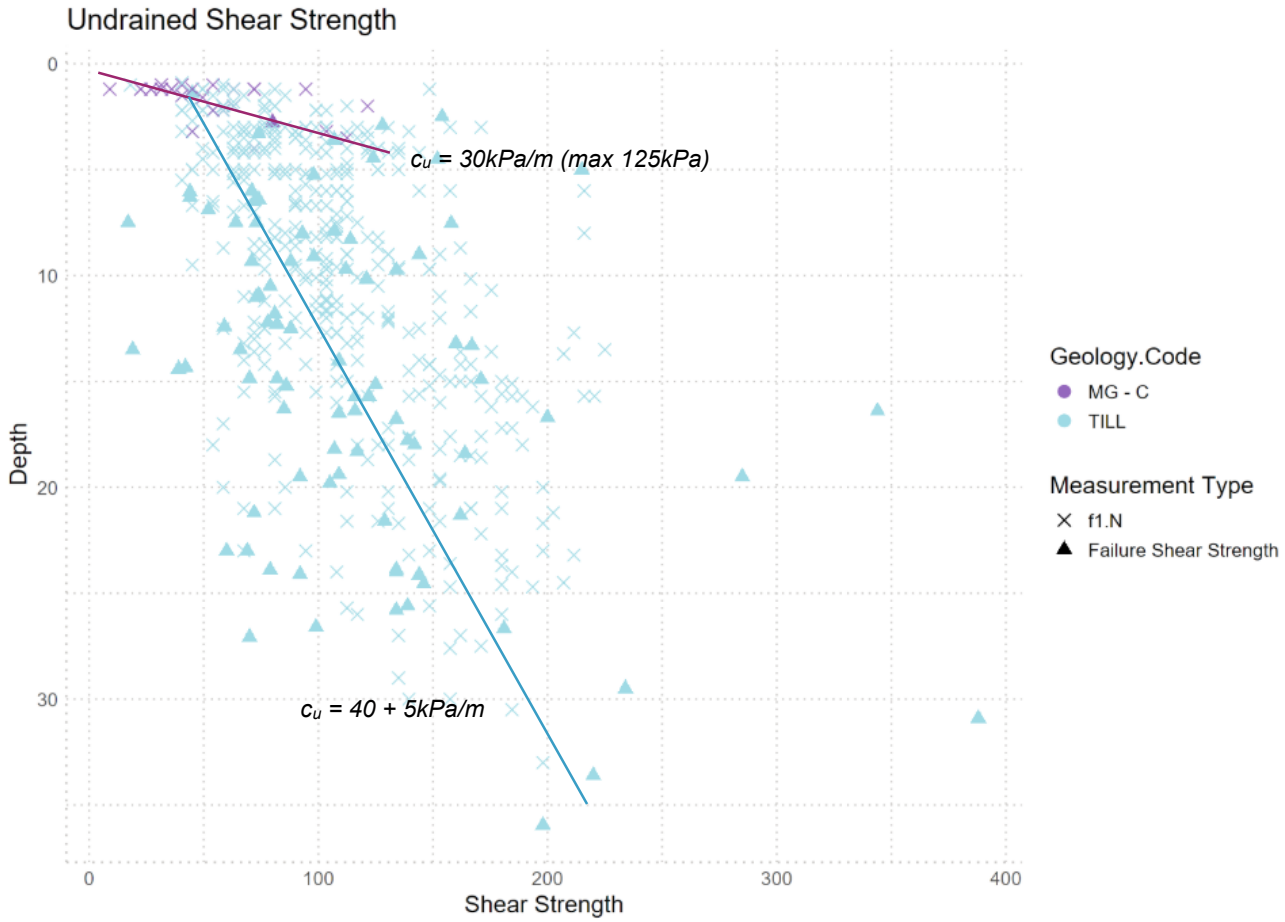


Figure 5-8 Undrained Shear Strength, Cu (kPa), vs Depth (m bgl) with characteristic trend lines.

5.2.16 There is a general increase in undrained shear strength (c_u) with increasing depth, however there is significant scatter to the data in both QUT and f1.N datasets which is representative of natural variation in water content and density, a consequence of the deformation process, the impact of composition and fabric of matrix-dominated till on the failure and the consequences of sampling and testing composite soils.

5.2.17 Some of the lowest QUT results may have also been significantly affected by sample disturbance or high moisture content. Characteristic trend lines of c_u have been plotted (based on engineering judgment) which are approximated by the following relationships with depth (z):

- MG-C: c_u = 30kPa/m (max 125kPa)
- TILL: c_u = 40 + 5kPa/m

5.2.18 The SHANSEP (Stress History and Normalized Soil Engineering Properties) strength model allows c_u to be estimated based on in-situ effective stress and over-consolidation ratio (OCR) The following relationship is an example for glacial deposits in north-eastern England (after Clarke [23]):

- SHANSEP general form: $c_u = A + \sigma_v' S(OCR)^m$

  $A = minimum\ undrained\ shear\ strength$

  $\sigma_v' = in\ situ\ effective\ vertical\ stress$

  $S = normally\ consolidated\ ratio\ of\ \left(\frac{\tau}{\sigma_v'}\right)_{nc}$

  $OCR = over\ consolidation\ ratio$

  $m = exponent\ typically\ between\ 0.75\ and\ 1$
- Relationship used by Clarke: $c_u = 0.3\sigma_v'(OCR)^{0.8}$

5.2.19 The undrained strength datasets for TILL have again been plotted versus depth, this time with trend lines of in-situ c_u for OCR of 1, 5, 10 and 20 based on the relationship proposed by Clarke and using a site-specific groundwater depth of 9m (refer to Figure 4-2). to predict vertical in-situ effective stress. This plot demonstrates the shallow samples (<5m depth) have undrained strength equivalent to an OCR of around 5-10. Below this depth the c_u of samples is equivalent to an OCR of less than 5, with an approximate average of around 2.



Figure 5-9 Glacial Till - Undrained Shear Strength, Cu (kPa), vs Depth (m bgl) with OCR Lines overlaid.

5.2.20 Laboratory Hand Shear Vane tests were performed on selected samples which were unsuitable for more advanced testing after extrusion. Twenty-two tests were carried out in total; twenty-one on samples of TILL and one on PMCM – SST. The results were as follows:

- TILL: 54 - >150kPa; and
- PMCM – SST: >150kPa.

Effective Shear Strength

5.2.21 Seventeen samples of TILL were submitted for Multistage Consolidated Undrained Triaxial tests to measure effective strength parameters; the results are summarised in Table 5-12 and Figure 5-10 below.

Table 5-12 Effective Strength Parameters TILL

Geology (code)	Effective Cohesion c' (kPa)	Effective Friction Angle (°)
TILL	8 - 34	17.6 – 31.1

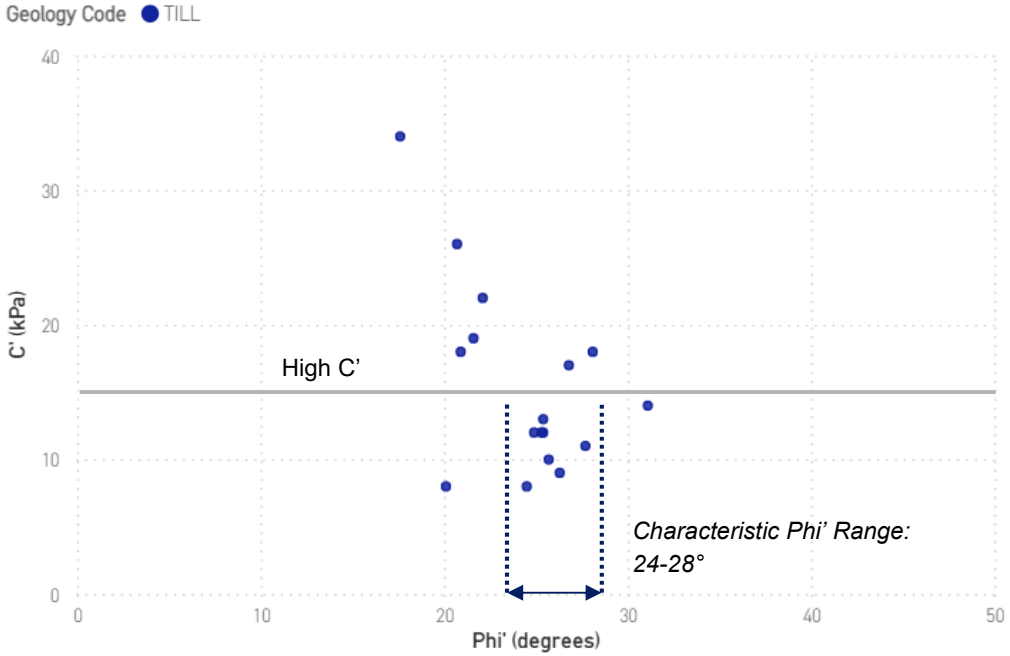


Figure 5-10 Consolidated Undrained Triaxial Results – Cohesion (c') vs Angle of Shearing Resistance (Phi)

5.2.22 Eleven small shear box (direct shear) tests were performed on six samples of MG – PFA and on five samples of TILL. A summary of the results is presented in the table and figure below.

Table 5-13 Shear Box Test Results in MG - PFA & TILL

Geology	C'$_{peak}$ (Kpa)	Φ'$_{peak}$ (°)	C'$_{res}$ (Kpa)	Φ'$_{res}$ (°)
MG - PFA	2 - 25	26 - 35	1 - 25	21 - 33
TILL	7 - 24	20 - 28	2 - 10	18.5 - 23

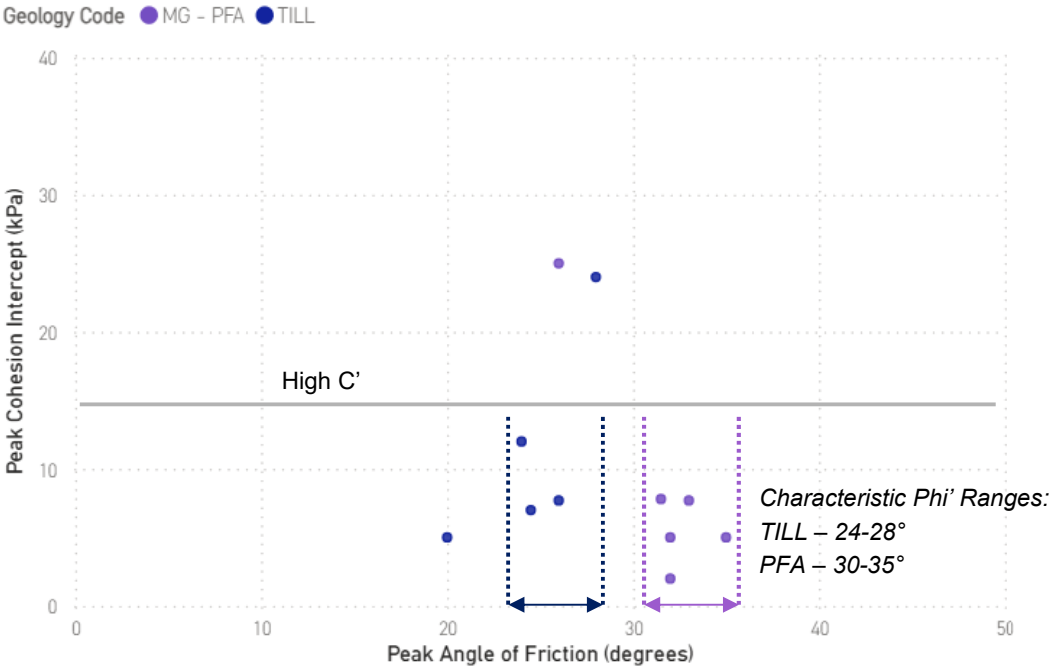


Figure 5-11 Shear Box Test Results – Peak Cohesion Intercept (c') vs Peak Angle of Shearing Resistance (Phi')

5.2.23 With respect to the samples of TILL, the true effective angle of friction is most likely in the range of 24 to 28° and for the samples of PFA in the range of 30 to 35°. The results from the consolidated undrained triaxial tests and the peak strength results of the shear box testing are comparable, however due to the effects that the fabric and composition of glacial tills have on the interpreted effective strength parameters from consolidated tests, c' is typically over estimated and phi' can be underestimated, hence plotted c'-phi' points with high c' (>15kPa) are unlikely to representative of the true effective shear strength.

5.2.24 Furthermore with respect to the TILL, the Phi' range of 24-28°is likely most representative of the true critical state effective stress parameters, considering the following:

- **Consistency**: The phi' values in this range show better clustering with low c', which aligns with critical state theory (where c' is often small or negligible.
- **Physical Meaning**: Higher c' values may reflect pre-consolidation effects or weak cementation, which are not part of the critical state but rather indicative of the soil's structure or stress history.
- **Critical State Behaviour**: At critical state, the soil's behaviour is dominated by the frictional component (phi') rather than cohesion (c'), especially for clays or clayey glacial tills.

5.2.25 Two large 300mm shear box tests (Specification for Highway Works Clause 636 Part 4 [25] - PFA Test Procedure) were undertaken on two composite samples of MG – PFA:

- PFACOMP-501 - ; TP501-1.6m, TP503-3.0m., TP506-0.6m and TP510-4.4m; and
- PFACOMP-502 – TP502-2.0m, TP 504-0.9m, TP505-4.2m and TP507-2.7m.

5.2.26 Peak effective cohesion values or 5 and 6kPa and angle of shearing resistance values of 29.5 and 32.5° were recorded respectively.

Consolidation (Oedometer)

5.2.27 One-dimensional Consolidation (oedometer) testing was undertaken on twenty-three samples in total: one in the MG – C (in BH511 at 2.5m bgl) and twenty-two in the TILL. The consolidation curves are presented together below in Figure 5-12 showing the relationship between the void ratio and the applied effective stress.

5.2.28 The oedometer tests were primarily conducted to assess the compressibility and consolidation characteristics of the Glacial Till at the site. They may also aid in the assessment of potential rebound behaviour of the soil under significant unloading conditions such as the removal of the PFA stockpiles in future development.

5.2.29 There are two apparent groupings to consolidation curves when they are all plotted on the same stress-void ratio chart: a grouping with higher initial void ratios (and higher natural water content) which are generally samples from less than 5m depth and samples with lower initial voids ratios which are generally samples from greater than 5m depth.

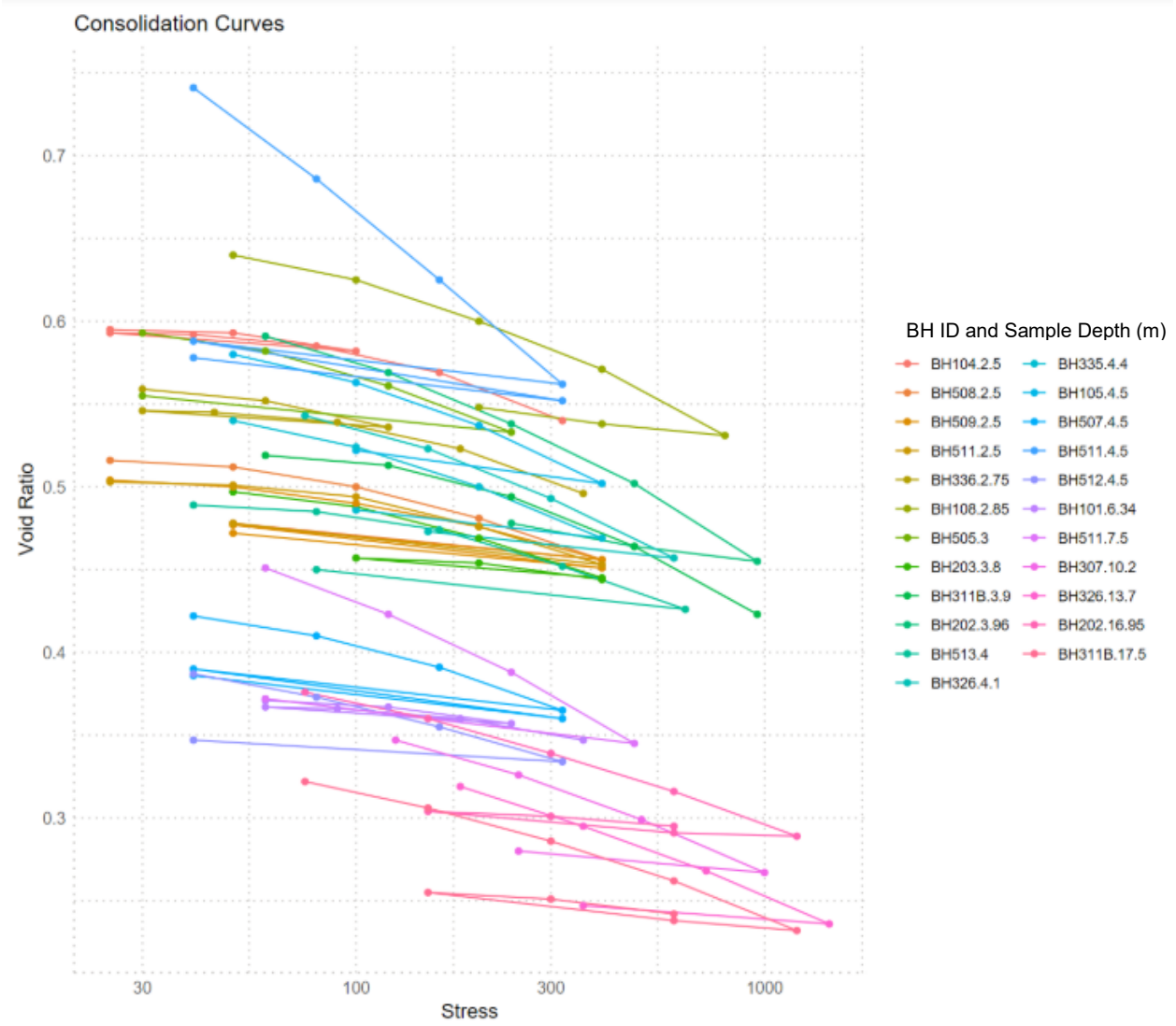


Figure 5-12 Summary of consolidation curves from oedometer testing.

5.2.30 The Compression Index (Cc), Recompression Index (Cr), and Unloading/Swell Index (CRu) have been calculated for each pressure stage of all oedometer tests using the general formula [$Cc = (e_1 - e_2) / (\log(\sigma_2) - \log(\sigma_1))$] taken from Craig's soil mechanics [26]. Cr and Cru a calculated with the same formula however Cr specially relates to the re-loading portion of the oedometer curve up to the pre-consolidation pressure and any reloading stage following and unloading stage, CRu relates to unloading stages and Cc is the virgin compression during loading stages beyond the pre-consolidation pressure.

5.2.31 In order to differentiate between Cc and Cr, the pre-consolidation pressure for each sample has been estimated using an approximate OCR of 5 for samples taken from depths of <6m and an approximate OCR of 2 for samples taken from depths >6m (refer to Figure 5-9), together with a groundwater depth of 9m (Section 4.3 Hydrogeology) in order to estimate in-situ effective overburden pressure.

5.2.32 A summary of the calculated compression indices from oedometer tests is presented in the following table:

Table 5-14 Summary of Compression Indices from Oedometer Testing Results

Geology	Cc			CR			CRu		
	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median
MG - C	0.076	0.076	0.076	0.007 – 0.060	0.030	0.023	0.028	0.028	0.028
TILL	0.043 – 0.156	0.099	0.096	0.005 – 0.209	0.056	0.053	0.007 – 0.047	0.025	0.024

5.2.33 The compression indices are also plotted on the chart below versus pressure stage end stress (log scale). Cc values are calculated above estimated pre-consolidation pressures of 320kPa and range between 0.043 and 0.156 with a mean (characteristic) value of 0.099 appropriate for the TILL. There is much greater variability in the range of Cr values as Cr is not constant when reloading samples up to pre-consolidation pressures (i.e. it is a curve on the Void Ratio-Log P' oedometer plots). A mean (characteristic) value of Cru for the TILL is 0.025.

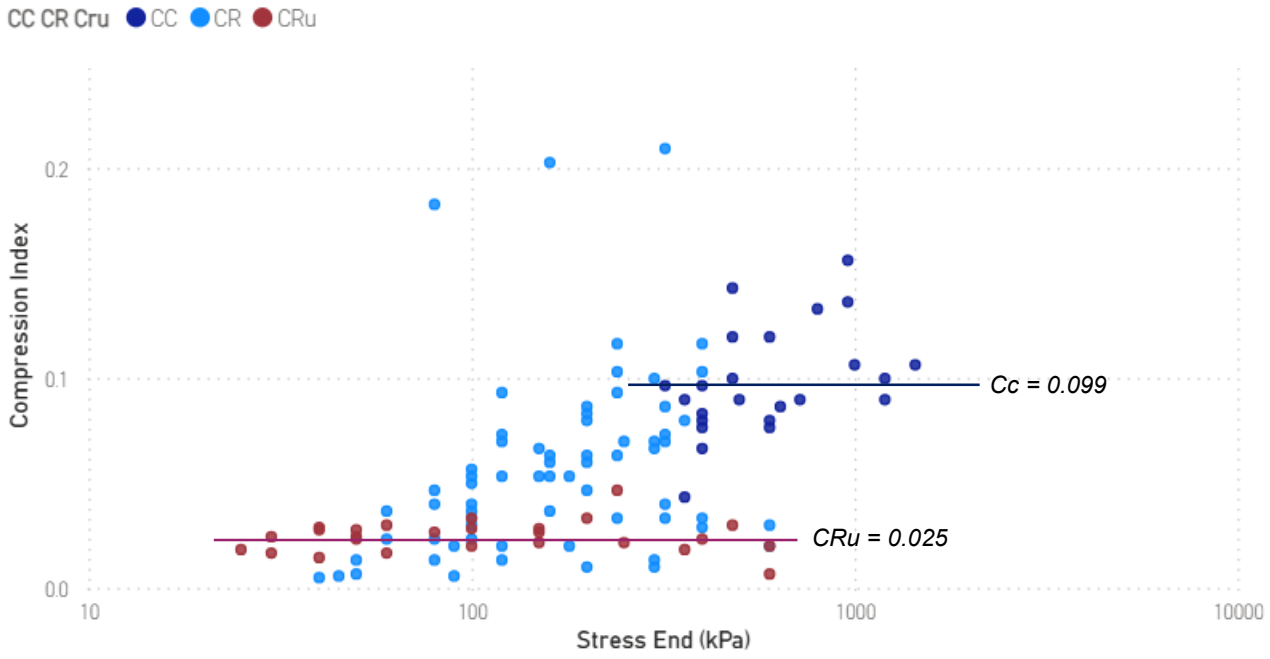


Figure 5-13 Compression Indices (CC, CR & CRu) vs End Stress (log scale)

Recompacted CBR

5.2.34 Recompacted CBR testing was carried out on sixty samples. Samples were recompacted at either received moisture content or OMC using a mixture of standard 2.5kg and modified 4.5kg proctor compaction. Selected samples were either unsoaked or soaked with a subset of the soaked tests on MG - PFA prepped with addition of 1 or 2% cement binder.

5.2.35 PFA samples prepped with cement binder and one sample of MG – BS50 (TP407 0.4-0.5m) were soaked for a non-standard period of 28days.

5.2.36 A summary of the results (averages of top and bottom of sample) by geological unit is presented in the table below:

Table 5-15 Summary of Lab CBR testing

Geology (code) / Binder	Soaked			Unsoaked		
	Test Count	Range of CBR (%)		Test Count	Range of CBR (%)	
		NMC	OMC		NMC	OMC
AL – ORG	-	-	-	2	1.85 – 3.85	-
MG – BS50	5	14.00 – 40.50	8.40 – 21.00	2	9.45 – 42.50	-
MG – C	1	0.50	-	6	1.35 – 22.50	8.25 – 11.50
MG – G	3	3.75 – 14.50		2	1.05 – 52.00	
MG – PFA	9	3.15	4.90 – 12.0	23	2.65 – 52.00	25.50 – 45.00
TILL	5	2.90 – 8.80	3.55	2	1.55	9.80
MG – PFA with 1% Cement Binder	3	-	8.00 – 20.0	-	-	-
MG – PFA with 2% Cement Binder	3	-	14.00 – 20.50	-	-	-

5.2.37 The above summary demonstrates a wide variation in CBR value across and within all geology/material types. For cohesive soils and PFA, samples recompacted at OMC typically produce higher CBR values.

5.2.38 Furthermore with regards cohesive soils and PFA there is a reasonably strong trend of decreasing CBR values with increasing moisture content (as would be expected) and as demonstrated in Figure 5-14.

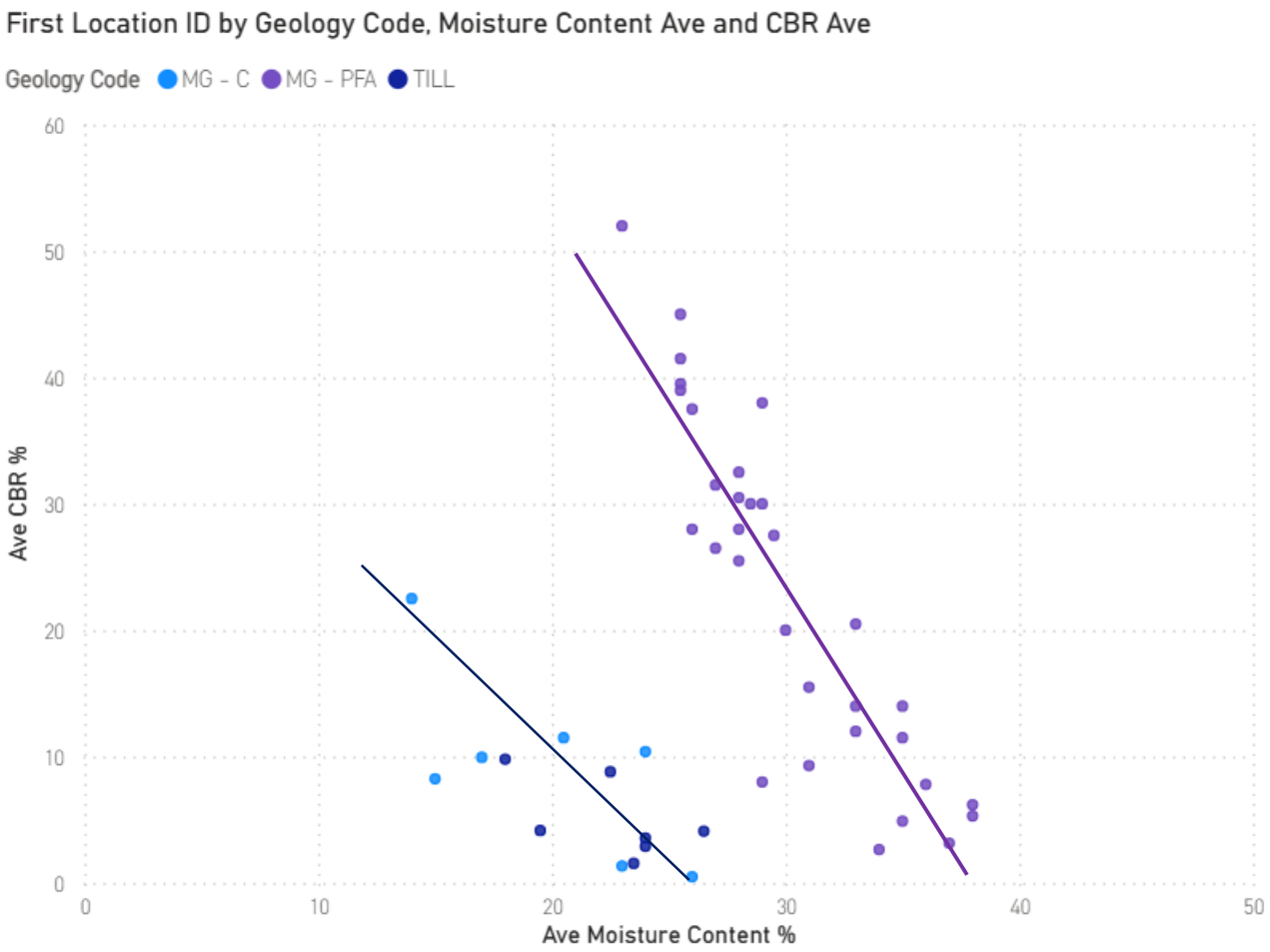


Figure 5-14 Plot of Laboratory CBR (average of Top and Bottom readings) vs Moisture Content (average of Top and Bottom readings) with characteristic trend lines.

Moisture Condition Value / Calibrations

5.2.39 Moisture Condition Calibrations were undertaken on forty-one samples and an additional 12 moisture condition values (i.e. outside of the calibration tests) were recorded for samples at natural moisture content.

5.2.40 The results from the MCV tests and compaction tests have been combined to produce the following table which summarises the available MCV points that are at OMC from the compaction curves.

Table 5-16 Summary of MCV values at OMC

Geology (code)	Sample Count	Optimum Moisture Content Range (%)	MCV Range (%)
AL – ORG	1	28	8.8
MG – BS50	1	18	8.9
MG – C	3	17 – 21	8.4 – 12.00
MG – G	1	23	11.1
MG – PFA	8	25 – 35	10.4 – 20.0
TILL	4	18 – 21	9.5 – 10.3

5.2.41 MCV tests were undertaken on six modified samples of PFA; three with 1% cement binder and three with 2% cement binder. The results were as follows:

- MCV (1% binder): 5.9 – 8.7%
- MCV (2% binder): 8.5 – 20.0%

Los Angeles Coefficient

5.2.42 Los Angeles Abrasion testing has been undertaken on eight samples of MG – G between depths of 0.30 1.70m bgl. Aggregates with LA Coefficients below 30% are generally considered high-quality, durable materials suitable for use in applications such as road base, concrete, or other structural loads. Aggregates with LA Coefficients above 40% are typically considered less durable, and their use might be restricted to lower-stress applications or non-structural purposes.

5.2.43 The results ranged from 18 to 42%, indicating a range of variable durability, with some samples being relatively resistant to wear (18%) and others being less resistant (42%). The wide range of LA Coefficient values (18% to 42%) suggests that Granular Made Ground varies significantly in composition and quality.

Rock Testing

5.2.44 Uniaxial compressive Strength (UCS) testing was undertaken on ninety-six core samples in total, with ninety-four within the PMCMs and two within the TILL. A summary of the failure strengths is presented below in Table 5-17.

Table 5-17 Summary of UCS Testing

Geology (code)	Test Count	Range of UCS (MPa)	Mean UCS (MPa)
PMCM - MDST	12	0.38 – 23.30	7.61
PMCM - SLT	9	5.89 – 31.00	17.57
PMCM - SST	73	0.93 – 88.90	29.03
TILL	2	0.76 – 1.00	0.88

5.2.45 Point load testing was undertaken on two hundred forty-one samples of PMCMs (one hundred fifty-five axial tests and eighty-six diametral tests). A summary of the point load strengths (as I_{s50} values, corrected for a reference diameter of 50mm) is presented in the Table 5-18 below.

- $I_{s50}=I_s\times(50/D)^{\alpha}$, where α = 0.5 adopted from ISRM guidance (1985) [27]

Table 5-18 Summary of Point Load Testing

Geology (code)	Test No.	Axial Samples		Diametral Samples	
		(I_{s50}) Range	(I_{s50}) Mean	(I_{s50}) Range	(I_{s50}) Mean
PMCM - MDST	78	0.05 – 2.25	0.53	0.01 – 0.69	0.19
PMCM - SLT	27	0.10 – 1.48	0.67	0.10 – 0.34	0.21
PMCM - SST	134	0.14 – 1.48	0.67	0.03 – 5.28	0.84
PMCM - COAL	2	0.74	0.74	0.29	0.29

5.2.46 An empirical relation between I_s and UCS allows UCS to be estimated from point load test results and to allow a combined rock strength dataset. The formula of UCS=k x I_{s50} is used where k = 24 which is typically used for most rocks [27]. The UCS values directly measured and estimated from axial point load tests are displayed below in Figure 5-15.

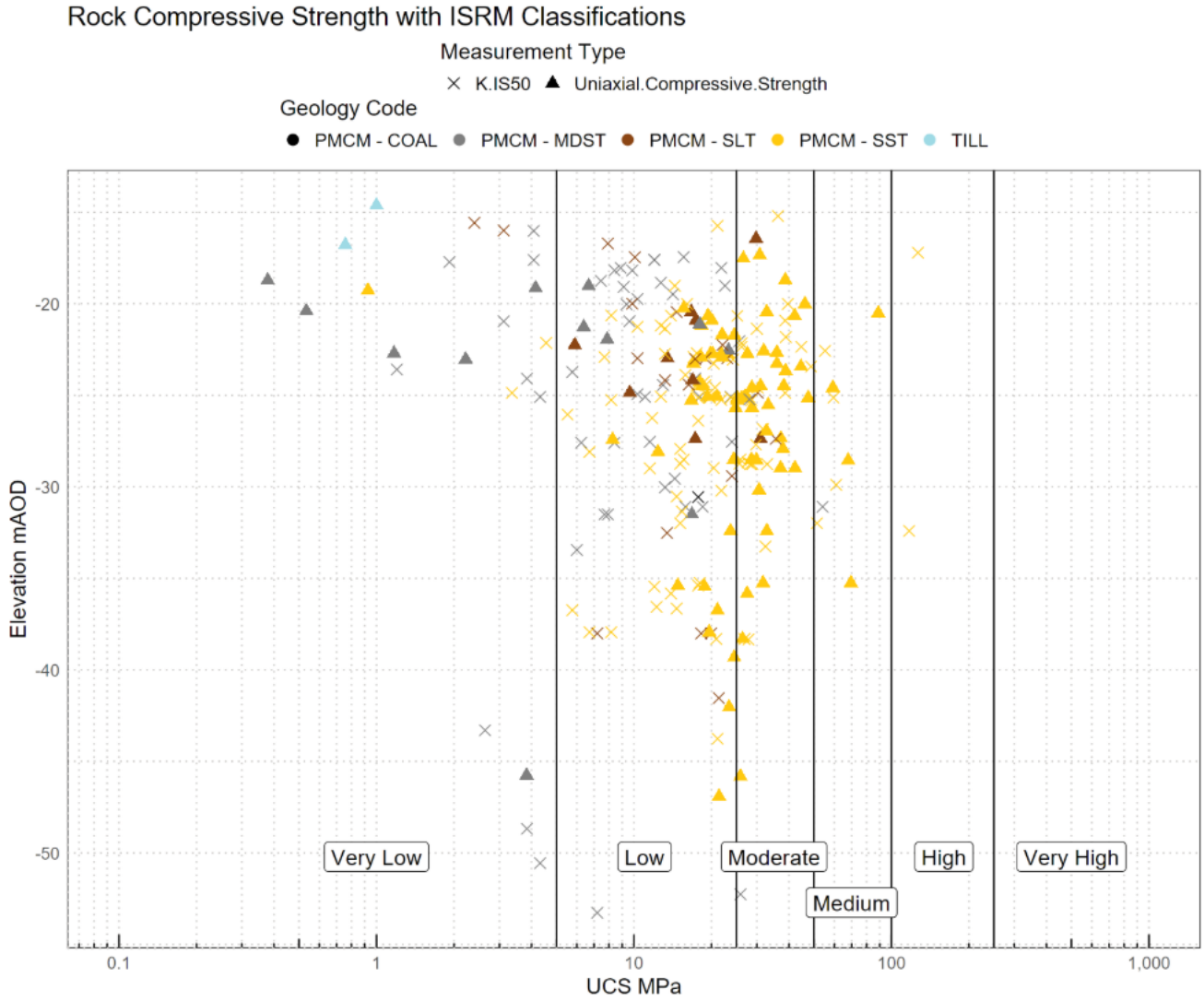


Figure 5-15 Uniaxial Compressive Strength (MPa) by Geology with ISRM Classifications [from UCS and Axial Point Load Tests] vs Depth

5.2.47 The strength classifications for the measured rock types are presented in the above figure with the combined results for each rock type predominantly falling into the following classifications:

- Coal – Low
- Mudstone – Very Low to Moderate
- Siltstone – Very Low to Moderate
- Sandstone – Low to Medium
- Till – Very Low

5.2.48 A summary of rock sample density and natural water content, based on ninety-six samples is summarised in the following table by geology and rock type.

Table 5-19 Summary of Rock Density and Natural Water Content

Geology (code)	Test No.	Bulk Density Mg/m^3	Dry Density Mg/m^3	Natural Water Content %
TILL	2	2.11 – 2.28	1.88 – 2.11	7.9 – 12.0
PMCM - MDST	12	2.28 – 2.57	2.04 – 2.48	3.3 – 14.0
PMCM - SLT	9	2.34 – 2.75	2.12 – 2.66	3.1 – 11.0
PMCM - SST	73	2.25 – 2.76	2.05 – 2.73	0.9 – 11.0

PFA Material Testing

5.2.49 A suite of BS EN 450 material testing was undertaken on eight samples of PFA from the mounds to provisionally assess conformity of physical and chemical properties with the specification. The results of the testing have been compared to BS EN 450 characteristic values [28], although the statistical conformity tests outlined in the specification have not been implemented as there are an insufficient number of samples in the provisional testing. Nevertheless, the comparison of single result values with the characteristic values (summarised in the table below) remains conservative.

Table 5-20 Summary of BS EN 450 Testing

Test	Limit	Range	No. of failed samples
Loss on Ignition (LOI)	Cat A ≤5% mass Cat B ≤7% mass Cat C ≤9% mass	7.93 – 11.70%	Cat A: **8** Cat B:**8** Cat C:**5**
Fineness - >0.	Cat N: ≤40% mass (≤±10% variation) Cat S: 12%	35.6 – 56.3%	**6** (5 vary by more than 10% from the mean)
Free Calcium Oxide	≤1.5% mass	0.01 – 0.40%	0
Chloride	≤0.1% mass	<0.01%	0
Sulphate Content	≤3.0% mass	0.37 – 0.84%	0
Particle Density	kg/m^3 - Variation of <± 200 kg/m^3 from declared value	2210 - 2317	0 (assuming declared value in the measured range)
Activity Index - 28 day	≥75%	71 – 78%	**1**
Activity Index - 90 day	≥85%	86 – 92%	0

5.2.50 Based on the above results, the PFA would not meet the requirements of BS EN 450 based on LOI and Fineness. One sample failed the 28 day activity index test however this value (71%) may be an outlier and would pass the “single result value” of ≥70% specified in BS EN 450.

5.2.51 Accelerated Swell Tests were undertaken on two composite samples of PFA:

- PFA-COMP503 –TP502 0.6-0.7m + TP504 1.9-2.0m
- PFA-COMP504 – TP507 2.0-2.1m + TP512 0.9-1.0m

5.2.52 Two sub samples were prepared from each sample with 1 or 2 % cement binder mixes. Swelling (percentage expansion) was measured after an initial 4-day cure and a final 7-day cure. Three of the four specimens were disrupted and unable to test at the 7-day stage. A UCS test was also undertaken at the final cure. A summary of results is presented below, and the full results are presented in Appendix F.

Table 5-21 Summary of PFA Accelerated Swell Tests

	4 Day Cure Average Initial Expansion (%)		7 Day Cure Average Final Expansion (%)		7 Day Cure Average UCS (N/mm²)	
Sample	Comparator	Accel. Swell Test	Comparator	Accel. Swell Test	Comparator	Accel. Swell Test
PFA-COMP503 1% Cement binder	0.0	0.3	0.6	¥	0.198	¥
PFA-COMP503 2% Cement binder	-1.1	-0.8	-0.4	-0.9	0.298	0.381
PFA-COMP504 1% Cement binder	-0.4	-0.5	0.7	¥	0.201	¥
PFA-COMP504 2% Cement binder	-1.1	0.6	1.9	¥	0.314	¥

¥ Sample disrupted/collapsed and was unable to be tested

5.3 Preliminary Geotechnical Characteristic Parameters

5.3.1 The following table presents preliminary characteristic geotechnical parameters determined for each stratum including reference to the relevant source data, method of derivation, any empirical relationships utilised for each parameter and/or published sources.

5.3.2 The parameters are frequently provided as a characteristic range rather than a singular value. This reflects the variability in the soil strata (composition, density, stress history, stiffness etc) and also factors variations with depth within the geological profile.

Table 5-22 Summary of Interpreted Characteristic Geotechnical Parameters

Parameter	Symbol Unit	Made Ground (MG)				Superficial Deposits			Bedrock (PMCM)		
		Cohesive (MG-C)	Granular (MG-G)	PFA (MG–PFA)	Burnt Shale (MG-BS50)	Alluvium (AL-ORG)	Glacial Channel Deposits (G-CD)	Glacial Till (TILL)	Mudstone (PMCM-MDST)	Siltstone (PMCM-SLT)	Sandstone (PMCM-SST)
Unit weight above water[1]	γ_d, kN/m³	18-21 [1]	17-21 [1]	13-15 [1]	17-22 [1]	17-20 [1]	17-20 [2]	22-23 [1]	23-26 [1]	21-26 [1]	20-27 [1]
Unit weight below water[1]	γ, kN/m³	18-21 [1]	17-21 [1]	-	17-22 [1]	17-20 [1]	18-22 [2]	22-23 [1]	23-26 [1]	21-26 [1]	20-27 [1]
Plasticity Index	P_I	22[1]	NP	23[1]	22[1]^	20-40[1]	NP	25[1]	NP	NP	NP
Undrained shear strength	C_u, kPa	δCu/δz = 30kPa/m (max. 125kPa) [3]	-	-	-	20-40kPa[4]	-	Cu0 + δCu/δz = 40 + 5kPa/m [3]	500-5,000 [5]	3,000-15,000 [5]	4,000-30,000 [5]
Constant Volume Effective Angle of Shearing Resistance [3]	ϕc_v, (°)	22-28 [6]	36-40 [6]	26-32 [6#]	32-36 [6#]	21-25 [6]	32-36 [6]	24-28 [7]	-	-	-
Peak Angle of Shearing Resistance [3]	$\phi_{p'}$ (°)	ϕc_v, [8]	ϕc_v, [8]	ϕc_v, [8]	ϕc_v, [8]	ϕc_v, [8]	ϕc_v, [8]	ϕc_v, [8]	-	-	-
Peak Effective Cohesion	C', kPa	0 [9]	0 [9]	0 [9]	0 [9]	0 [9]	0 [9]	0 [9*]	-	-	-
OCR	-	-	-	-	-	1-1.5 [10]	5-10 (<5m), 2-5 (>5m) [11]		-	-	-
Undrained Poisson's Ratio	v_u	0.3-0.45 [12]	FD	0.3-0.45 [12]	0.3-0.45 [12]	0.3-0.45 [12]	FD	0.3-0.45 [12]	-	-	-
Drained Poisson's Ratio	v'	0.15-0.40 [12]	0.15-0.3	0.2-0.35 [12]	0.2-0.35 [12]	0.2-0.4 [12]	0.1-0.3 [12]	0.1-0.3 [12]	-	-	-
Small Strain Shear Modulus	G0, MPa	-	-	-	-	-	-	50-200 [13]	-	-	-
Undrained Young's Modulus (0.5% strain)	Eu, MPa	3 [14]	-	-	-	0.5-1 [14]	-	24-95 [15]	-	-	-
Drained Young's Modulus (0.5% strain)	Ed, MPa	-	95 [14]	-	95 [14]	-	135 [14]	20-80 [15]	-	-	-
Constrained Modulus	M, MPA							20-40 [13]			
Compression Index	Cc	0.2-0.4 [16]	-	-	-	0.3-0.5 [16]	-	0.08-0.15 [17]	-	-	-
Compression Index (unloading)	CRu	0.04-0.08 [18]	-	-	-	0.06-0.10 [18]	-	0.01-0.03 [17]	-	-	-
Optimum Moisture Content	OMC, %	14-24 [1]	6-27 [1]	25-35 [1]	14-18 [1]	21-28 [1]	No data	14-21 [1]	-	-	-
MCV at OMC	MCV_{OMC}, %	8-12 [1]	11 [1]	10-20 [1]	No data	9 [1]	No data	10 [1]	-	-	-
Recomp. CBR at OMC	CBR_{OMC}, %	4-10 [1]	No data	10-30 [1]	No data	<2 [1]	No data	4-10 [1]	-	-	-

1 Lab test data.

2 Estimate from BS8002 typical unit weights above and below water table.

3 CPT and Lab QUT Correlations

4 Estimate based on soil consistency descriptions (Soft to Firm)

5 UCS lab results. Cu = UCS/2

6 Estimate using methods set out in BS8002 using PSD gradings and relative density for granular soils and PI for fine soils.

7 Interpreted range based on CUM test results

8 $\phi_{p'}$ (°) = ϕc_v, (°). 0 dilatancy assumed

9 C'=0. Drained loading conditions allowing pore water pressures to dissipate, and the behaviour of the soil is governed by frictional resistance. The contribution of cohesion (c') to shear strength is negligible

10 Alluvium assumed to be normally consolidated to slightly over-consolidated.

11 Interpreted from undrained strength (measured and estimated) and CPT estimations.

12 Published literature – various sources.

13 CPT profiles

14 Modulus of Elasticity, E (McCarthy, 1998)

15 Based on small strain shear modulus, adjust for 0.5% strain (Hardin and Drnevich, 1972) and calculate E using Poisson ratio.

16 Based on empirical correlation with Liquid Limit. Cc = 0.009 (LL-10)

17 Values calculated from Oedometer curves (Void raito and LogP)

18 CRu = 0.1 to 0.3 x Cc. A factor of 0.2 has been used.

^ Limited samples exhibit plastic behaviour.

Assumes moderate compaction, some moisture but not fully saturated.

* CUM lab results indicate c' = 5-15kPa which may be applicable to short term, peak strength conditions however c'=0 is specified as this remains conservative.

FD Free draining soil

6 Geotechnical Appraisal

6.1 General

6.1.1 For the purposes of planning, the Proposed Development is for the development of a data centre campus comprising up to 10 data centres of Class B8 use totalling up to 540,000 square metres (sqm) gross internal area (GIA), in addition to ancillary structures, substation, emergency generators and other associated works.

6.2 Site Preparation and Earthworks

6.2.1 Prior to construction works any Topsoil, and/or any areas of particularly poor-quality Made Ground should be removed beneath proposed buildings and hardstanding areas, to facilitate construction. This should be complicit with any required remediation measures detailed in the Arcadis 2024, Outline Remediation Statement, Planning Document Ref: 4.12. [29].

6.2.2 All earthworks should be undertaken in accordance with a materials management plan (MMP) and an asbestos management plan in line with findings of the geoenvironmental assessment [4].

6.2.3 At the time of writing, it is assumed an earthworks programme will be required to establish the development platform for the site. The breaking out of current surface hardstanding will be required and general turnover or removal of shallow Made Ground may be required but can be undertaken on a risk-based approach. Concrete and masonry should be crushed to a suitable grading (e.g., 6F2) for re-use in the development (e.g., working platforms, road capping etc).

6.2.4 Excavations formed during demolition activities will require adequate backfilling to a suitable specification to ensure appropriate performance.

6.2.5 Sorting and screening to remove deleterious materials and crushing of oversized items (concrete blocks, blocks of masonry, etc.) should be undertaken where necessary to facilitate and improve the compaction of site-won fill materials during placement. This process may generate material that is unsuitable for re-use (including potentially deleterious materials such as timber) and as such these are likely to require off-site disposal.

6.2.6 Site won granular materials should be used preferentially in areas beneath proposed structures to reduce the effects of long-term settlement. site won cohesive materials would be used as general fill (in landscape areas for example) where settlement is less critical.

6.2.7 Ground conditions should be capable of excavation using traditional hydraulic plant. However, sides may become unstable, particularly where groundwater is encountered in the Made Ground or granular superficial deposits, and allowance should be made for battering excavations at a suitable angle. site trials could be undertaken to confirm the appropriate angles of slope batter.

Obstructions

6.2.8 The obstructions encountered during the ground investigation are detailed within section 4.2 and are presented on the plan in **Appendix B**. In summary, widespread concrete and macadam hardstanding is present across the site with frequent buried concrete slabs and concrete lined channels and ducts, also present.

6.2.9 It should be noted that in a previous desk study produced for the site by Parsons Brinkerhoff [17] reference was made to the presence of possible tunnels on the site, although the route and location of these was not clear. Limited investigation was undertaken by Arcadis in the suspected areas of the tunnels, but no evidence to confirm their presence was identified.

6.2.10 It is likely that additional in-ground obstructions within the Made Ground across the site are likely considering the site's history, including relic services or infrastructure.

6.3 Foundations and Floor Slabs

6.3.1 The proposed development comprises a data centre campus comprising up to ten data centres of Class B8 use totalling up to 540,000 square metres (sqm) gross internal area (GIA).

6.3.2 In addition, the development will include ancillary structures, substation, emergency generators and other associated works.

6.3.3 Data centre buildings will be of steel framed construction. Main supporting column loads are expected to be between 1800 – 2400 kips (8000 - 10675 kN). Foundation loads for other ancillary equipment are expected to be between 150 – 200 kips (670 – 890 kN).

6.3.4 Serviceability limit state requirements are not known at the time of writing. However, it is anticipated that allowable total and differential settlement will be less than 25mm.

6.3.5 Foundations should be designed by a geotechnical specialist based on the finalised layout and knowledge of the magnitude and distribution of structural loads. The following sections are intended as high-level, generic guidance only.

6.3.6 Existing Made Ground and alluvium are not considered suitable to support new structures due to the risk of unacceptable total and differential settlement.

6.3.7 Shallow foundations bearing onto the TILL may be suitable to support small, lightly loaded structures subject to assessment of ultimate limit state (ULS) and serviceability limit state (SLS) requirements.

6.3.8 However, based on the expected column loads, it is unlikely that shallow foundations will be feasible for the proposed data centres. Piled foundations are therefore anticipated. Detailed design should be considered by a specialist pile designer. While a wide range of driven and bored piles may be suitable in the ground conditions proven, continuous flight auger (CFA) piles, taken through the Made Ground and TILL, and socketed into the PMCM, are anticipated to be one possible solution for anticipated column loads.

6.3.9 Driven pre-cast concrete piles, driven into the TILL are unlikely to be sufficient to support the higher anticipated column loads, but may be viable to support lower column loads.

6.3.10 To provide a level development plateau, some cutting/filling is expected. It is likely that floor slabs will span materials of varying engineering behaviour and may result in unacceptable amounts of differential settlement.

6.3.11 It is therefore anticipated that floor slabs will need to be suspended. Driven pre-cast concrete piles may be suitable to support floor slabs. Alternatively, ground improvement (e.g. by the application of vibro-stone columns) may be feasible to reduce the anticipated total and differential settlement below floor slabs.

6.3.12 For small structures which are not sensitive to settlement, and which are underlain by less than 600mm of non-engineered Made Ground, ground bearing floor slabs may be feasible.

6.4 Pavement Design

6.4.1 Plate load testing was undertaken in twenty-six locations The testing was undertaken in shallow trial pits to a maximum depth of 0.5m bgl, on MG-G. The CBR results ranged from 0 – 279% and a modulus of subgrade reaction from 10 to 375 MPa. Full test results are included in the Stage 1 factual report [2].

6.4.2 It is a suggested a minimum subgrade surface modulus value of 30 mPa or 2.5% CBR is required for a for new pavement design [30].

6.4.3 Five of the twenty-six samples fall below the recommended 2.5% CBR value and subgrade surface modulus value of 30 mPa which indicate soft zones are present within the variable Made Ground.

6.4.4 Where soft spots are found, they will likely require excavating and replacing between 500 and 1000mm of the soft subgrade with granular fill but in-situ compaction may be suitable for free draining materials.

6.4.5 Although the testing was undertaken in the shallow granular Made Ground, if the surface level is reduced, formation level may be within the shallow Glacial Till. In any case the design value will need to be reviewed and confirmed by suitable in-situ testing at formation levels following earthwork operations and prior to pavement construction.

6.5 Concrete Classification

The geotechnical chemical data analysis for each geological layer is presented within Table 6-1 below where characteristic values have been calculated according to BRE Special Digest 1: 2005 “Concrete in aggressive ground” guidance [31]. The interpretation of this data and summary of the assessment for all geological layers is presented in Table 6-2. The assessment was undertaken for brownfield site with pyrite and a mobile groundwater regime for a 100 year design life.

Table 6-1 Summary of Testing and Characteristic Values for Geotechnical Chemical Data

Geology (code)	pH		Total Potential sulfate (%)		Water soluble sulphate (in 2:1 extract) (mg/l)		Water soluble magnesium (in 2:1 extract) (mg/l)	
	Count	Characteristic value	Count	Characteristic value	Count	Characteristic value	Count	Characteristic value
MG-C	46	8.55	14	1.04	14	954.67	9	29.00
MG-G	53	11.13	19	1.88	19	1282.50	3	270.00
MG-BS50	16	8.51	11	3.39	11	935.67	4	54.50
MG-PFA	55	10.65	33	1.17	33	1882.86	21	51.20
AL-ORG	10	8.05	8	0.51	8	1500	5	30.00
G-CD	1	7.40	1	0.09	1	86.00	1	14.00
TILL	87	8.62	69	1.59	78	430.00	69	42.86
PMCM-MDST	15	9.03	15	7.75	15	226.67	14	24.33

Geology (code)	pH		Total Potential sulfate (%)		Water soluble sulphate (in 2:1 extract) (mg/l)		Water soluble magnesium (in 2:1 extract) (mg/l)	
	Count	Characteristic value	Count	Characteristic value	Count	Characteristic value	Count	Characteristic value
PMCM-SLT	6	9.20	6	0.54	6	210.00	6	21.00
PMCM-SST	31	8.70	24	1.07	31	162.86	25	38.80
PMCM-COAL	8	8.71	7	20.85	8	1300.00	5	73.00

Table 6-2 Summary of Design Sulphate and Aggressive Chemical Environment for Concrete

Strata	Geology Code	Design Sulphate Class (DS)	Aggressive Chemical Environment for Concrete (ACEC) classification**	ACEC classification Table D1
Made Ground	MG-C	DS-3	AC-3	DC-3 + one APM* of choice
	MG-G	DS-4	AC-4	DC-4 + one APM* of choice
	MG-BS50	DS-5	AC-5	DC-4 + APM3***
	MG-PFA	DS-3	AC-3	DC-3 + one APM* of choice
Superficial Deposits	AL-ORG	DS-2	AC-2	DC-2
	G-CD	DS-1	AC-1	DC-1
	TILL	DS-4	AC-4	DC-4 + one APM* of choice
Pennine Middle Coal Measures	PMCM-MDST	DS-5	AC-5	DC-4 + APM3***
	PMCM-SLT	DS-2	AC-2	DC-2
	PMCM-SST	DS-3	AC-3	DC-3 + one APM* of choice
	PMCM-COAL	DS-5	AC-5	DC-4 + APM3***

* APM additional protection measure as defined in BRE SD1.
** DS and ACEC class include results derived from calculation of Total Potential Sulphate.
***APM3 provide surface protection

6.5.1 The above DS and ACEC classifications are based on both water soluble sulphate/pH and total potential sulphate (calculated as 3 x Total Sulphur). However, where concrete is placed within pyritic ground but is initially low in soluble sulphate, concrete does not have to be designed to withstand high potential sulphate class unless it is exposed to ground which has been disturbed to the extent that contained pyrite may oxidise. Examples of foundation solutions with reduce ground disturbance include use of pre-cast or cast insitu piles.

6.6 PFA

Unloading of Stockpiles

6.6.1 The potential rebound of the ground beneath the large PFA stockpiles after their removal has been estimated based on the compression index for unloading CRu of the underlying Glacial Till and the applied stresses. The stockpiles, with a height of up to 17 m and a bulk unit weight of approximately 15kN/m³, exert a maximum vertical stress of 255 kPa on the ground.

6.6.2 The superficial soils beneath the stockpiles are approximately 20m thick, the majority of which is Glacial Till for which a bulk density of 22kN/m³ and a CRu value of 0.025 has been determined from laboratory tests.

6.6.3 The estimated rebound settlement was calculated using the following formula.

$$Estimated\ Rebound = \sum_{i=1}^{n} \Delta h_i$$

$$\Delta h = C_{ru} \cdot H \cdot \log_{10}(\sigma_1/\sigma_2)$$

6.6.4 Substituting the relevant parameters, the potential rebound is estimated to be approximately 225mm. This value provides an indication of the elastic recovery of the ground once the loading is removed and may vary depending on local soil conditions and other site-specific factors. Given that the majority of the rebound will be elastic and therefore gradually occur as the stockpile is excavated and removed, any post construction rebound is expected to be minimal.

Material Reuse

6.6.5 As summarised in 5.2.47, eight composite samples of PFA were subject to material testing of chemical and physical properties in line with BS EN450 for suitability of use within concrete. All eight samples failed for LOI exceedances and six of eight failed for fineness and one failed for the 28-day activity index test. Therefore, the indicative results suggest the PFA may not be suitable for use in its current condition for use within concrete. Further testing may be undertaken to assess suitability after further processing of the PFA, removing any material that is of a more variable nature that has been added to stockpiles or heavily degraded material from weathering.

6.7 Excavations and Groundwater

6.7.1 During the Arcadis investigation and groundwater monitoring shallow perched water within the Made Ground was identified above the contact with the underlying Glacial Till. With the Glacial Till, water is indicated to be hosted within discrete granular layers within the Glacial Till.

6.7.2 Any excavations within the Made Ground and shallow deposits will likely encounter perched water and excavation below the groundwater table will require dewatering particularly the deep excavations for the proposed shafts.

6.7.3 Groundwater control measures could take the form of local dewatering either by the construction of perimeter drains and sump pumping, or well point/ deep well dewatering. Guidance for dewatering requirements can be taken from CIRIA Report C515 [32]. However, a detailed assessment of the de-watering requirements including the density and depth of any well points and pumping rates should be undertaken as part of the temporary works design. A specialist dewatering contractor should be consulted once development proposals and permanent works details have been finalised

6.8 Infiltration Drainage

6.8.1 No infiltration testing was performed as part of the Arcadis 2024 ground investigation however, four soakaway tests were undertaken in the Glacial Till in the 2021 Rolton Group Ground Investigation [5] within stiff sandy gravelly clay (Glacial Till) between depths of 1.45m – 3.75m bgl. No infiltration was recorded; therefore, the shallow Glacial Till is not considered feasible to provide natural drainage of stormwater. The overlying Made Ground is also not considered suitable owing to the presence of contaminants and its variable nature.

6.9 Coal Mining Risk

6.9.1 This section should be read in conjunction with the Arcadis Coal Mining Risk Assessment [33].

6.9.2 The Moorland coal seam is mapped to sub crop beneath superficial Glacial Till deposits in the north-western site area, dipping at a shallow angle to the north-west. Deep workings are recorded beneath the site, at a depth of greater than 100m bgl. Ground investigation completed by Arcadis and others, has not identified any mining related voids, however intact coal has been observed at various depths within 100m of the surface.

6.9.3 There is no evidence of shallow underground workings beneath the site, and the risk from historical unrecorded shallow coal mining causing potential surface instability and affecting the proposed development is considered low. Therefore, no mitigation measures are required. However, observations should be maintained during groundworks, and foundation excavations should be certified by an experienced engineer to confirm the absence of unrecorded coal mining features.

Gas Risk

6.9.4 The ground gas assessment undertaken for the site as part of the Arcadis Phase 2 Geoenvironmental Assessment [4], indicated that the gas risk is considered as low. Groundwater level monitoring completed on wells installed within the PMCM indicates groundwater within the bedrock is confined beneath the Glacial Till. The deep mine workings beneath the site therefore appear to be permanently flooded.

6.9.5 No mine entries are recorded within 100m of the site boundary and a significant thickness of cohesive Glacial Till clay is also present across the site which will act as a barrier to mine gas migration. The potential risk to the development associated with mine gas emissions is therefore considered to be low.

6.9.6 Should foundation design for new structures include piling through the Glacial Till, and advancing into the PMCM, consideration and assessment should be completed to understand if this will create any preferential pathways for gas migration. This assessment should be completed as part of any geotechnical design or piling risk assessment.

6.9.7 Routine gas monitoring should be undertaken during construction, in any trenches or confined spaces where man entry is required.

7 Geotechnical Risk Register

7.1 Geotechnical Hazards

The following key geotechnical hazards have been identified:

- Variable Made Ground of varying thickness
- Deep coal workings
- Aggressive ground conditions

7.2 Preliminary Risk Register

Table 7 4 presents a geotechnical risk register for the scheme. The risks highlighted in Table 7-4 have been considered following a review of the available data only. These risks shall form the basis of a 'live' risk register document that will be further developed during the project, and maintained for the lifetime of the scheme, updated on every review of geotechnical risks, as undertaken. The risks have been evaluated using the risk classification matrix suggested in CD 622 Managing Geotechnical Risk [34]. The extracts are provided in Table 7-1, Table 7-2, and Table 7-3.

It should be noted that a summary of the geoenvironmental risks has also been included in Table 7 4, however reference should be made to the Arcadis Geoenvironmental report [4] for full details.

Table 7-1 Risk Matrix

Likelihood		Severity				
		1	2	3	4	5
		Minor	Moderate	Serious	Major	Catastrophic
1	Extremely unlikely	1	2	3	4	5
2	Unlikely	2	4	6	8	10
3	Likely	3	6	9	12	15
4	Extremely likely	4	8	12	16	20
5	Almost certain	5	10	15	20	25

Table 7-2 Risk Classification and required actions

Risk Classification	
Low (1-8)	Ensure assumed control measures are maintained and reviewed as necessary.
Medium (9-19)	Additional control measures needed to reduce risk rating to a level that is equivalent to a test of “reasonably required” for
High (20-25)	Activity not permitted. Hazard to be avoided or risk to be reduced to tolerable level.

Table 7-3 Potential severity of harm occurring

Potential severity of harm occurring		
1	Minor	Minor damage or loss – (no human injury)
2	Moderate	Moderate damage or loss – (Slight injury or illness)
3	Serious	Substantial damage or loss – (Serious injury or illness)
4	Major	Major damage or loss (Fatal injury)
5	Catastrophic	Catastrophic loss or damage – (Multiple fatalities)

Table 7-4 Preliminary Geotechnical Risk Register

Risk No.	Hazard Description	Potential Consequences	Risk Before Control			Design Mitigation Measures to Manage the Risk	Risk After Control	Risk Owner		
			S	L	R		S	L	R	
1	Uncertainty on ground conditions and properties - variable ground conditions.	Unexpected variation in ground conditions (e.g., soft spots leading to inadequate design or design change during construction. Total or differential settlements of foundation solutions greater than assessed using current data.	5	3	15	During construction of ancillary structures, the contractor will be required to undertake inspection of foundation levels with testing (e.g., hand shear vanes and plate load testing) to confirm ground conditions and material parameters. The larger data centre units are likely to be unaffected as deeper piles would likely be utilised. Contractor to include information in a Geotechnical Feedback report in the H&S file.	5	1	5	Designer/ Principal Contractor
2	High groundwater	Only perched water is expected in Made Ground and sand and gravel horizons within the Glacial Till. Unable to ingress into excavations. Loss of strength on water ingress. Potential for heave at base of excavations/chambers and swelling pressures and lateral thrust on excavation sides.	5	2	10	Groundwater control measures may be required to enable construction of below ground structures where there is perched water in Made Ground or sand and gravel horizons. During construction, Contractor is required to monitor groundwater level. Conservative groundwater levels considered for the design of geotechnical elements.	3	2	6	Designer/ Principal Contractor

Risk No.	Hazard Description	Potential Consequences	Risk Before Control			Design Mitigation Measures to Manage the Risk	Risk After Control	Risk Owner		
			S	L	R		S	L	R	
3	Unstable excavations	Collapse of excavation leading to safety risk, potential for serious injury or death of construction workers and damage to asset under construction.	4	4	16	Excavation to be designed by appropriate temporary works designer and inspected during progression. Temporary works design to include appropriate excavation support/ restraint or stable side slopes, surface water and groundwater control where appropriate.	4	2	8	Principal Contractor
4	Soft ground	Unacceptable total or differential settlement of foundations. Low CBR values at pavement foundation.	3	3	9	Designer to adopt appropriate parameter values for foundation design. Contractor shall inspect and test pavement subgrade to ensure design CBR value or subgrade modulus is being achieved.	3	2	6	Designer/Principal Contractor
5	Dewatering	Ground subsidence on site or surrounding area due to changes in effective stress in ground or loss of fines during dewatering operations.	4	3	12	Dewatering works to be designed with consideration of potential ground settlement on site and surrounding area, where zone of influence extends beyond site limits. Mitigation measures to be included in dewatering design (e.g., groundwater exclusion). Appropriate instrumentation and monitoring to be undertaken during construction.	4	2	8	Principal Contractor

Risk No.	Hazard Description	Potential Consequences	Risk Before Control			Design Mitigation Measures to Manage the Risk	Risk After Control	Risk Owner		
			S	L	R		S	L	R	
6	Buried services (mapped and unknown)	Damage to existing services, proposed infrastructure or injury or death of construction workers.	5	3	15	Requirements set out in HSE47 are to be complied with prior to breaking ground.	5	1	5	Principal Contractor
7	Potential for aggressive ground conditions	Potentially aggressive conditions for buried concrete and expansive secondary reactions	3	5	15	BRE SD1 analysis indicates that buried concrete can be designed in accordance with class DS-5 ACEC class AC-5 of BRE Special Digest 1(2005), assuming mobile groundwater is present.	3	1	3	Designer
8	Materials Management	Site won materials are likely to be a combination of cohesive/granular Made ground, cohesive superficial deposits with secondary fractions of granular materials. Such materials are susceptible to moisture content changes, where suitability for use will tend to deteriorate with increasing water content. If materials are not managed appropriately, they may be unsuitable for inclusion in the works.	4	4	16	Treatment of unsuitable materials to render them suitable may be required. Alternatively, import of suitable materials due to potential requirement for removal of unsuitable materials off-site. Additional costs would be incurred.	4	2	8	Principal Contractor
9	Contaminated land and unforeseen contamination	Owing to the size and history of the site it is possible unforeseen contamination may be encountered during earthworks.	3	4	12	Contractor should employ safe systems of work if unforeseen contamination is encountered and use appropriate PPE and working methods in line with	2	2	4	Principal Contractor

Risk No.	Hazard Description	Potential Consequences	Risk Before Control			Design Mitigation Measures to Manage the Risk	Risk After Control	Risk Owner		
			S	L	R		S	L	R	
		Asbestos fibres and ACM are known on site in addition to other CoC such as hydrocarbons.				findings of the geoenvironmental assessment.				
10	Hazardous ground gas conditions	A quantitative gas risk assessment has identified a 'low risk' of hazardous ground gas conditions at the site.	5	2	10	Post earthworks gas monitoring will be required as proposed in the outline remediation statement. Gas protection measures may be required based on the additional monitoring.	5	1	5	Designer
11	Slope stability – temporary slopes	Temporary slopes associated with earthwork construction and stockpiling of materials could become unstable.	4	3	12	Temporary slopes to be designed by appropriate temporary works designer and inspected during progression. Temporary works design to include appropriate stable side slopes.	4	2	8	Principal Contractor

8 Summary and Conclusions

8.1.1 This GIR report has updated the previous assessment of ground conditions [1] incorporating both phases of the Arcadis ground investigations. The assessment has presented the updated Leapfrog™ ground model. Across the full site.

8.1.2 Ground conditions were generally found to comprise of variable Made Ground (granular, cohesive, PFA and >50% Burnt Shale) down to depths of up to 4.80m bgl, overlying superficial deposits of Glacial Till. Glacial channel deposits and alluvium were also encountered locally across the site. Pennine Middle Coal Measures underlay the superficial from approximately 18.84m bgl with bands of mudstone, siltstone, sandstone and coal proved to >100m bgl.

8.1.3 The general hydrogeological conditions comprised of shallow perched water within the Made Ground, identified above the contact with the underlying Glacial Till, with water hosted within discrete granular layers within the Glacial Till. Groundwater within the Pennine Middle Coal Measures is generally confined by the predominantly cohesive Glacial Till superficial deposits above.

8.1.4 Geotechnical parameters have been derived based on the available information from historical and the 2024 ground investigation. Geotechnical considerations are discussed within Section 6.

8.1.5 The assessment has shown that deep piles may be required owing the heterogeneity of the Glacial Till and the widespread coverage of variable Made Ground at shallow depths across the site.

8.1.6 An assessment of potential aggressive ground was completed based on laboratory testing results obtained as part of the investigation. The assessment suggests that any concrete that is to be used as part of the development should comply with a AC4-DS4 classification within the Made Ground and superficial classification and AC5-DS5 classification for the bedrock geology owing to the present of oxidisable sulphates.

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10Study Limitations

IMPORTANT. This section should be read before reliance is placed on any of the information, opinions, advice, recommendations or conclusions contained in this report.

1 This report has been prepared by Arcadis (UK) Ltd ('Arcadis'), with all reasonable skill, care and diligence within the terms of the Appointment and with the resources and manpower agreed with Renaissance Land Limited (the 'Client'). Arcadis does not accept responsibility for any matters outside the agreed scope.

2 This report has been prepared for the sole benefit of the Client unless agreed otherwise in writing. otherwise in writing. The contents of this report may not be used or relied upon by any person other than this party without the express written consent and authorisation of Arcadis.

3 Unless stated otherwise, no consultations with authorities or funders or other interested third parties have been carried out. Arcadis is unable to give categorical assurance that the findings will be accepted by these third parties as such bodies may have unpublished, more stringent objectives. Further work may be required by these parties.

4 All work carried out in preparing this report has used, and is based on, Arcadis' professional knowledge and understanding of current relevant legislation. Changes in legislation or regulatory guidance may cause the opinion or advice contained in this report to become inappropriate or incorrect. In giving opinions and advice, pending changes in legislation, of which Arcadis is aware, have been considered. Following delivery of the report, Arcadis has no obligation to advise the Client or any other party of such changes or their repercussions.

5 This report is only valid when used in its entirety. Any information or advice included in the report should not be relied upon until considered in the context of the whole report.

6 Whilst this report and the opinions made are correct to the best of Arcadis' belief, Arcadis cannot guarantee the accuracy or completeness of any information provided by third parties. provided by third parties. Arcadis has taken reasonable steps to ensure that the information sources used for this assessment provided accurate information and has therefore assumed this to be the case.

7 This report has been prepared based on the information reasonably available during the project programme. All information relevant to the scope may not have been received.

8 This report refers, within the limitations stated, to the condition of the site at the time of the inspection. No warranty is given as to the possibility of changes in the condition of the site since the time of the investigation.

9 The content of this report represents the professional opinion of experienced environmental consultants. Arcadis does not provide specialist legal or other professional advice. The advice of other professionals may be required.

10 Where intrusive investigation techniques have been employed, they have been designed to provide a reasonable level of assurance on the conditions. Given the discrete nature of sampling, no investigation technique is capable of identifying all conditions present in all areas. In some cases the investigation is further limited by site operations, underground obstructions and above ground structures. Unless otherwise stated, areas beyond the boundary of the site have not been investigated.

11 If below ground intrusive investigations have been conducted as part of the scope, safe location of exploratory holes has been carried out with reference to the Arcadis ground disturbances procedure. No guarantee can be given that all services have been identified. Additional services, structures or other below ground obstructions, not indicated on the drawing, may be present on site.

12 Unless otherwise stated the report provides no comment on the nature of building materials, operational integrity of the facility or on any regulatory compliance issues.

13 Unless otherwise stated, an inspection of the site has not been undertaken and there may be conditions present at the site which have not been identified within the scope of this assessment.

14 Unless otherwise stated, samples from the site (soil, groundwater, building fabric or other samples) have not been obtained.

15 Arcadis has relied upon the accuracy of documents, oral information and other material and information provided by the Client and others, and Arcadis assumes no liability for the accuracy of such data, although in the event of apparent conflicts in information, Arcadis would highlight this and seek to resolve.

16 Unless otherwise stated, the scope of works has not included an environmental compliance review, health and safety compliance review, hazardous building materials assessment, interviews or contacting Local Authority, requests for information to the petroleum officer, sampling or analyses of soil, ground water, surface water, air or hazardous building materials or a chain of title review.

Appendix A

Illustrative Development Plan

LEGEND

- SITE BOUNDARY
- SITE PRIMARY ENTRANCE
- EMERGENCY ACCESS ROAD
- OVERHEAD PYLON
- FLOOD ZONE
- AREA OF HERITAGE INTEREST
- RETENTION POND
- PUBLIC RIGHT OF WAY
- WATERCOURSE OPEN
- 66KV ELECTRICAL CABLE
- RAILWAY
- PROTECTED ZONE
- AREA OF HERITAGE INTEREST
- FOOTPATH / CYCLING
- IMPOSED PRoW IN OCTOBER
- WATERCOURSE BURIED OR UNKNOWN TBC
- PROPOSED WATERCOURSE
- SECURITY FENCE



Appendix B

Drawings



Legend

Site Boundary

Investigation Locations

- Borehole Locations (*Denotes where rotary drilling completed following a CPT)
- Cone Penetration Tests
- Windowless Sampling Locations

Notes

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All entities shown on this drawing are to be regarded as approximate and are indicative only. No measurement taken from this drawing should be used for design. Symbols for investigation locations are representations of location only and unless otherwise specified, do not represent the true size of the feature.

This plan does not present all locations completed as part of the investigation, however shows all drilled locations only.

TITLE: Arcadis Ground Investigation - Drilled Investigation Locations

SITE: Former Coal Stocking Yards, Cambois, Blyth

CLIENT: QTS Data Centers

Project No. 30226657

DATE: 12/11/2024

DRAWN BY: RL



Legend

- Site Boundary
- Investigation Locations
  - Trial Pits
  - Hand Excavated pits
  - Resistivity Testing
  - Surfacewater Sampling Locations

Notes

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All entities shown on this drawing are to be regarded as approximate and are indicative only. No measurement taken from this drawing should be used for design. Symbols for investigation locations are representations of location only and unless otherwise specified, do not represent the true size of the feature.

This plan does not present all locations completed as part of the investigation, and all drilled locations can be seen on a seperate plan.

TITLE: Arcadis Ground Investigation - Non-Drilled Investigation Locations

SITE: Former Coal Stocking Yards, Cambois, Blyth

CLIENT: QTS Data Centers

Project No. 30226657

DATE: 12/11/2024

DRAWN BY: RL



Legend

- Site Boundary
- Observed concrete slabs or above ground concrete obstructions
- Observed Britishvolt infastructure - including foundations or services

Notes

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All entities shown on this drawing are to be regarded as approximate and are indicative only. No measurement taken from this drawing should be used for design. Boundaries are representations of location only based on field observations, and unless otherwise specified, do not represent the true size of the feature.

These obstructions are based on investigation findings and observations only. Additional obstructions may be present that were not identified or represented on this drawing.

TITLE:
Observed Obstruction Plan

SITE:
Former Coal Stocking Yards,
Cambois, Blyth

CLIENT: QTS Data Centers

Project No. 30226657

DATE: 12/11/2024

DRAWN BY: RL

Legend

- Site Boundary
- Possible drainage - Britvolt
- Dense vegetation
- Moderate UXO
- Overhead powerlines
- Bridge
- Drains - open
- Historical conveyors
- Observed Japenese Knotweed
- Observed open water
- Possible culverts
- Possible Ducts and streetlights
- Possible tunnels
- Protected area
- Public Footpath
- Ecologically sensitive areas identified during investigation works

0 100 200 m

Notes

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All entities shown on this drawing are to be regarded as approximate and are indicative only. No measurement taken from this drawing should be used for design. Features are representations of the location only based on field observations, and unless otherwise specified, do not represent the true size of the feature.

Additional constraints may be present that were not identified during the investigation or are represented on this drawing.

TITLE: Observed Constraints Plan

SITE: Former Coal Stocking Yards, Cambois, Blyth

CLIENT: QTS Data Centers

Project No. 30226657

DATE: 12/11/2024

DRAWN BY: RL

Appendix C

Geotechnical Laboratory Testing Summary by Geology

Appendix C - Geotechnical Laboratory Testing – Number of Tests by Test Type and Geological Unit.

Geology	Lab HSV	Lab CBR	Compaction	Consolidation	Density	Atterberg	Moisture Content	Moisture Condition Value	Particle Density	PSD	Shear Box	Effective Stress	Total Stress	Point Load	Rock Density	Rock UCS	Rock WC	BRE SD1 Full Suite*	TRL 447 Suite
Granular Made Ground (MG – G)	-	5	10	-	-	3	16	4	10	28	-	-	-	-	-	-	-	53	11
Cohesive Made Ground (MG – C)	-	7	9	1	-	18	25	5	7	19	-	-	1	-	-	-	-	46	5
Burnt Red Shale (MG – BS50)	-	7	6	-	-	4	11	5	6	11	-	-	-	-	-	-	-	15	2
PFA (MG – PFA)	-	32	18	-	5	26	36	37	23	31	12	-	-	-	-	-	-	55	10
Alluvium (AL-ORG)	-	2	4	-	-	9	11	4	6	7	-	-	-	-	-	-	-	10	3
Glacial Channel Deposits (G – CD)	-	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	1	-
Glacial Till (TILL)	21	7	6	22	7	173	216	7	5	95	7	17	102	-	2	2	4	87	-
PMCM – Mudstone (PMCM – MST)	-	-	-	-	-	-	1	-	-	-	-	-	-	78	12	12	4	15	-
PMCM – Siltstone (PMCM – SLT)	-	-	-	-	-	-	1	-	-	-	-	-	-	27	9	9	2	6	-
PMCM -Sandstone (PMCM – SST)	1	-	-	-		-	1	-	-	-	-	-	-	134	73	73	14	31	-
PMCM - Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	8	-

Appendix D

Summary of Pressuremeter Testing

Appendix D – Detailed Summary of Pressure Meter Test Results.

Test ID	Depth	Max. test pressure	p_o	Undrained strength			G_i	Loop No.	G_{ur}	e_c	Non linear stiffness		Secant shear modulus			
				$S_{u\ (M\&R)}$	$S_{u\ (loading)}$	P_L										
	(m)	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)	(MPa)		(MPa)	(%)	α (MPa)	β	Shear strain			
													1%	0.1%	0.01%	0.001%
BH328																
1	2.70	176	48	-	125	397	0.7	1	10.0	0.210	1.324	0.706	5	10	20	39
								2	10.7	0.256	1.568	0.710	6	12	23	44
								3	14.7	0.216	2.569	0.740	8	15	28	51
								4	16.1	0.232	3.161	0.756	10	17	30	52
2	5.70	549	115	103	103	579	8.0	1	8.7	0.840	1.660	0.685	7	15	30	63
								2	10.8	0.871	2.245	0.708	9	17	33	65
								3	15.6	0.706	3.178	0.733	11	20	37	69
								4	12.6	0.776	2.387	0.711	9	18	34	66
3	17.60	1111	342	588	588	2268	5.8	1	28.9	0.270	-	-	-	-	-	-
								2	40.6	0.285	7.478	0.728	26	49	91	171
								3	51.4	0.293	11.516	0.754	36	63	111	195
								4	51.4	0.336	10.222	0.745	33	59	107	192
BH333																
1	27.80	Initial arm lift off variable, greater expansion of the membrane at the top in an uneven pocket, resulting in a burst at 1048kPa.														
2	31.20	6205	1300	4040	4040	17712	85.8	1	510.5	0.095	71.695	0.737	241	441	807	1478
								2	646.7	0.106	99.647	0.745	323	580	1044	1879
								3	707.3	0.128	125.098	0.756	385	676	1186	2082
								4	712.1	0.128	119.103	0.752	374	661	1171	2074
3	34.70	16168	4688	No	material yield		552.4	1	1290.5	0.048	852.885	0.947	1088	1228	1387	1566
								2	1705.2	0.057	997.923	0.928	1392	1644	1942	2294
								3	2044.3	0.087	1401.177	0.947	1791	2025	2289	2588
								4	1894.6	0.104	1159.545	0.933	1576	1837	2142	2497
4	37.60	13646	3534	7838	7838	44643	606.8	1	1495.1	0.052	936.464	0.940	1237	1421	1633	1877
								2	2007.5	0.050	1194.360	0.933	1627	1899	2217	2588
								3	1953.1	0.093	1256.451	0.937	1677	1937	2238	2586
								4	1904.1	0.095	1165.973	0.934	1582	1843	2146	2500

Appendix E

Arcadis 2024 Factual Reports (Stage 1 & 2)

Accelerated Swell Test with Terminal UCS Test Certificate

Client Details

PSL

5-7 Hexthorpe Rd, Doncaster DN4 0AR

Report Details

Project ID	A241111
Project Name	PSL
Schedule ID	A241111_B01
Report Number	CEGT_24007058
Report Date	18/12/2024

Sample Details

Location ID	PFA-COMP 503	Sample Type	Amal	Sample Description
Sample Reference	PFA-COMP 503 +1% CEM1	Sample Depth (m)	0.00 - 1.00	Mix deisign - 1% Cement binder
Sample ID	CEGT202411255	Date Sampled	11/09/2024	

Test Details

Test Method	BS EN 13286 - Part 49	Date of Test	17/12/2024

Single Point Proctor Test

Moisture Content (%)	28.3	Bulk Density (Mg/m3)	1.40	Dry Density (Mg/m3)	1.09

Accelerated Swell Test

Stage 1: Immediately Following Manufacture

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	50.83	50.95	51.12	50.63	51.06	50.86	50.96	50.85
Diameter (mm)	50.37	50.44	50.44	50.50	50.49	50.45	50.42	50.48
Volume (cm3)	101.28	101.79	102.15	101.42	102.23	101.68	101.74	101.78
Moisture Content (%)	28.7	29.9	26.2	28.6	28.9	28.3	28.3	28.6
Bulk Density (Mg/m3)	1.36	1.35	1.34	1.35	1.35	1.35	1.35	1.35
Dry Density (Mg/m3)	1.06	1.04	1.06	1.05	1.05	1.05	1.05	1.05

Stage 2: Following Initial 4 Day Cure

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	51.24	51.44	51.21	51.76	51.77	50.79	51.29	51.44
Diameter (mm)	50.23	50.27	50.30	50.28	50.24	50.28	50.27	50.27
Volume (cm3)	101.51	102.08	101.76	102.76	102.63	100.85	101.79	102.08
Initial Expansion (%)	0.2	0.3	-0.4	1.3	0.4	-0.8	0.0	0.3

Stage 3: Following Normal Curing for 7 Days (C) or 7 Days Immersion at 40°C (AST)

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	51.30	51.39	51.36				51.35	
Diameter (mm)	50.42	50.33	50.35				50.37	
Volume (cm3)	102.43	102.23	102.28				102.31	
Moisture Content (%)	31.6	33.2	35.3				33.4	
Bulk Density (Mg/m3)	1.31	1.33	1.31				1.32	
Dry Density (Mg/m3)	0.99	1.00	0.97				0.99	
UCS (N/mm2)	0.190	0.216	0.189				0.198	
Final Expansion (%)	1.1	0.4	0.1				0.6	

Remarks	Samples disrupted, unable to test	Signed	S. Bourton - Managing Director

UKAS TESTING

21581

Accelerated Swell Test results are outside of the scope of UKAS accreditation.

Test Certificate by: CE Geotech Ltd, CEG Laboratories, Matlock Rd, Ashover, S45 0DX, 01629 584 416

Accelerated Swell Test with Terminal UCS Test Certificate

Client Details

PSL

5-7 Hexthorpe Rd, Doncaster DN4 0AR

Report Details

Project ID	A241111
Project Name	PSL
Schedule ID	A241111_B01
Report Number	CEGT_24007059
Report Date	18/12/2024

Sample Details

Location ID	PFA-COMP 503	Sample Type	Amal	Sample Description
Sample Reference	PFA-COMP 503 +2% CEM1	Sample Depth (m)	0.00 - 1.00	Mix deisign - 2% Cement binder
Sample ID	CEGT202411256	Date Sampled	11/09/2024	

Test Details

Test Method	BS EN 13286 - Part 49	Date of Test	17/12/2024

Single Point Proctor Test

Moisture Content (%)	32.0	Bulk Density (Mg/m3)	1.40	Dry Density (Mg/m3)	1.06

Accelerated Swell Test

Stage 1: Immediately Following Manufacture

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	51.76	51.14	51.16	51.36	51.75	50.04	51.35	51.05
Diameter (mm)	50.42	50.54	50.50	50.51	50.51	50.39	50.49	50.47
Volume (cm3)	103.32	102.58	102.49	102.93	103.67	99.78	102.80	102.12
Moisture Content (%)	31.8	33.1	31.0	32.3	32.4	31.5	32.0	32.0
Bulk Density (Mg/m3)	1.33	1.35	1.33	1.34	1.33	1.37	1.34	1.34
Dry Density (Mg/m3)	1.01	1.01	1.02	1.01	1.00	1.04	1.01	1.02

Stage 2: Following Initial 4 Day Cure

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	51.18	51.00	51.11	50.84	51.65	51.00	51.09	51.16
Diameter (mm)	50.45	50.24	50.35	50.26	50.22	50.18	50.34	50.22
Volume (cm3)	102.30	101.08	101.75	100.84	102.30	100.86	101.71	101.33
Initial Expansion (%)	-1.0	-1.5	-0.7	-2.0	-1.3	1.1	-1.1	-0.8

Stage 3: Following Normal Curing for 7 Days (C) or 7 Days Immersion at 40°C (AST)

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	51.47	51.12	51.27	51.01	50.92	50.93	51.28	50.95
Diameter (mm)	50.45	50.36	50.42	50.23	50.27	50.33	50.41	50.28
Volume (cm3)	102.88	101.83	102.35	101.08	101.05	101.33	102.35	101.15
Moisture Content (%)	32.0	31.8	32.7	44.5	46.4	47.3	32.2	46.1
Bulk Density (Mg/m3)	1.31	1.32	1.31	1.46	1.48	1.47	1.32	1.47
Dry Density (Mg/m3)	0.99	1.01	0.99	1.01	1.01	1.00	1.00	1.00
UCS (N/mm2)	0.298	0.321	0.276	0.350	0.407	0.385	0.298	0.381
Final Expansion (%)	-0.4	-0.7	-0.1	-1.8	-2.5	1.6	-0.4	-0.9

Remarks		Signed	S. Bourton - Managing Director

Accelerated Swell Test results are outside of the scope of UKAS accreditation.

Accelerated Swell Test with Terminal UCS Test Certificate

Client Details

PSL

5-7 Hexthorpe Rd, Doncaster DN4 0AR

Report Details

Project ID	A241111
Project Name	PSL
Schedule ID	A241111_B01
Report Number	CEGT_24007060
Report Date	18/12/2024

Sample Details

Location ID	PFA-COMP 504	Sample Type	Amal	Sample Description
Sample Reference	PFA-COMP 504 +1% CEM1	Sample Depth (m)	0.00 - 1.00	Mix deisign - 1% Cement binder
Sample ID	CEGT202411257	Date Sampled	11/09/2024	

Test Details

Test Method	BS EN 13286 - Part 49	Date of Test	17/12/2024

Single Point Proctor Test

Moisture Content (%)	30.9	Bulk Density (Mg/m3)	1.37	Dry Density (Mg/m3)	1.05

Accelerated Swell Test

Stage 1: Immediately Following Manufacture

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	52.07	52.09	52.16	51.92	52.22	51.59	52.10	51.91
Diameter (mm)	50.39	50.33	50.35	50.32	50.32	50.52	50.36	50.39
Volume (cm3)	103.84	103.62	103.83	103.26	103.86	103.40	103.76	103.51
Moisture Content (%)	30.5	31.0	31.0	31.2	30.9	30.3	30.9	30.8
Bulk Density (Mg/m3)	1.30	1.30	1.29	1.31	1.31	1.30	1.30	1.31
Dry Density (Mg/m3)	1.00	1.00	0.98	1.00	1.00	1.00	0.99	1.00

Stage 2: Following Initial 4 Day Cure

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	51.95	52.31	52.25	51.92	52.00	51.86	52.17	51.93
Diameter (mm)	50.24	50.21	50.21	50.27	50.26	50.25	50.22	50.26
Volume (cm3)	102.96	103.55	103.45	103.06	103.18	102.85	103.32	103.03
Initial Expansion (%)	-0.8	-0.1	-0.4	-0.2	-0.7	-0.5	-0.4	-0.5

Stage 3: Following Normal Curing for 7 Days (C) or 7 Days Immersion at 40°C (AST)

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	52.05	52.37	51.49				51.97	
Diameter (mm)	50.39	51.08	50.34				50.60	
Volume (cm3)	103.79	107.31	102.47				104.51	
Moisture Content (%)	30.8	31.1	30.6				30.8	
Bulk Density (Mg/m3)	1.28	1.25	1.30				1.27	
Dry Density (Mg/m3)	0.98	0.95	0.99				0.97	
UCS (N/mm2)	0.205	0.218	0.181				0.201	
Final Expansion (%)	-0.1	3.6	-1.3				0.7	

Remarks	Samples disrupted, unable to test	Signed	S. Bourton - Managing Director

21581

Accelerated Swell Test results are outside of the scope of UKAS accreditation.

Test Certificate by: CE Geotech Ltd, CEG Laboratories, Matlock Rd, Ashover, S45 0DX, 01629 584 416

Accelerated Swell Test with Terminal UCS Test Certificate

Client Details

PSL

5-7 Hexthorpe Rd, Doncaster DN4 0AR

Report Details

Project ID	A241111
Project Name	PSL
Schedule ID	A241111_B01
Report Number	CEGT_24007061
Report Date	18/12/2024

Sample Details

Location ID	PFA-COMP 504	Sample Type	Amal	Sample Description
Sample Reference	PFA-COMP 504 +2% CEM1	Sample Depth (m)	0.00 - 1.00	Mix deisign - 2% Cement binder
Sample ID	CEGT202411258	Date Sampled	11/09/2024	

Test Details

Test Method	BS EN 13286 - Part 49	Date of Test	17/12/2024

Single Point Proctor Test

Moisture Content (%)	30.0	Bulk Density (Mg/m3)	1.37	Dry Density (Mg/m3)	1.05

Accelerated Swell Test

Stage 1: Immediately Following Manufacture

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	51.80	51.84	51.82	51.46	51.64	51.55	51.82	51.55
Diameter (mm)	50.26	50.24	50.24	50.34	50.39	50.42	50.25	50.38
Volume (cm3)	102.77	102.74	102.73	102.41	102.99	102.92	102.75	102.77
Moisture Content (%)	30.3	29.9	29.9	29.3	30.4	29.7	30.0	29.8
Bulk Density (Mg/m3)	1.32	1.33	1.32	1.34	1.32	1.32	1.33	1.33
Dry Density (Mg/m3)	1.02	1.03	1.02	1.04	1.01	1.02	1.02	1.02

Stage 2: Following Initial 4 Day Cure

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	52.37	50.24	50.23	51.06	52.63	52.08	50.94	51.92
Diameter (mm)	50.38	50.44	50.40	50.38	50.35	50.33	50.41	50.35
Volume (cm3)	104.39	100.37	100.20	101.76	104.79	103.60	101.65	103.39
Initial Expansion (%)	1.6	-2.3	-2.5	-0.6	1.8	0.7	-1.1	0.6

Stage 3: Following Normal Curing for 7 Days (C) or 7 Days Immersion at 40°C (AST)

	Comparator Test			Accelerated Swell Test			Average	
	C1	C2	C3	AST1	AST2	AST3	Cavg	ASTavg
Height (mm)	52.39	52.50	52.63				52.51	
Diameter (mm)	50.38	50.40	50.37				50.38	
Volume (cm3)	104.44	104.73	104.86				104.68	
Moisture Content (%)	30.6	30.4	29.8				30.3	
Bulk Density (Mg/m3)	1.27	1.27	1.25				1.26	
Dry Density (Mg/m3)	0.97	0.97	0.96				0.97	
UCS (N/mm2)	0.366	0.298	0.279				0.314	
Final Expansion (%)	1.6	1.9	2.1				1.9	

Remarks	Samples disrupted, unable to test	Signed	S. Bourton - Managing Director

21581

Accelerated Swell Test results are outside of the scope of UKAS accreditation.

Test Certificate by: CE Geotech Ltd, CEG Laboratories, Matlock Rd, Ashover, S45 0DX, 01629 584 416

Appendix F

Falling Head Tests

Variable Head Permeability Test

Test method in accordance with BS EN ISO 22282-2:2012

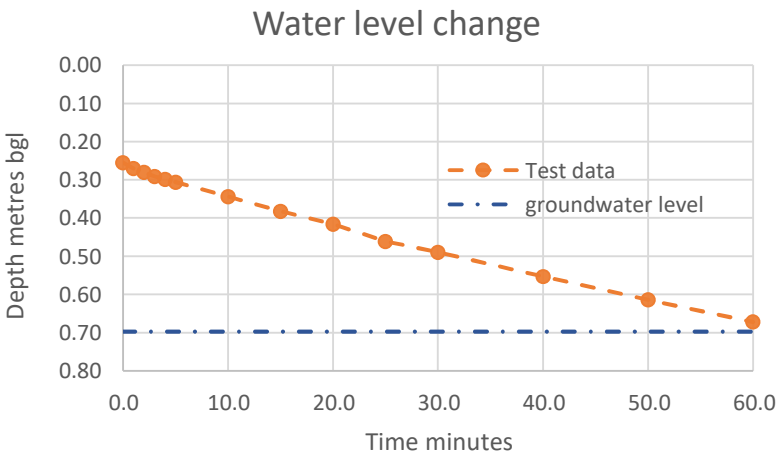
Project	Cambois Data Centre Campus	Status	**LOCATION ID**
Project ID	30226657	PRELIMINARY	**BH513**

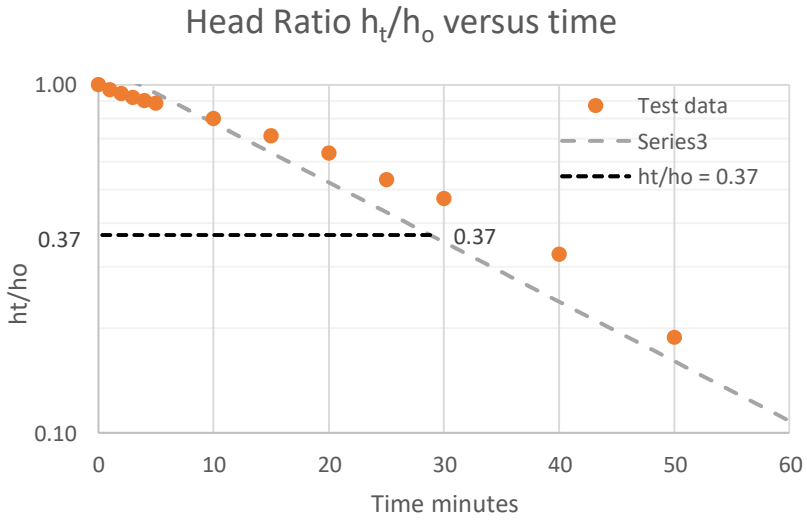
Test Zone Soil Description		Date and Time	27/11/2024 10:15	Test carried out in	BOREHOLE
Sl sandy sl gravelly clay.		Coordinates	312593.42 mE	Filter material used	Y
Test Zone Top	4.00 m bgl		583702.41 mN	Well diameter (mm)	150
Test Zone Base	10.00 m bgl	Ground Level	7.90 mOD	Installed pipe ID (mm)	50

Test Data

Elapsed Time (mins)	Water Level mbgl	(ht/ho)
0	0.26	1.00
1	0.27	0.97
2	0.28	0.94
3	0.29	0.92
4	0.30	0.90
5	0.31	0.88
10	0.34	0.80
15	0.38	0.71
20	0.42	0.64
25	0.46	0.53
30	0.49	0.47
40	0.55	0.33
50	0.61	0.19
60	0.67	0.06

Note: -ve water level = above gl (in casing)





Casing height above ground level m	0.0
Initial ground water level m bgl	0.70

Filter material used

Gravel

BS EN ISO 22282-2:2012 B4.1 Velocity Method

The general equation for an open borehole is

$$ln\left[\frac{h0}{h(t)}\right] = \frac{k\,.F\,.(t-to)}{S}$$

where

h	is the head at times to and t		
S	cross-sectional of casing/tubing	0.0020	m^2
F	intake factor from L/D, L/D =	40.000	
F =	8.60 and α is a slope factor	0.0394	

ln(ho/ht) versus time is non-linear, method not suitable to determine k

k = N/A ms^{-1}

BS EN ISO 22282-2:2012 B4.2 Hvorselv Method

The Hvorlev method can be applied only below the water table.

It is assumed L > 10.R

$$k = \frac{r^2.\ln(\frac{L}{R})}{2\,L\,to}$$

where

L	length of test section	=	6.00	m
R	radius of test section	=	0.075	m
r	radius of casing tube	=	0.025	m
t_o	time for 0.37 head change	=	1728	sec
L/D	40.00			

k = 1.32E-07 ms^{-1}

Carried out by	Notes:	Test by	Checked
ARCADIS UK LTD		TG	DF

Variable Head Permeability Test

Test method in accordance with BS EN ISO 22282-2:2012

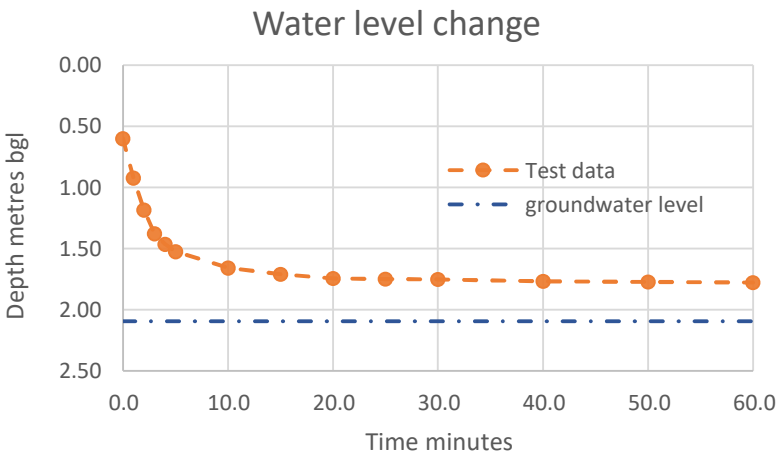
Project	Cambois Data Centre Campus	Status	**LOCATION ID**
Project ID	30226657	PRELIMINARY	**BH601**

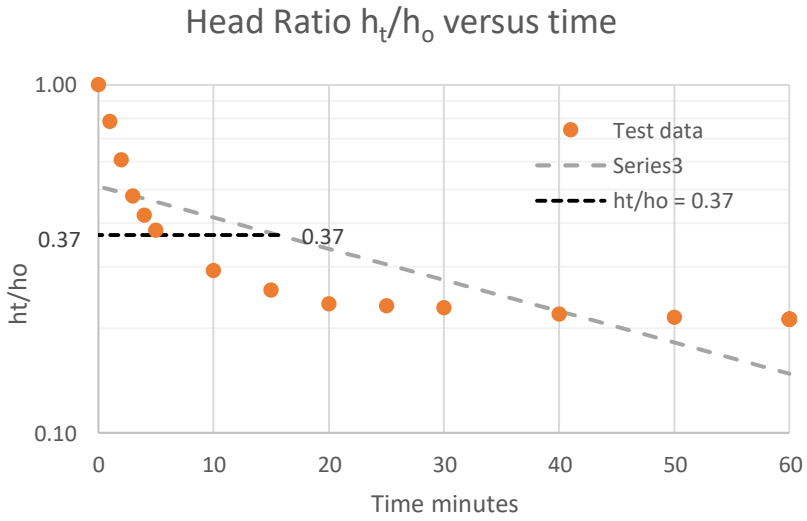
Test Zone Soil Description		Date and Time	26/11/2024 13:20	Test carried out in	BOREHOLE
Sl sandy sl gravelly clay.		Coordinates	312593.42 mE	Filter material used	Y
Test Zone Top	4.00 m bgl		584491.50 mN	Well diameter (mm)	200
Test Zone Base	10.00 m bgl	Ground Level	9.97 mOD	Installed pipe ID (mm)	50

Test Data

Elapsed Time (mins)	Water Level mbgl	(ht/ho)
0	0.60	1.00
1	0.92	0.78
2	1.19	0.61
3	1.38	0.48
4	1.46	0.42
5	1.52	0.38
10	1.66	0.29
15	1.71	0.26
20	1.74	0.23
25	1.75	0.23
30	1.75	0.23
40	1.77	0.22
50	1.77	0.21
60	1.78	0.21

Note: -ve water level = above gl (in casing)





Casing height above ground level m	0.0
Initial ground water level m bgl	2.09

Filter material used

Gravel

BS EN ISO 22282-2:2012 B4.1 Velocity Method

The general equation for an open borehole is

$$ln\left[\frac{h0}{h(t)}\right] = \frac{k\,.F\,.(t-to)}{S}$$

where

h	is the head at times to and t		
S	cross-sectional of casing/tubing	0.0020	m^2
F	intake factor from L/D, L/D =	30.000	
F =	9.21 and α is a slope factor	0.0207	

ln(ho/ht) versus time is non-linear, method not suitable to determine k

k = N/A ms^{-1}

BS EN ISO 22282-2:2012 B4.2 Hvorselv Method

The Hvorlev method can be applied only below the water table.

It is assumed L > 10.R

$$k = \frac{r^2.\ln(\frac{L}{R})}{2\,L\,to}$$

where

L	length of test section	=	6.00	m
R	radius of test section	=	0.100	m
r	radius of casing tube	=	0.025	m
t_o	time for 0.37 head change	=	937	sec
L/D	30.00			

k = 2.28E-07 ms^{-1}

Carried out by	Notes:	Test by	Checked
ARCADIS UK LTD		TG	DF

Variable Head Permeability Test

Test method in accordance with BS EN ISO 22282-2:2012

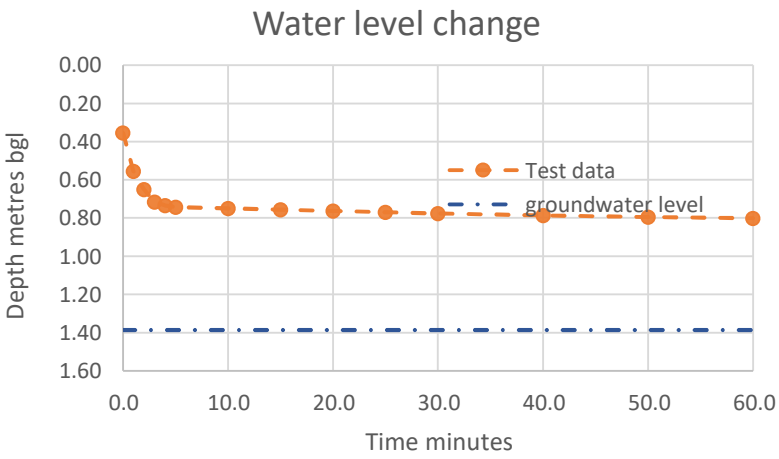
Project	Cambois Data Centre Campus	Status	**LOCATION ID**
Project ID	30226657	PRELIMINARY	**WS118**

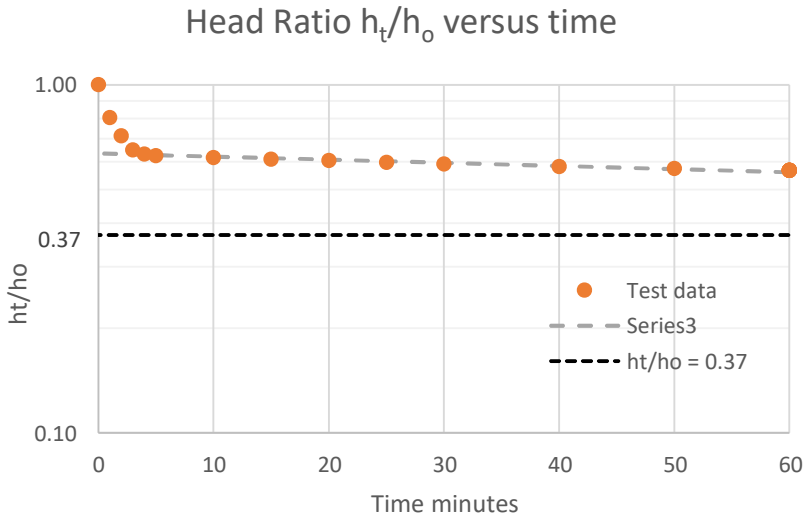
Test Zone Soil Description		Date and Time	27/11/2024 08:48	Test carried out in	BOREHOLE
Sl sandy sl gravelly clay.		Coordinates	312593.42 mE	Filter material used	Y
Test Zone Top	4.00 m bgl		583895.10 mN	Well diameter (mm)	82
Test Zone Base	10.00 m bgl	Ground Level	6.11 mOD	Installed pipe ID (mm)	50

Test Data

Elapsed Time (mins)	Water Level mbgl	(ht/ho)
0	0.36	1.00
1	0.56	0.81
2	0.65	0.71
3	0.72	0.65
4	0.73	0.63
5	0.74	0.62
10	0.75	0.62
15	0.76	0.61
20	0.76	0.61
25	0.77	0.60
30	0.78	0.59
40	0.79	0.58
50	0.79	0.57
60	0.80	0.57

Note: -ve water level = above gl (in casing)





Casing height above ground level m	0.0
Initial ground water level m bgl	1.39

Filter material used

Gravel

BS EN ISO 22282-2:2012 B4.1 Velocity Method

The general equation for an open borehole is

$$ln\left[\frac{h0}{h(t)}\right] = \frac{k\,.F\,.(t-to)}{S}$$

where

h	is the head at times to and t		
S	cross-sectional of casing/tubing	0.0020	m^2
F	intake factor from L/D, L/D =	24.390	
F = 3.23	and α is a slope factor	0.0051	

k = 3.08E-06 ms^{-1}

BS EN ISO 22282-2:2012 B4.2 Hvorselv Method

The Hvorlev method can be applied only below the water table.

It is assumed L > 10.R

$$k = \frac{r^2.\ln(\frac{L}{R})}{2\,L\,to}$$

where

L	length of test section	=	2.00	m
R	radius of test section	=	0.041	m
r	radius of casing tube	=	0.025	m
t_o	time for 0.37 head change	=	15590	sec
L/D	24.39			

k = 3.90E-08 ms^{-1}

Carried out by	Notes: Results from 0 to 3 minutes are ommited as plot is non linear and to account for saturation of the test zone.	Test by	Checked
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