OMEGA ZONE 8, ST HELENS

Omega St Helens Ltd / T. J. Morris Limited

Ground Investigation Report
& Remediation Strategy
Main Text
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Omega Warrington Limited

OMEGA SOUTH, ZONE 8A & 8B

Ground Investigation Report and Remediation Strategy

70062937/11482
DECEMBER 2019

CONFIDENTIAL

Omega Warrington Limited

OMEGA SOUTH, ZONE 8A & 8B

Ground Investigation Report and Remediation Strategy

CONFIDENTIAL

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APPENDICES

EXECUTIVE SUMMARY

WSP was instructed by Omega Warrington Limited (OWL) to undertake geotechnical and geo-environmental reporting on a parcel of land referred to as Zones 8A and 8B of the Omega South development area. The overall objective of this assessment was to identify potential geotechnical and environmental constraints and opportunities associated with the planned development of the site for the proposed commercial end use.

The investigation has confirmed that ground conditions comprise a general sequence of topsoil overlying predominantly cohesive Glacial Till deposits over the Sherwood Sandstone, which was encountered from between 7.60m and 14.20m bgl. Made Ground was observed locally and limited in thickness and generally associated within land drains. Two groundwater bodies were encountered during the investigation; perched shallow water within the Till, considered to be in limited vertical and lateral connectivity with the wider groundwater environment and a deeper regional groundwater body within the bedrock.

Environmental Conclusions

Based on the findings of this investigation, the potential health risk associated with chemical contamination is low and acceptable based on a proposed commercial development at the site. No asbestos or asbestos containing material was identified. It is noted additional areas of localised Made Ground may be present onsite. Therefore, it would be prudent to take precautions to minimise dust generation during the ground disturbance works. If suspected ACM is encountered during the ground works, professional advice should be sought.

Elevated exceedances of metals, sulphate, TPH and PAHs were recorded from groundwater in samples when compared with WQS protective of groundwater and surface waters. Groundwater samples collected from the Till are considered to represent perched bodies of water present within granular pockets are considered unlikely to be in connectivity with the underlying sandstone (Principal Aquifer) or surface water features. Based on the surface water and groundwater assessments, there is a low risk posed to controlled waters.

The preliminary ground gas risk assessment classifies the site as Characteristic Situation 1 based on the assessment of ground gas monitoring data. Our preliminary conclusion is that no ground gas protective measures are required. This is based on 3 ground gas monitoring visits out of 6 so a final report with an updated gas risk assessment will be submitted upon completion of the required number of gas monitoring visits.

The remediation strategy recommends the following:

A watching brief should be maintained during earthworks to identify and deal with any localised contamination, if encountered.

The management of the reuse of site won materials should be undertaken under a Materials Management Plan (MMP) in accordance with the Definition of Waste: Development Industry Code of Practice' (DoW CoP).

A validation report should be completed at the end of works to demonstrate appropriate remediation works have been completed for the proposed commercial development.

Geotechnical Conclusions and Recommendations

Material parameters for the strata recorded on site have been derived from cautious estimates of laboratory, field tests, and published correlations complemented with engineering judgement

A Design Sulphate Class of DS-1 an ACEC classification of AC-1 may be assumed for the design of buried concrete; and,

A Geotechnical Design Report (GDR) in accordance with BS EN 1997 will need to be prepared to support any future development and additional investigations may be required to reduce ground risk and value engineer the design of foundations, floor slabs and external works.

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1 INTRODUCTION AND OBJECTIVES

1.1 AUTHORISATION

WSP was instructed by Omega Warrington Limited (OWL) to undertake geotechnical and geo-environmental reporting on a parcel of land referred to as Zones 8A and 8B of the Omega South development area (henceforth referred to as 'the site').

A site location plan is presented as Figure 1 within Appendix A.

1.2 STUDY AIM & OBJECTIVES

WSP understands that OWL intends to secure planning consent for a commercial development at the site. The aim of this report is to present the conceptual ground model for the site, provide information in support of the proposed development by characterising potential ground related risks and support the discharge of future land quality related planning conditions. The scope of works was designed to address the aspects as detailed below;

- Develop a conceptual ground model for the site and its proposed use;
- Identify potential constraints and opportunities with respect to geotechnical design which may be realised during development;
- Identify potential constraints and opportunities with respect to contamination of land; and
- Undertake assessments for foundation and buried concrete design.

This report represents a Geotechnical Interpretive Report (GIR) as outlined in BS EN 1997-2 (guidance referenced in Section 1.4 below) and will be used in preparation of a Geotechnical Design Report which shall be issued separately.

1.3 DEVELOPMENT PROPOSAL

The current proposed development is indicated in Aja Architects Drawing 6385 - 150 included in Appendix A. The scheme comprises a large distribution warehouse over the central portion of the site with associated infrastructure including service yards, offices and HGV parking. A portion of land in the east is designated as expansion land.

1.4 LEGISLATIVE CONTEXT AND GUIDANCE

The assessment was undertaken in general accordance with the following good practice and statutory guidance:

- British Standard 'Eurocode 7 – Geotechnical Design – Part 2: Ground investigation and testing'. BS EN 1997-2:2007.
- British Standard 'Investigation of Potentially Contaminated Sites – Code of Practice', BS EN 10175:2013.
- British Standard 'Code of Practice for Ground Investigations', BS 5930:2015.
- Environment Agency 'Model Procedures for the Management of Land Contamination', CLR11 (2004).
- CIRIA 'Assessing Risks Posed by Hazardous Ground Gases to Buildings' C665 (2007).
- Defra 'Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance', PB13735 (2012).

1.5 SOURCES OF INFORMATION

The following sources of information were used in the production of this report:

Source	Report
WSP Reports	'Omega Zone 8 – Warrington Phase 1 Geo-Environmental Assessment' (ref: 11191042/11158(002) dated May 2019[1]. 'Omega South Zones 1 and 2– Geotechnical and Geo-Environmental Interpretive Report' (ref: 11191042/1146)) dated September 2019[2]. 'Omega South Zones 7E and 7F Geo-Environmental Interpretive Report' (ref: 70037840/10889(i)) dated October 2017.
Third Party Reports	Geotechnics 'Factual Ground Investigation Report Omega Development' (ref PN194027) dated November 2019. Lankelma 'Warrington, Soil Investigation, CPT Report' (ref P-107284-10) dated November 2019 Coal Authority Report 'CON29M Coal Mining Report, Omega West, Warrington, WA5 3UZ' (ref: 51002108134001) dated 13 May 2019. Zetica 'UXO Desk Study and Risk Assessment' (ref: P7831-18-R1) dated 11 September 2019. Coal Authority Report 'CON29M Non-Residential Mining Report, Omega West, Warrington, WA5 3UZ' (ref: 51001980112001) dated 03 January 2019.
Public Information	Landmark 'Envirocheck Report' (ref: 174134158_1_1) dated 21 August 2018 British Geological Society (BGS) 1:50,000 series Map Sheet 97 Runcorn Solid and Drift Edition.
Notes	The report contains British Geological Survey materials ©NERC 2017 database right.

1.6 CONFIDENTIALITY STATEMENT AND LIMITATIONS

This report is addressed to and may be relied upon by the following party:

Omega Warrington Limited

This assessment has been prepared for the sole use and reliance of the above-named party. This report shall not be relied upon or transferred to any other parties without the express written authorisation of WSP. No responsibility will be accepted where this report is used, either in its entirety or in part, by any other party.

General limitations of the assessment are included as Appendix I.

2 SITE SETTING

2.1 SITE DESCRIPTION AND CURRENT USE

A detailed description of the site is included within the WSP Phase I report (WSP 2019) which should be consulted for further details. It should be noted that the site boundary within the Phase I report relates to the wider Omega Zone 8 site. Table 2-1 summarises pertinent site details and information obtained over the course of the intrusive works for the current Zone 8A and 8B site boundary. A site layout plan is presented as Figure 2 in Appendix A.

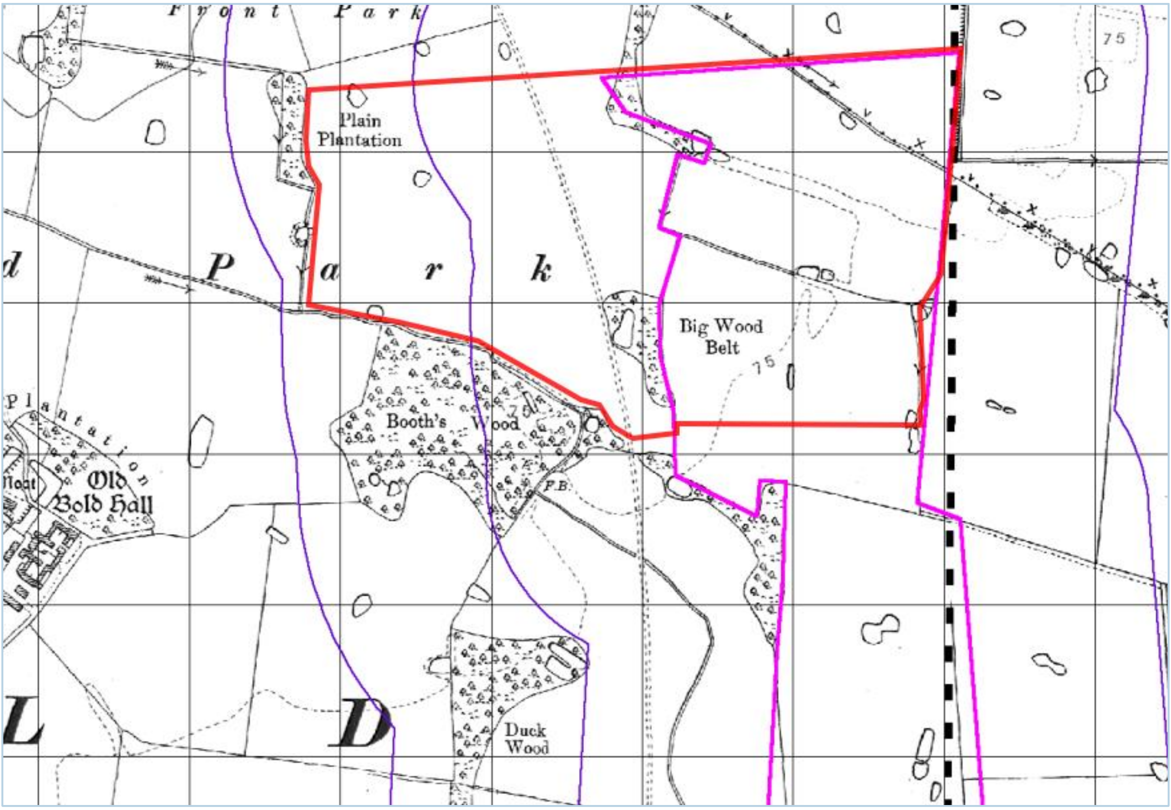
Table 2-1 – Summary of Site Details

Site Feature	Details
Site Address	Omega Zones 8A and 8B, Omega South, Warrington (WA5 3UZ closest post code).
National Grid Coordinates	E355224, N390505 (approximate centre of the site)
Area	Approximately 65.8 hectares
Site Description and Current Use	Omega Zone 8A and 8B comprises an area to the west of the wider site known as 'Omega South' located approximately 50m to the south of the M62 motorway. The site is currently used for agricultural purposes comprising several open fields separated by wooden post and wire fences and shrubs and mature trees. Drainage ditches are generally present between fields, which were observed to have standing water in them at the time of the site investigation. A localised area of mature trees approximately 1ha in size is present in the south. A drain is culverted underneath the M62 which resurfaces at the sites northern boundary transecting the site a NW-SE direction. A number of ponds between 20m and 80m in length are also present onsite. The surface water features are indicated in Figure 2 in Appendix A.
Site Boundaries	The site is bounded by the following land uses: North: An embankment approximately 3 – 4m in height associated with the M62 is located to the north of the site with the Omega North development beyond. East: Omega South development areas, which comprise large commercial distribution warehouses including a Royal Mail depot. South: Largely undeveloped land used for agricultural purposes. West: Open agricultural fields.
Topography	The site gradually falls from approximately 25m above Ordnance Datum (m AOD) in the west to 22.6m AOD in the east.
Flooding	According to site sensitivity data contained within the WSP Phase 1 report (WSP 2019), there is a high risk of flooding from surface water which is generally associated with field drains and ponds located onsite. During the site investigation and subsequent monitoring programme, large areas of surface water flooding was apparent throughout the site.

2.2 SITE HISTORY SUMMARY

The following information is summarised from a review of the WSP Phase 1 report (WSP 2019) which should be consulted for further details. It should be noted the site boundary provided in the historical Ordnance Survey (OS) maps corresponds to a portion of the wider Omega Zone 8 boundary. The site boundary for which the history has been summarised is shown in red on the OS 1928 map extract below.

Extract 1 – Envirocheck Boundary and Site Boundary- 1928 OS map



In summary, mapping indicates the site has remained generally undeveloped until present day. Earliest mapping from 1849 shows the site to comprise open fields used for agricultural purposes with a number of ponds present in addition to a track trending through the centre of the site in a north – south trajectory. By 1908, two ponds in the north of the site appear to have been infilled as they are no longer indicated to be present. Development onsite is limited to the construction of two electricity pylons in the 1990s which trend in a south-westerly direction from the northeast.

The site remains in a predominantly rural setting until the mid-1950s when Burtonwood Airfield was developed approximately 250m east. The airfield was in operation for around 20 years before being demolished by 1990. This area has subsequently been re-developed for commercial purposes (predominantly warehouse distribution) associated with the wider Lingley Mere and Omega Business Parks.

3 ENVIRONMENTAL SETTING

3.1 GEOLOGY

Published geological mapping indicates the site is underlain by Till (unsorted glacial sediment comprising clay and boulders of intermediate size) whilst the solid geology is shown to be the Chester Formation (formerly the Chester Pebble Beds Formation) of the Sherwood Sandstone Group.

There are two faults which transect the site in a north – south direction, which are both downthrown to the west. The most westerly fault is named the Roaring Meg Fault.

Intrusive investigations in the wider Omega South area to the east and southeast (WSP 2017, WSP 2019[2]) have identified the following general ground sequence, which is consistent with published geology:

Table 3-1 – Summary of Strata Recorded During Wider Omega South Investigations

Stratum	Description	General Depth to Base of Strata (m bgl*)
Topsoil/	Dark brown slightly gravelly sandy clay with rootlets.	0.35 – 0.50
Made Ground	Made Ground was encountered either at ground level or below the topsoil horizon. Made Ground comprised sand and gravel mixtures and soft through to stiff, low to medium strength, gravelly clays with brick and concrete.	1.00 – 2.00
Till	Firm and stiff clay with occasional lenses of sand	8.00 – 13.00
Chester Formation	Weak fine to course grained sandstone.	Not proven (15.00)

** metres below ground level*

A Coal Authority (CA) Report (presented in Appendix B) was obtained as part of the WSP Phase 1 report (2019) which indicated the site is within the likely zone of influence from workings in seven seams of coal at 630m and 960m depth, which were last worked in 1984. The CA considers that ground movement from these coal workings should have ceased by now.

A damage notice or claim for alleged subsidence damage was made in July 2002 for a parcel of land in the northeast, part of a wider claim for land associated with a farm located to the north. However, the claim was rejected by the CA.

3.2 HYDROGEOLOGY

The Environment Agency (EA) classifies the Till as a Secondary (undifferentiated) aquifer and the Chester Formation as a Principal Aquifer. The Secondary undifferentiated aquifer classification indicates Till underlying the site is a deposit with variable groundwater characteristics. Principal aquifers are classified as deposits with a high fracture permeability and water storage capacity and may support water supply and river base flow on a strategic scale.

The site is located within a Groundwater Source Protection Zone 3 (SPZ 3). There is one groundwater abstraction within 250m of the site located 240m south. The abstraction is operated by North West Water and used for public water supply.

Due to the presence of a significant thickness of low permeability soils it is considered that groundwater within the Till is likely to be perched and significant connectivity between the surface water features and the underlying Principal Aquifer is unlikely as migration of groundwater will be significantly restricted.

3.3 HYDROLOGY

A number of ponds (approximately eight) are present onsite in addition to a number of drainage ditches between fields, which were observed to contain standing water at the time of the site investigation. These surface water features are indicated on Figure 2 in Appendix A.

A stream is located approximately 100m southwest which flows in a southerly direction before flowing eastly and eventually discharging into Whittle Brook, classed as a Main River by the EA.

3.4 UNEXPLODED ORDNANCE (UXO)

Given the site is located adjacent to a former airbase, a UXO Desk Study has been conducted by Zetica and is presented as Appendix C. Whilst the site boundary provided in the report corresponds to only part of the site, email correspondence from Zetica (dated 13 May 2019 included in Appendix C) confirms the conclusions of the report remain valid for the entire site area i.e. the risk from unexploded ordnance (UXO) at the site is low.

4 PRELIMINARY CONCEPTUAL SITE MODEL

4.1 INTRODUCTION

A preliminary conceptual site model (CSM) has been formulated utilising available information to determine the presence of plausible exposure pathways and hence the presence of potential risk to susceptible receptors. For a significant or identifiable risk to exist, an exposure pathway must be present which requires each of the following to be identified.

The presence of substances that may cause harm (source);
The presence of a receptor which may be harmed (receptor); and
The existence of means of exposing a receptor to the source (pathway).

The potential sources of contamination, receptors that could be impacted and exposure pathways are described below.

4.2 POTENTIAL SOURCES OF CONTAMINATION

Based upon current and historical site uses, it is considered the presence of significant widespread contamination within the site is unlikely. There is the potential for contamination associated with the current agricultural use in additional the potential for ground gases associated with the current and former ponds (potentially infilled) and organic rich sediments. Table 4-1 summarises the potential onsite contamination sources identified.

Table 4-1 – Sources of Contamination

Description	Potential Contaminants in Soil and Groundwater
Current site use for agricultural purposes	Pesticides and herbicides, hydrocarbons, asbestos and/or asbestos containing materials (ACM)
Made Ground associated with current land use and infilled ponds	Metals, polycyclic aromatic hydrocarbons (PAHs) petroleum hydrocarbons (TPH), asbestos and/or ACM, hazardous ground gases
Current ponds and organic rich sediments	Hazardous ground gases

4.3 POTENTIAL RECEPTORS

Based on the proposed site end use, the potential receptors are considered to include:

Construction workers involved in the redevelopment.
Future site users and maintenance workers (commercial end use).
Shallow perched/groundwater within the Till (Secondary Undifferentiated aquifer).
Groundwater within the bedrock (Principal Aquifer)
Onsite surface water features including drainage ditches and ponds.
Off-site watercourses including a tributary of Whittle Brook
Built environment including plastic pipes and buried concrete.

It is considered that significant connectivity between the shallow perched water within the Till and the surface water features and underlying Principal Aquifer is unlikely as migration of groundwater will be significantly restricted due the nature of predominantly cohesive drift deposits.

4.4 POTENTIAL PATHWAYS

The potential contamination pathways are considered to include the following.

- Direct contact, ingestion or inhalation of soil bound contaminants (including asbestos) / dust.
- Inhalation of vapours associated with volatile soil / groundwater contamination.
- Accumulation of ground gases resulting in a potentially explosive atmosphere.
- Migration of leachable / mobile contamination into groundwater followed by migration to the wider environment.
- Permeation of contamination through water pipework.

4.5 PLAUSIBLE CONTAMINANT LINKAGES

Given the above sources, pathways and receptors, the following contaminant linkages are considered to be potentially viable.

1. Direct contact, ingestion and inhalation of soil bound contamination by future site users and maintenance and construction workers.
2. Inhalation of vapours associated within volatile ground contamination by future site users and construction and maintenance workers.
3. Inhalation of ground gases by future site users and construction and maintenance workers.
4. Migration of mobile contamination into the groundwater and surface water features and potential migration to offsite surface water and wider groundwater environment.
5. Permeation of contamination through water pipework leading to contamination of drinking water supply.

5 GROUND INVESTIGATION

5.1 FIELDWORKS

The ground investigation was designed by WSP to provide sufficient geotechnical information to allow an appropriate assessment of the ground conditions and obtain sufficient data to assess the contamination status of the site in line with the preliminary conceptual site model.

The ground investigation was carried out by contractor Geotechnics between 16 September and 30 October 2019 under the supervision of WSP. The draft Geotechnics factual report containing logs and site investigation data is presented in Appendix D. It should be noted that whilst the factual report contains site investigation data the wider Zone 8 area, this GIR report pertains to Zone 8A and 8B only. Table 5-1 presented below summarises the fieldworks undertaken as part of the site investigation. An exploratory hole location plan is presented in Figure 3 in Appendix A.

Table 5-1 – Summary of Fieldworks

Investigation Method	No.	Exploratory Hole Reference	Range of Depths (m bgl)	Rationale
Cable Percussion Boreholes with Rotary Follow on	11	BH8A01, BHA802A, BH8A03 – BH8A08, BH8B03	20.4 – 28.50	To provide geotechnical coverage across the proposed building footprint.
Cable Percussion Boreholes	2	BH8A02, BH8B01 – BH8B02	7.60 - 8.11	To provide general site coverage in the expansion land.
Cone Penetration Tests	19	CPT8A01 – CPT8A11, CPT8A13 CPT8B01 – CPT8B03, CPT-P8A01 – CPT-P8A03, CPT-P8A04A and CPT-P8B01	7.36 – 13.48	To provide geotechnical coverage across the proposed building footprint.
Window Sample Holes	10	WS8A01 – WS8A03, WS8B01 – WS8B07	2.45 – 5.45	To target ponds and infilled ponds and provide general site coverage.
Trial Pits	37	TP8A01 – TP8A13, TP8B01 – TP8B18, TP8B18A-B, TP8B19, TP8B19A, TP8B20, TP8B21, TPAB21A-B	1.50 - 3.00	To provide geotechnical information at proposed carparking, along road networks and to target infilled site ponds.
Plate Load Tests	15	PLT8A01 – PLT8A11, PLT8B01 – PLT8B04	0.45	
Dynamic Cone Penetration	13	DCP8A01 – DCP8A05, DCP8B01 – DCP8B08	1.00	

Locations suffixed with an A or B indicate positions where additional attempts were required to get the exploratory location to the target depth. Due a stakeholder request to minimise ground disturbance in Zone 8A, seven trial pit locations (TP8A05 - TP8A07, TP8A09 – TP8A10, TP8A12 – TPA813) were advanced using cable percussive methods. In addition, due to access issues into Zone 8A, four window sample locations (WS8B01, WS8B02, WS8B06 and WS8B07) were advanced using cable percussive techniques to minimise rig standing time.

5.2 MONITORING INSTALLATIONS

Groundwater and ground gas monitoring wells were installed in boreholes as summarised in Table 5-2 below. The cable percussive boreholes (BH8A01-BH8A03, BH8A05-BH8A06, BH8A08, BH8B01, BH8B03) were installed to target groundwater whilst the window samplers (WS8A02-WS8A03, WS8B02-WS8B05) were installed to target potential sources of ground gas. Monitoring wells were constructed from 50mm perforated plastic pipe with pea gravel surround and fitted with air tight gas valves. As a minimum requirement, each monitoring well comprised plain pipe from ground level to 0.5m bgl with a bentonite pellet surround. Monitoring installations were finished with a top hat lockable cover.

Details of each installation are shown in Table 5-2 below and on borehole records contained within the Geotechnical Factual Report presented in Appendix D.

Table 5-2 – Monitoring Well Installations

Exploratory Hole Location	Ground Level (m AOD)	Standpipe Diameter (mm)	Screen Top and Base Depth (m bgl)	Screen Top and Base (m AOD)	Strata Targeted
BH8A01	23.89	50	1.00 – 6.00	22.89 – 17.89	Till
BH8A02	25.99	50	1.00 – 5.00	24.99 – 20.99	Till
BH8A03	26.09	50	12.00 – 20.10	14.09 – 5.99	Sandstone
BH8A05	23.85	50	6.00 – 8.50	17.85 – 15.35	Till
BHA806	24.90	50	6.00 – 8.00	18.90 – 16.90	Till
BH8A08	24.01	50	6.00 – 12.00	18.01 – 12.01	Till
BH8B01	22.16	50	1.00 – 6.00	21.16 – 16.16	Till
BH8B03	23.11	50	9.00 – 19.00	14.11 – 4.11	Sandstone
WS8A02	25.22	50	1.00 – 5.45	24.22 – 19.77	Till
WS8A03	24.90	50	1.00 – 5.45	23.9 – 19.45	Till
WS8B02	22.27	50	1.00 – 5.00	21.27 – 17.27	Till
WS8B03	21.70	50	0.50 – 4.50	21.2 – 17.2	Till
WS8B04	22.83	50	0.50 – 4.50	22.33 – 18.33	Till

Exploratory Hole Location	Ground Level (m AOD)	Standpipe Diameter (mm)	Screen Top and Base Depth (m bgl)	Screen Top and Base (m AOD)	Strata Targeted
WS8B05	22.41	50	1.00 – 4.00	21.41 – 18.41	Till
WS8B06	22.41	50	0.50 – 5.00	21.91 – 14.71	Till
WS8B07	22.16	50	1.00 – 5.00	21.16 – 17.16	Till

5.3 CONE PENETRATION TESTING

Cone penetration testing (CPT) using a CPT probe was completed by Lankelma between 25 September and 01 October 2019 to provide geotechnical information on ground conditions beneath the proposed building footprint.

A total of 19 CPT probing locations (CPT8A01 – CPT8A07, CPT8A08A, CPT8A01, CPT8A09 – CPT8A11, CPT8B01 – CPT8B03, CPT-P8A01 – CPT-P8A03, CPT-P8A04A and CPT-P8B01) were advanced to depths between 7.36m and 13.48m bgl. Each location was handpitted to 1.2m bgl prior to advancement of the probe. It should be noted that due to access issues and time constraints onsite CPT tests were not performed in two locations; CPT8B08 and CPT8A08.

The factual report containing the available CPT data and estimated soil type is presented in Appendix 7 of the Geotechnics Factual Report (Appendix D).

5.4 PRESSUREMETER TESTING

During the CPT investigation, 10 pressuremeter tests were carried out at four locations (CPT-P8A01, CPT-P8A03, CPT-P8A04A and CPT-PBA01) at various depths between 2.0m and 6.42m bgl with the results used to obtain undrained shear strength, stiffness and in situ stress information on the ground. The results of the pressuremeter testing are presented in Appendix 7 of the Geotechnics Factual Report (Appendix D) and discussed in Section 7.

5.5 ADDITIONAL IN-SITU & FIELD SOIL TESTING

5.5.1 STANDARD PENETRATION TESTS

Standard Penetration Tests (SPTs) were performed within the cable percussive and window sample boreholes. The results are presented on the exploratory hole records provided in Appendix D and a plot of SPT N_{60} (corrected for hammer efficiency, and extrapolated where required) versus depth is presented as Figure A.1 in Appendix A.

5.5.2 HAND SHEAR VANE

Hand Shear Vane (HSV) tests were undertaken in the trial pits. The results of the HSV tests are presented on the exploratory hole records presented in Appendix D and are discussed within Section 7.

5.5.3 PLATE LOAD TESTING (CBR)

Plate load tests were undertaken using a 600mm diameter plate at 15 locations (PL8A01 – PL8A11, PL8B01, TP8B01, TP8B11 and TP8B17) at a depth of 0.45m bgl. CBR values were calculated at each location in accordance with BS 1377-9:1990 in order to aid pavement design. The results are presented in Appendix D.

5.5.4 DYNAMIC CONE PENETROMETER TESTING

Dynamic cone penetrometer (DCP) testing was undertaken at 13 locations adjacent to trial pits (TP8A01, TP8A02, TP8A04, TP8A08, TP8A11, TP8B03, TP8B05, TP8B06, TP8B09, TP8B13, TP8B14, TP8B17 and TP8B18) and numbered DCP8A01 to DCP8A05 and DCP8B01 and DCP8B08 respectively to assess the likely subgrade strength along the proposed road network. The results of the DCP tests are presented in Appendix D and discussed in Section 7.

5.6 SAMPLING AND LABORATORY TESTING

A summary of the sampling and laboratory analysis undertaken during the investigation is presented in Table 5-3 below. Geotechnical analysis of soil samples was undertaken at the Geotechnics Laboratory whilst soil and groundwater environmental analysis was undertaken at DETS Laboratory, in general accordance with accredited methods.

The geotechnical and environmental laboratory reports are presented in Appendix D. It should be noted that some geotechnical laboratory analysis is currently outstanding.

Table 5-3 – Summary of Laboratory Chemical Analysis & Geotechnical Testing

Geotechnical Testing	Chemical Analysis – Soil	Chemical Analysis – Groundwater
Moisture content determination Atterberg limits Particle size distribution Particle density Single stage, quick undrained triaxial Oedometer testing Point load determination Dry density/moisture content relationship (2.5kg) Laboratory CBR Soluble sulphate Total sulphate pH Organic matter content	Asbestos soil screen Toxic nine metals suite (arsenic, cadmium, chromium, lead, mercury, copper, nickel, selenium and zinc) Hexavalent Chromium Polyaromatic Hydrocarbons (PAH) (Total of 16) Total Petroleum Hydrocarbon by Criteria Working Group (TPH-CWG) pH Pesticides and herbicides Water soluble sulphate Soil Organic Matter (SOM) Total Organic Carbon (TOC)	Toxic nine metals suite PAH TPH pH Water soluble sulphate

5.7 MONITORING WELL DEVELOPMENT AND GROUNDWATER SAMPLING

On 29 October 2019, selected monitoring wells were purged dry using a dedicated bailer to remove water and fine soils that might have entered the monitoring well during drilling or installation and to maximise the filter capacity of the gravel pack.

Groundwater samples were collected on 05 and 07 November 2019 using dedicated bailers from two locations installed within the Till (BH8A06 and BH8B01) and using hydrasleeves in one location installed within the Sandstone (BH8A03). A sample could not be obtained from BH8B03 installed within the sandstone due to the limited presence of groundwater within the monitoring well.

The groundwater samples were analysed for a range of compounds listed in Section 5.6.

5.8 GROUND GAS MONITORING

At the time of writing, three ground gas monitoring visits have been undertaken between 29 October and 29 November 2019. Three further monitoring visits are due to be completed in accordance within the recommendations within guidance CIRIA C665 – six monitoring visits over two months for a low sensitivity, low gas generation potential site. A revised report shall be issued once the required monitoring visits have been completed (anticipated January 2020).

Groundwater depths were gauged and ground gas concentrations and flow rates were measured using an infra-red gas analyser (GFM435). Initial and steady concentrations of methane (CH_4) carbon dioxide (CO_2) and oxygen (O_2) and trace gases (including carbon monoxide, hydrogen sulphide) were recorded along within initial and steady gas flow rates. Atmospheric pressure was also noted.

Monitoring records are presented in Appendix F and an assessment of the ground gas monitoring is presented in Section 8.

6 GROUND AND GROUNDWATER SUMMARY

6.1 GROUND CONDITIONS

The ground conditions within the site have been characterised predominantly from the cable percussive boreholes, window sample boreholes and trial pits, supplemented with data and estimated soil type from the CPTs. An exploratory hole location plan is presented as Figure 3 in Appendix A.

BGS mapping indicates that the site is underlain by Till and sandstone bedrock. The current ground investigation generally recorded a sequence of topsoil overlying predominantly cohesive Till deposits over the Chester Formation sandstone, which was recorded between 7.60m and 14.20m bgl. Limited thicknesses of Made Ground were observed locally and generally associated with land drains.

A yellowish brown slightly gravelly sand was also recorded in a limited number of exploratory holes underlying the topsoil. No anthropogenic constituents were recorded in this deposit and given the limited development recorded on the available historical mapping, it has been interpreted as a natural superficial deposit, possibly the Blown Sand (Shirdley Hill Sand), which is recorded on BGS mapping (BGS, 1977) in the wider area.

The ground summary is presented in Table 6-1 below.

Table 6-1 – Summary of Recorded Strata

Strata	Depth to Base (m bgl)	Thickness (m)	Typical Description	Notes
Topsoil	0.10 – 0.60	0.10 – 0.60	Grass over dark brown slightly gravelly clay with rootlets	Recorded across the full site area. Rare localised surface lying Made Ground inclusions likely associated with current farm activity.
Cohesive Made Ground	0.5 – 1.4	0.15 – 1.10	Soft to firm yellowish brown sandy clay with brick and sandstone	Predominantly associated with shallow land drains. Recorded in TP8A01, TP8A12, TP8A13, BH8A03, WS8B03, TP8B03, TP8B08, TP8B12, TP8B14, TPB15, TP8B18, TP8B18A, and TP8B19A
Granular Made Ground	.70	0.30	Slightly gravelly slightly silty fine to medium sand. Gravel comprises brick fragments and sandstone	Only recorded in BH8B03
Blown Sand	0.5 – 1.0	0.10 – 0.60	Yellowish brown slightly clayey fine to medium sand	Only recorded in BH8A05, BH8A06, TP8A10, WS8B01, WS8B02, WS8B06, and WS8B07

Strata	Depth to Base (m bgl)	Thickness (m)	Typical Description	Notes
Cohesive Till	7.60 – 12.30	7.10 – 14.20	Firm to stiff brown slightly sandy slightly gravelly clay	Recorded in all locations beneath the Topsoil / Made Ground / Blown Sand
Granular Till	14.20	1.90	Very dense very gravelly fine to coarse sand	Only recorded in BH8A07
Chester Formation Sandstone	Not proven (28.50) *	Not proven (12.00)	Very weak to medium strong reddish-brown medium to coarse grained sandstone.	Encountered across the full site area. Rockhead level generally falls to the south.

**Brackets indicate maximum unproven depth and thickness*

6.2 GROUNDWATER CONDITIONS

Limited groundwater strikes were observed within the boreholes during drilling, typically within the Till. The majority of groundwater monitoring wells were installed within the Till, two locations were installed within the Sandstone, as detailed within Table 6-2 below.

To date, groundwater level gauging has been undertaken during ground gas monitoring on three occasions between 29 October and 29 November 2019. Groundwater depths are included in the ground gas monitoring results presented in Appendix F. It should be noted that during the groundwater monitoring during Round 1, surface water flooding was apparent across the site, likely attributed to extended periods of heavy rain combined within a slow infiltration rate.

A summary of groundwater depths recorded in the monitoring wells is presented in Table 6-2 along within groundwater elevations from Round 2 (15 November 2019).

Table 6-2 – Summary of Groundwater Information

Exploratory Hole	Screen (m bgl)	Geology of Response Zone	Groundwater depth (m bgl)		Groundwater elevation (m AOD) – Round 2
			Min	Max	
BH8A01	1.00 – 6.00	Till	0.52	0.70	23.19
BH8A02	1.00 – 5.00	Till	0.83	1.13	25.05
BH8A03	12.00 – 20.00	Sandstone	17.91	17.97	8.13
BH8A05	6.00 – 8.50	Till	5.52	5.90	18.33
BHA806	6.00 – 8.00	Till	1.85	1.98	23.05
BH8A08	6.00 – 12.00	Till	2.78	3.10	21.23
BH8B01	1.00 – 6.00	Till	3.03	3.10	19.13
BH8B03	9.00 – 19.00	Sandstone	16.98	17.00	6.13

Exploratory Hole	Screen (m bgl)	Geology of Response Zone	Groundwater depth (m bgl)		Groundwater elevation (m AOD) – Round 2
			Min	Max	
WS8A01	1.00 – 5.45	Till	0.81	0.95	24.35
WS8A03	1.00 – 5.45	Till	0.83	0.91	23.99
WS8B02	1.00 – 5.00	Till	0.78	0.86	21.47
WS8B03	0.50 – 4.50	Till	0.19	0.29	21.42
WS8B04	0.50 – 4.50	Till	0.08	0.29	22.68
WS8B05	1.00 – 4.00	Till	0.51	0.55	21.88
WS8B06	0.50 – 5.00	Till	0.21	0.25	22.18
WS8B07	1.00 – 5.00	Till	1.91	2.06	20.25

A review of the data indicates the following:

- Groundwater depths within the Till have varied over the monitoring period between 0.08m bgl (WS8B04 located in the centre north adjacent to a pond) and 5.90m bgl (BH8A05 located in the centre). Groundwater depths within the Sandstone have varied between 16.98m bgl (BH8B03 located in the centre and 17.97m bgl (BH8A03) located in the east.
- Groundwater depths within individual monitoring wells have varied by between 0.04m (WS8B06) and 0.41m (BH8A05).

Within the Till there is no clear discernible groundwater flow direction, suggesting that the shallow groundwater is perched and discontinuous. The potential for lateral and vertical migration of groundwater within the Till is considered to be limited due to the predominantly cohesive nature of the deposits.

Based on groundwater elevations, the groundwater flow direction within the sandstone is estimated to be generally towards the west, which corresponds to the recorded dip in bedrock.

6.3 EVIDENCE OF CHEMICAL CONTAMINATION

During the intrusive investigation no visual or olfactory evidence of contamination was encountered in soils or groundwater.

6.4 GROUND GAS CONDITIONS

At the time of writing, three out of the proposed six rounds of ground gas monitoring has been undertaken between 29 October and 29 November 2019. Three further monitoring visits are due to be completed in accordance within the recommendations within guidance CIRIA C665 – six monitoring visits over two months for a low sensitivity, low gas generation potential site. A revised report shall be issued once the required monitoring visits have been completed.

Atmospheric pressure during the monitoring varied between 1004 (Round 1) and 988 (Round 3). Regional barometric pressure was falling during Round 1 and Round 3, considered to represent worst case conditions and rising during Round 2. The results for the gas monitoring to data are presented in Appendix F and summarised in Table 6-3 below.

Table 6-3 – Summary of Ground Gas Monitoring Results

Monitoring well	Response Zone (RZ)	Maximum CH_4 (% v/v)		Maximum CO_2 (% v/v)		Flow Rate (l/hr)		Frequency of RZ flooding
		Initial	Steady	Initial	Steady	Initial	Steady	
BH8A01	1.00 – 6.00	0.00	0.00	1.50	0.30	3.00	0.00	3 of 3
BH8A02	1.00 – 5.00	0.00	0.00	0.30	1.30	3.60	0.00	2 of 3
BH8A03	12.00 – 20.10	0.00	0.00	5.40	7.60	42.00	42.00	0 of 3
BH8A05	6.00 – 8.50	0.00	0.00	0.60	0.90	0.00	0.00	0 of 3
BHA806	6.00 – 8.00	0.00	0.00	0.80	0.90	8.30	0.00	0 of 3
BH8A08	6.00 – 12.00	0.00	0.00	0.20	0.80	0.00	0.00	3 of 3
BH8B01	1.00 – 6.00	0.00	0.00	0.60	1.60	0.20	0.00	0 of 3
BH8B03	9.00 – 19.00	0.00	0.00	6.70	7.30	57.30	57.10	0 of 3
WS8A01	1.00 – 5.45	0.00	0.00	7.30	3.10	26.00	0.00	3 of 3
WS8A03	1.00 – 5.45	0.00	0.00	0.40	3.00	58.60	0.00	3 of 3
WS8B02	1.00 – 5.45	0.00	0.00	0.60	1.60	07.50	0.40	3 of 3
WS8B03	1.00 – 5.00	0.00	0.00	2.00	2.00	20.50	3.70	3 of 3
WS8B04	0.50 – 4.50	0.00	0.00	7.20	0.30	0.00	0.00	3 of 3
WS8B05	0.50 – 4.50	0.00	0.00	1.20	1.60	6.70	0.00	3 of 3
WS8B06	1.00 – 4.00	0.00	0.00	0.60	1.70	3.40	0.50	3 of 3
WS8B07	0.50 – 5.00	0.00	0.00	0.50	1.50	9.30	2.00	0 of 3

The data indicates the following:

No methane concentrations above the limit of detection (0.1%v/v) were recorded.

Elevated carbon dioxide concentrations (above 5%v/v) were detected in four locations (BH8A03, BH8B03, WS8A01 and WS8B04), all recorded during the third round of monitoring only. The maximum recorded concentration was 7.60%v/v which was a steady reading from BH8A03, installed within the sandstone. The second highest reading was 7.30%v/v which was a steady reading from BH8B03, which was also recorded in the sandstone. The highest carbon dioxide concentration from a borehole installed within the Till was an initial reading of 7.30%v/v from WS8A01. This reading had reduced to 3.1%v/v for steady state conditions.

Steady flow rates above the limit of detection typically ranged between 0.40l/hr and 3.70l/hr. Significantly higher flow rates were recorded in BH8A03 and BH8B03 during the third round of monitoring (45l/hr and 57.1l/hr respectively).

Elevated carbon dioxide concentrations and high flow rates have been recorded in BH8A03 and BH8B03 on one occasion only (Round 3). It is considered the soil gas observed in these wells has likely migrated under high pressure through isolated fractures and joints within the bedrock. It is noted detected ground gas concentrations can potentially increase during falling pressure and rapid drops of barometric pressure, when increased emission rates occur. The atmospheric pressure during Round 3 was low and falling. The ground gas results from BH8A03 and BH8B03 during Round 3 appear to be anomalous and not considered to be representative of the ground gas regime in the sandstone on site. Therefore, these results have been discounted from the ground gas risk assessment.

It is noted that a number of locations which had reported high carbon dioxide concentrations or high flow rates, had fully flooded response zones during the monitoring on one or more occasions. This indicates the gas concentrations in these wells may not accurately reflect ambient soil gas concentrations as ground gas will not be able to flow freely into the well from the unsaturated zone.

A preliminary ground gas risk assessment in presented in Section 8.

7 GROUND CONDITIONS AND MATERIAL PROPERTIES

7.1 INTRODUCTION

The following section discusses the ground conditions and material properties determined from the ground investigation and geotechnical testing described in Section 5.

Where necessary, determination of characteristic parameters has been based on a cautious estimate of results derived from laboratory, published correlations and field tests, complemented with engineering judgement and consideration of the relevant limit state.

Where material parameters are assumed, derived by calculation, or taken from published sources, further details are provided as to their derivation.

Some geotechnical testing is still outstanding and this report will be updated upon receipt of all the results.

7.2 TOPSOIL

Topsoil was recorded in exploratory position across the site and ranged in thickness between 0.3m and 0.4m.

No specific geotechnical testing was undertaken on the Topsoil.

7.3 MADE GROUND

Made Ground was recorded in locally across the site in fourteen locations and was typically recorded in association with land drains. The Made Ground was predominantly cohesive, with granular materials recorded in one location.

The Cohesive Made Ground generally comprised a soft to firm slightly gravelly sandy clay and ranged in thickness between 0.5m and 1.4m bgl. The gravel content comprised natural lithologies and brick fragments, and the material is considered likely to be reworked Glacial Till.

Granular Made Ground, comprising slightly gravelly slightly silty fine to medium sand, was recorded to a depth of 0.7m bgl in borehole BH8B03. The gravel content comprised natural lithologies and brick fragments.

Table 7-1 presents a summary of in-situ and laboratory testing for the Made Ground.

Table 7-1 – Summary of In-Situ & Laboratory Testing – Made Ground

Parameter	No. of Tests	Min – Max	Mean
Moisture Content (%)	2	13 & 16	14
Liquid Limit (%)	2	29 & 32	31
Plastic Limit (%)		13 & 16	15
Plasticity Index (%)		16	16
Undrained shear strength, c_u (kN/m^2) – HSV	8	37 – 67	54

Parameter	No. of Tests	Min – Max	Mean
Water soluble sulphate SO_4 (2:1) (mg/l)	3	16 – 66	33
pH	3	6.6 – 7.4	7.1

7.3.1 MOISTURE CONTENT & CLASSIFICATION TESTS

Two Atterberg Limits tests were undertaken on samples of the Cohesive Made Ground. The results indicate the Cohesive Made Ground is a clay of low plasticity (Class CL) with the moisture content lying at the plastic limit.

7.3.2 UNDRAINED SHEAR STRENGTH

The undrained shear strength of the Cohesive Made Ground was measured by hand shear vane with results ranging between 37kN/m^2 and 67kN/m^2. Based on the testing undertaken and field descriptions of the material as "soft", an undrained shear strength of 40kN/m^2 is suggested.

7.3.3 CHEMICAL ATTACK ON BURIED CONCRETE

Made Ground samples were tested for water soluble sulphate concentration and pH. The assessment of the Design Sulphate Class and Aggressive Chemical Environment for Concrete has been undertaken in accordance with guidance presented in BRE SD1 (BRE, 2005)

Based on the analysis undertaken, a Design Sulphate Class of DS-1 and Aggressive Chemical Environment for Concrete of AC-1 are considered appropriate for below ground concrete in contact with the Made Ground.

7.4 BLOWN SAND

A slightly clayey fine to medium sand, interpreted to be Blown Sand, was recorded underlying the Topsoil in seven of the exploratory positions and ranging in thickness between 0.1m and 0.6m.

Due to its inconsistency across the site and its limited thickness, no insitu or geotechnical laboratory testing was undertaken on the stratum.

7.5 COHESIVE GLACIAL TILL

Cohesive Glacial Till was recorded underlying either the Topsoil, Blown Sand or the Made Ground within all the exploratory holes. The stratum generally comprised a firm becoming stiff slightly sandy slightly gravelly clay with rare cobbles of various natural lithologies. In BH8A02 a granite boulder was recorded at the base of the stratum.

The Cohesive Glacial Till was recorded to depths between 7.60m and 12.30m bgl, ranging in thickness between 7.10m and 14.20m with the thickness generally increasing southwards (in conjunction with the fall in rockhead).

Table 7-2 presents a summary of the in-situ and laboratory geotechnical testing undertaken on the Cohesive Glacial Till.

Table 7-2 - Summary of In-Situ & Laboratory Testing – Cohesive Glacial Till

Parameter		No of Tests	Min - Max	Mean
Moisture Content (%)		54	8 – 20	13
Liquid Limit (%)		37	22 – 35	28
Plastic Limit (%)			9 – 16	14
Plasticity Index (%)			11 – 21	14
Undrained shear strength, c_u (kN/m^2) – HSV		57	28 – 120	66
SPT N_{60}*		89	13 – 555†	35#
Undrained shear strength, c_u (kN//m^2) – laboratory triaxial		18	53 – 451	145
Bulk Density (Mg/m^3)		18	1.74 – 2.33	2.21
Coefficient of volume compressibility, m_v (m^2/MN at σ_v' + 100kN/m^2)		8	0.01 – 0.04	0.03
Particle Size Distribution (%)	Clay	4	21 – 28	24
	Silt		29 – 31	31
	Sand		38 – 42	40
	Gravel		4 – 6	5
Optimum Moisture Content (%) – 2.5kg effort		6	8 – 12	10
Maximum Density (Mg/m3) – 2.5kg effort		6	1.83 – 1.93	1.9
Water soluble sulphate SO_4 (2:1) (mg/l)		16	10 – 64	26
pH		16	7.1 – 8.3	7.9
Organic Matter Content (%)		8	0.6 – 0.9	0.8
Total Sulphur (%)		8	0.01	0.01
Total Sulphate (%)		8	0.01 – 0.03	0.014
Undrained shear strength, c_u (kN/m^2) – in-situ pressuremeter test		9	60 – 222	122
Shear Modulus, G_{ur} (MN/m^2)		12	22 – 101	55

Parameter		No of Tests	Min - Max	Mean
California Bearing Ratio (%)	Plate Load Test	11	0.5 – 3.0	1.4
	Dynamic Cone Penetrometer	13	2.4 – 92.1	20

* corrected for hammer efficiency

† includes extrapolated values

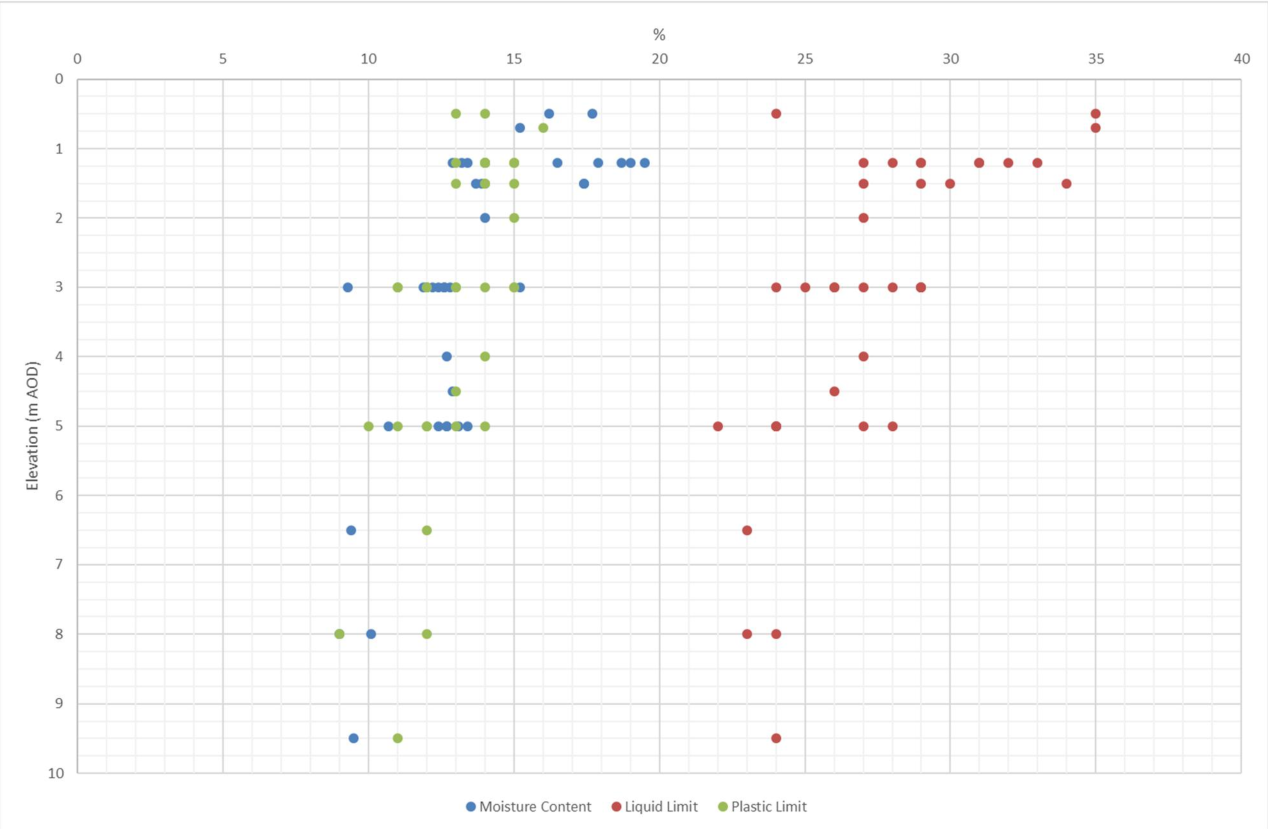
excludes refusal values from mean

7.5.1 MOISTURE CONTENT & CLASSIFICATION TESTS

The Cohesive Glacial Till is a clay of low plasticity (Class CL).

Figure 7-1 presents a plot of moisture content, plastic limit, and liquid limit versus elevation. The moisture content, liquid limit, and plastic limit appear to decrease with depth. Above 4m bgl the moisture content is generally above the plastic limit, but below 4m bgl the recorded moisture contents are generally below the plastic limit.

Figure 7-1 - Moisture Content, Plastic Limit, & Liquid Limit vs Elevation - Cohesive Glacial Till



7.5.2 UNIT WEIGHT

The unit weight has been calculated from the mean of the bulk density testing according to the following equation:

$\gamma_b(kN/m^3) = g * \rho_b$

Where g is gravitational acceleration, taken as 9.81m/s^2 and ρ_b is the mean bulk density.

Based on this and guidance given in BS 8002:2015 (BSI, 2015), a bulk unit weight of 21.7kN/m^3 is considered appropriate.

7.5.3 UNDRAINED SHEAR STRENGTH

Undrained shear strength, c_u was measured by direct hand shear vane testing, laboratory triaxial testing, in-situ pressuremeter testing, and estimated from the following relationship with SPT N_{60}:

$c_u(kN/m^2)$ = $f_1 N_{60}$ (Clayton, 1995)

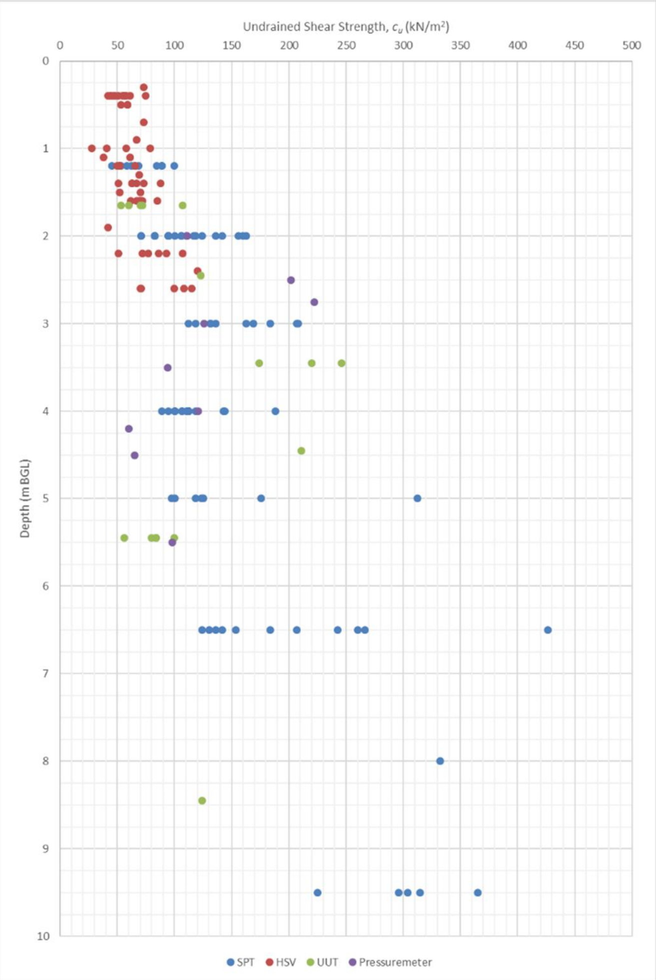
Where *f1* is a factor related to the mean plasticity index, taken as 5 for a moderately conservative plasticity index.

The results of the direct testing and the above relationship are presented on Figure 7-2. Between 0.5m and 3.5m bgl the results suggest a linear increase in strength from approximately 50kN/m^2 to approximately 175kN/m^2.

Between 3.5m and 6m BGL, the data appears to suggest a decrease in undrained shear strength, with triaxial and pressuremeter testing records undrained shear strengths in the region of 50kN/m^2 to 125kN/m^2. The SPT N_{60} relationship appears to overestimate the undrained shear strength, suggesting values in the range of 80kN/m^2 to 150kN/m^2.

Below 6m BGL, the undrained shear strength can be seen to increase.

Figure 7-2 - Undrained Shear Strength vs Depth - Cohesive Glacial Till

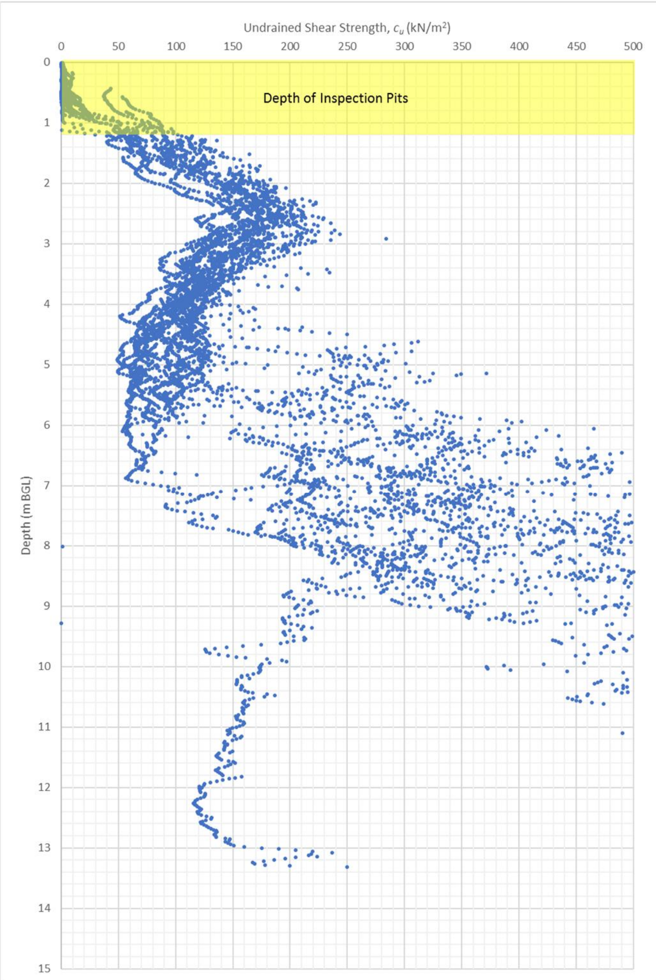


The undrained shear strength has also been determined by Lankelma from net cone tip resistance measured during the cone penetration testing. The following formula was used after Lunne et al (1997)

$c_u = (q_c - \sigma_{v0}) / N_k$ (Lunne et al., 1997)

Where q_c is the cone tip resistance, and N_k is an empirical factor which varies with soil type, and σ_{v0} is the total in-situ vertical stress. Lankelma have derived a range of shear strengths based on N_k factors based on the analysis of triaxial testing and net tip resistance for a variety of clays (Mayne & Peuchen, 2018). The N_k factor of 22.5 for an overconsolidated fissured clay is considered appropriate and Figure 7-3 presents a plot of undrained shear strength versus depth calculated accordingly.

Figure 7-3 - Undrained Shear Strength (from CPT data) vs Depth - Cohesive Glacial Till



The CPT data indicates a linear increase in undrained shear strength from approximately 50kN/m^2 at 1.2m bgl to approximately 150kN/m^2 at 3m bgl.

Below 3m BGL, the undrained shear strength appears to decrease to be between approximately 50kN/m^2 and 100kN/m^2 at 6m BGL, and showing a similar to trend to that discussed above.

Below 6m BGL, the undrained shear strength can be seen to increase significantly.

Based on the above, and considering the various testing methods undertaken, the following profile of undrained shear strength is considered appropriate:

c_u = 60kN/m^2 at 0.5m bgl then increasing linearly to 125kN/m^2 at 3.0m BGL

c_u = 100kN/m^2 between 3m BGL and 6m BGL

c_u = 200kN/m^2 between 6m and 10.0m BGL

7.5.4 STIFFNESS

Values of drained Young's Modulus (*E'*) were determined from the SPTs, pressuremeter testing, oedometer testing, undrained shear strength testing and according to the methods detailed below.

From SPT N_{60}

$E'(MN/m^2)$ **=** **0.9**N_{60} (Clayton, 1995)

From undrained shear strength (Triaxial and hand shear vane)

$E'(MN/m^2)$ **=** **270** $* c_u$**/ 1000** (Stroud and Butler, 1975)

From oedometer testing

$E'(MN/m^2)$ **=** **1/** m_v

Where m_v is taken at in-situ effective stress plus 100kN/m^2 from a recompression curve

From shear modulus (pressuremeter testing)

A series of pressuremeter tests were undertaken during the cone penetration testing in CPT8A01, CPT8A03, CPT8A04, and CPT8B01, the results of which are presented in Appendix 7 of the Geotechnics Factual Report (Appendix D).

The pressuremeter testing provides the Shear Modulus, *G*. The relationship between the Shear Modulus and Young's Modulus, *E'* is as follows:

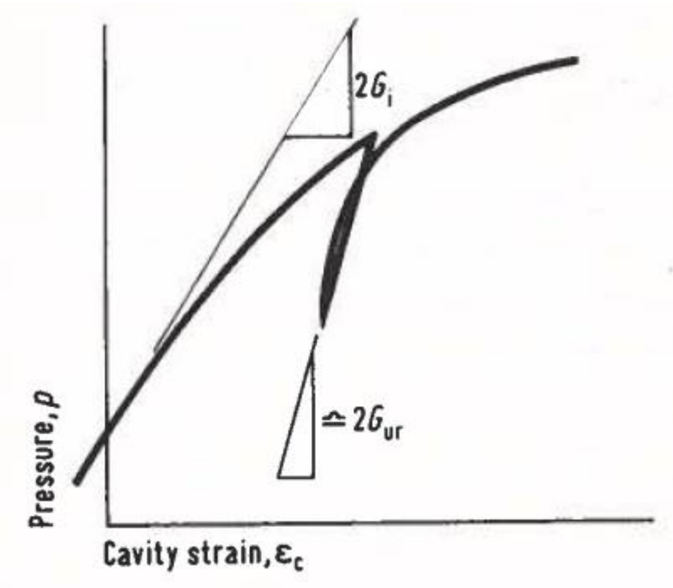
E' **=** **2**G**(1 +** v'**)**

Where *v* is the Poisson's Ratio.

A value of 0.2 Has been adopted for the Poisson's Ratio (Tomlinson, 2001).

Figure 7-4 shows the initial and unload-reload gradients from which Shear Modulus is derived. It is preferable to take moduli calculated from the slope of the unload-reload curve as the installation of the pressuremeter always creates some disturbance (Mair and Wood, 1987).

Figure 7-4 - Determination of shear moduli from initial expansion and unload-reload gradients



Values of Shear Modulus and Young's Modulus from the unload-reload and reload-unload loops are presented in Figure 7-4. Lankelma note that creep movement was observed during the hold period before the unload-reload loops, but not for the reload-unload loops and, as such, recommend that more credence should be given to values derived from the reload-unload loops.

Table 7-3 – Shear & Young's Modulus from Pressuremeter Testing

CPT Location	Test Depth (m BGL)	Loop Type	Shear Modulus, G_{sec} at 0.3% strain (MN/m^2)	Young's Modulus, *E'* at 0.3% strain (MN/m^2)
CPT8A01	2	R-U	17.6	42
CPT8A04	2.5	R-U	53.4	128
CPT8B01	2.75	R-U	25.6	61
CPT8A03	3	R-U	24.9	60
CPT8A01	4	R-U	22.0	53
CPT8B01	4.2	R-U	14.7	35
CPT8A04	4.5	R-U	16.6	40
CPT8B01	5.5	R-U	20.0	48
CPT8A01	2	U-R	12.7	30
CPT8B01	2.75	U-R	46.7	112
CPT8B01	2.75	U-R	21.6	52
CPT8A03	3	U-R	14.0	34
CPT8B01	3.5	U-R	18.4	44
CPT8B01	3.5	U-R	16.4	39
CPT8A01	4	U-R	25.7	62
CPT8B01	4.2	U-R	23.2	56
CPT8A04	4.5	U-R	10.1	24
CPT8B01	5.5	U-R	23.3	56
CPT8B01	5.5	U-R	16.1	39
CPT8B01	5.5	U-R	17.2	41

Values of drained Young's Modulus derived from the methods described above are presented on Figure 7-5. Values greater than 100MN/m^2 are omitted for clarity.

Values derived from SPTs, oedometer tests, and undrained shear strength testing show fairly good correlation between 0.5m and 3m bgl. Pressuremeter test derived moduli in this depth range are generally significantly higher than those derived from other methods and generally remain so throughout the depth range of the Glacial Till. Between 3m and 6m bgl, the moduli values appear to show a slight decrease, before starting to increase again below 6m bgl.

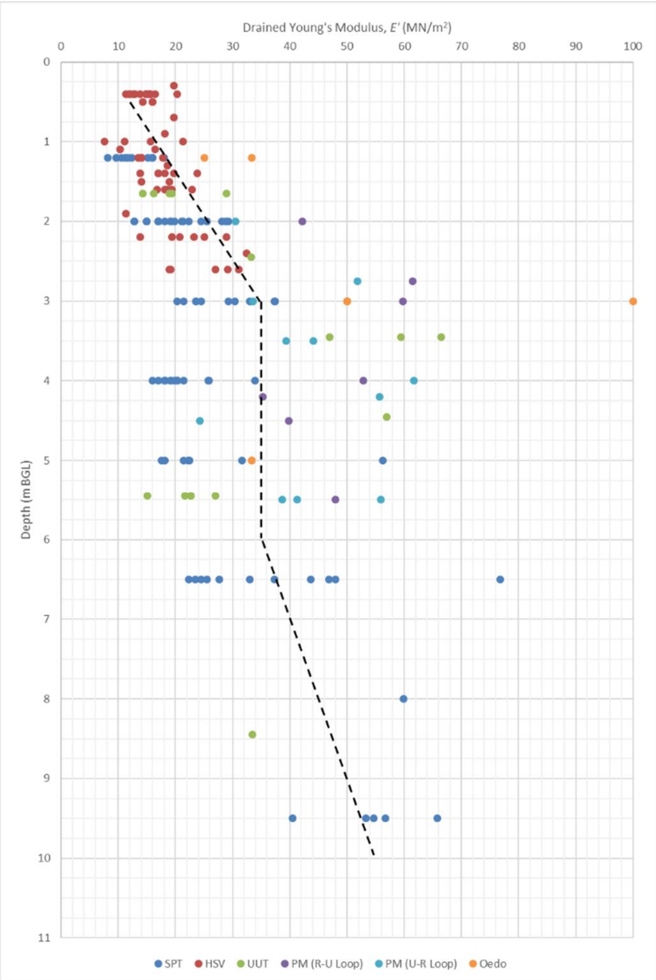
Based on the above, the following stiffness profile is considered appropriate:

E' = 12MN/m^2 at 0.5m BGL then increasing linearly to 35MN/m^2 at 3.0m BGL.

E' = 35MN/m^2 between 3.0m BGL and 6.0m BGL

E' = 35MN/m^2 at 6.0m BGL then increasing linearly to 55MN/m^2 at 10.0m BGL.

Figure 7-5 - Drained Young's Modulus vs Depth - Cohesive Glacial Till



7.5.5 CALIFORNIA BEARING RATIO

The results of the plate load test derived California Bearing Ratios (CBR) are, on the whole, considered to be low for the material type and ranged between 0.5% and 3%.

CBR values derived from dynamic cone penetrometer testing (DCP) showed an increase with depth from approximately 3% at 0.4m bgl to approximately 10 at 1m bgl.

Values of CBR have also been estimated from the following relationship with undrained shear strength:

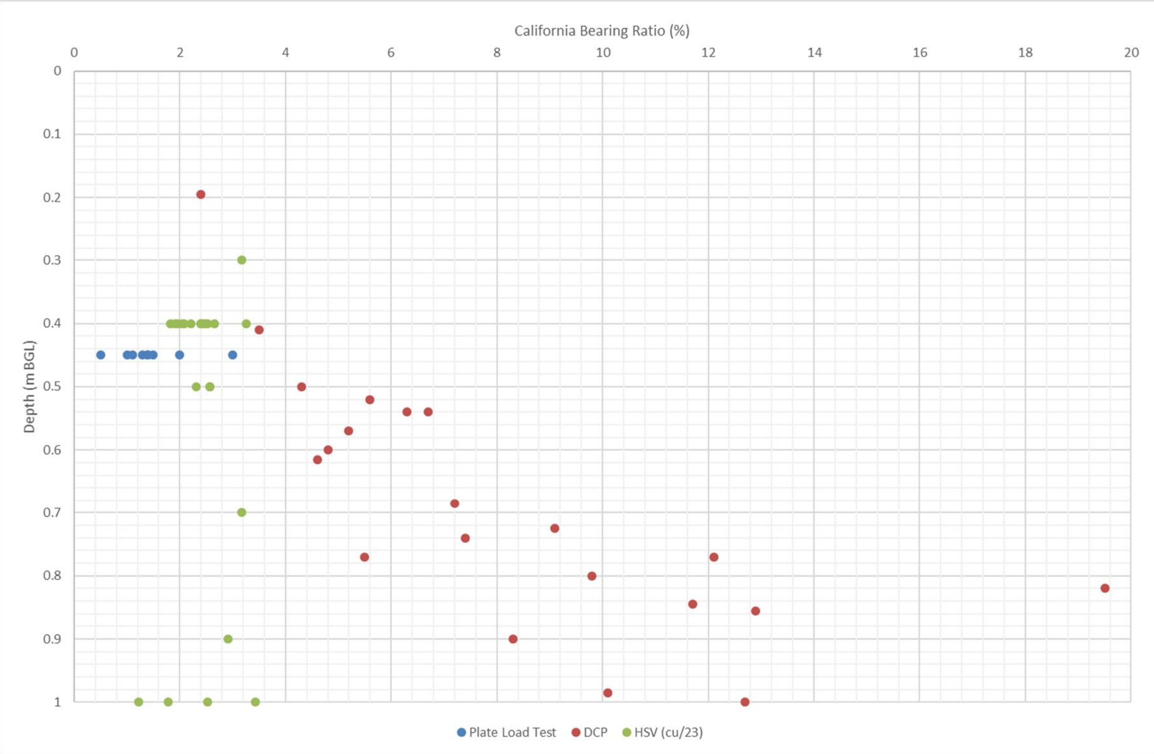
$CBR = c_u$**/ 23** (Black and Lister, 1979)

Based on a characteristic undrained shear strength of 60kN/m^2 at 0.5m bgl, the above relationship suggests a CBR of approximately 2.7%.

Interim Advice Note 73/06 (2009) would suggest an equilibrium CBR value of 3-4% (Thin pavement construction).

Based on the results of the in-situ testing and the above relationship, a characteristic CBR of 3% is considered appropriate for preliminary design.

Figure 7-6 - California Bearing Ratio vs Depth - Cohesive Glacial Till



7.5.6 CHEMICAL ATTACK ON BURIED CONCRETE

Based on the analysis undertaken, a Design Sulphate Class of DS-1 and Aggressive Chemical Environment for Concrete of AC-1 are considered appropriate for below ground concrete in contact with the Glacial Till.

7.6 GRANULAR GLACIAL TILL

Granular Glacial Till was recorded between 12.3m and 14.2m bgl in BH8A07 and comprised very dense reddish brown very gravelly fine to coarse sand with rare cobbles. Gravel comprised sandstone, mudstone, and coal.

In-situ testing for the Granular Glacial Till is summarised in Table 7-4. Due to its limited occurrence on site and the limited testing undertaken, no parameters have been derived for the Granular Glacial Till.

Table 7-4 – Summary of In-Situ Testing – Granular Glacial Till

Parameter	No. of Tests	Min – Max	Mean
SPT N_{60}	1	-	129

Parameter	No. of Tests	Min – Max	Mean
SPT $N1_{60}$*	1	-	102

* corrected for hammer efficiency and effective stress

7.7 CHESTER FORMATION

Bedrock of the Chester Formation was recorded underlying the Glacial Till at depths between 7.9m and 14.2m bgl with rockhead level generally falling in a southerly direction.

The majority of the Chester Formation was recorded as sandstone, however extremely weak reddish-brown mudstone was recorded in BH8A03 and BH8A07 and ranged in thickness between 1.3m and 1.34m.

The sandstone is recorded as comprising an upper weathered zone grading with depth into intact rock. Within this report the weathered zone has been taken as the depth over which the sandstone is recorded as having been recorded as gravelly fine to coarse sand. This zone is recorded to be between 1.22m and 3m thick.

The intact sandstone is generally recorded as extremely weak to medium strong fine and medium grained sandstone with rare clasts of quartz and mudstone.

The main discontinuity set, likely representing bedding, is recorded as extremely closely to closely spaced, horizontal to sub horizontal, planar, smooth, and clean.

A second, infrequently spaced, discontinuity set was recorded as sub horizontal to sub vertical, planar, smooth, and clean.

Plots of the recorded Rock Quality Designation (RQD) and Total Core Recovery (TCR) for the rotary core sections are presented as Figures A.2 – A.4 in Appendix A. Throughout the depth of the boreholes, the RQD generally ranged between 20% and 60% with occasional more heavily fractured regions. No particular correlation is evident between the boreholes at similar depths.

Recorded TCR is generally greater than 80% throughout the depth range of the boreholes.

The results of the in-situ and laboratory testing is summarised in Table 7-5.

Table 7-5 – Summary of In-Situ & Laboratory Testing – Chester Formation

Parameter	No. of Tests	Min – Max	Mean
Mudstone			
SPT N_{60}	1	-	36
Sandstone			
SPT N_{60}	19	210 – 1100*	370
SPT $N1_{60}$			
Axial Point Load Index, I_{S50} (MN/m^2)	53	0.032 – 0.548	0.22

Parameter	No. of Tests	Min – Max	Mean
Unconfined Compressive Strength (MN/m^2)	8	4.4 – 7.4	6.3
Bulk Density (Mg/m^3)	8	2.05 – 2.28	2.2

* extrapolated values

WEATHERED CHESTER FORMATION SANDSTONE

Based on the borehole recorded, the highly weathered zone has been interpreted as being typically up to 2.5m thick.

7.7.1 UNIT WEIGHT

The SPT N_{60} results indicate that the Weathered Chester Formation Sandstone is equivalent to a dense to very dense sand (BS 5930, (BSI, 2015)), corresponding to a unit weight of $20kN/m^3$ for such materials below the groundwater table, in accordance with BS 8002: 2015 (BSI, 2015).

7.7.2 SHEAR STRENGTH

The weathered sandstone has been taken as that stratum which is recorded as being recovered as a sand and, as such, is considered as a granular soil. In-situ testing indicates a very dense sand and based on correlations with SPT N160 (Stroud, 1989) a characteristic φ'peak of 42° is considered appropriate.

7.7.3 STIFFNESS

Values of drained Young's Modulus, *E'* for the Weathered Chester Formation Sandstone have been determined using the following relationship:

$E'(MN/m^2) = 2N_{60}$ (Clayton, 1995)

Based on this relationship and a lower bound SPT N_{60} of 210, a drained Young's Modulus of $420MN/m^2$ is suggested. However, based on WSP's experience and engineering judgement, a value of $250MN/m^2$ is considered more appropriate.

INTACT CHESTER FORMATION SANDSTONE

7.7.4 UNIT WEIGHT

Unit weight has been calculated from the mean bulk density testing according to the equation given in Section 7.5.2. Based on this, a bulk unit weight of $21.3kN/m^3$ is considered appropriate.

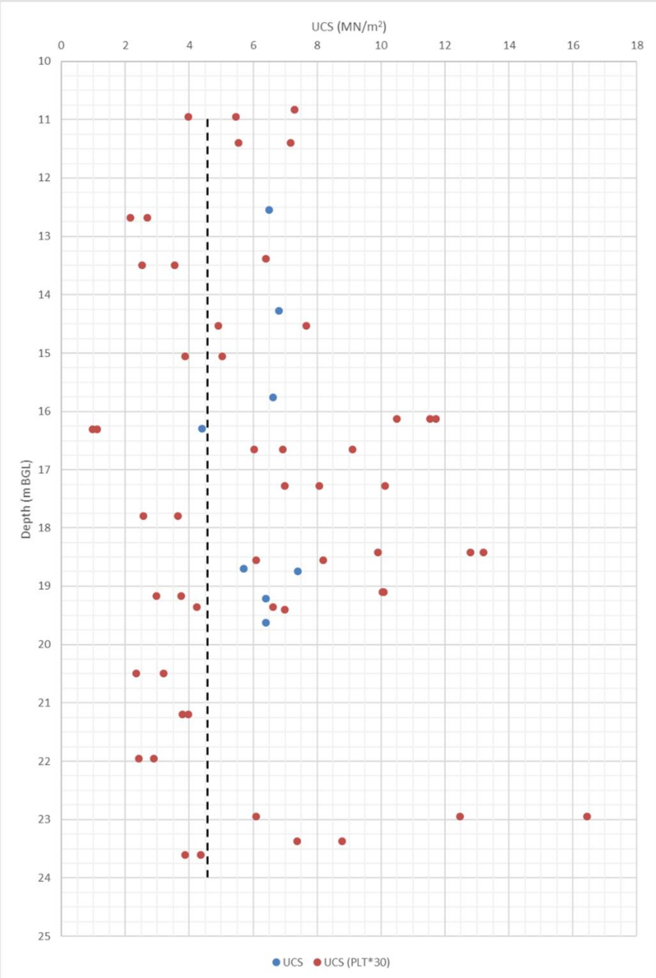
7.7.5 UNCONFINED COMPRESSIVE STRENGTH

Figure 7-7 presents a plot of unconfined compressive strength versus elevation based on point load testing and direct laboratory UCS testing of samples of the Intact Chester Formation Sandstone.

The point load index (I_{S50}) is converted to an equivalent UCS through the application of a correction factor, *K*. This correction factor is derived by correlating I_{S50} results with direct UCS tests at equivalent depths, and a *K* factor of 30 has been adopted for the site.

Based on Figure 7-7, a UCS of $4.5MN/m^2$ is considered appropriate for the Intact Chester Formation Sandstone.

Figure 7-7 - Unconfined Compressive Strength vs Depth - Chester Formation Sandstone



7.7.6 STIFFNESS

Values of Young's Modulus, *E'*, for the Intact Chester Formation Sandstone have been derived from the following relationship developed by Whitworth and Turner (1989) and presented in CIRIA 181 (Gannon et al, 1980):

$$E'(MN/m^2) = 275 * \sqrt{UCS}$$

Based on the UCS relationship and the characteristic UCS given in the previous section, the relationship suggests a Young's Modulus of 580 MN/m².

7.8 SUMMARY OF CHARACTERISTIC PARAMETERS

Table 7-6 – Summary of Characteristic Parameters

Parameter	Characteristic Value	Justification
Cohesive Made Ground		
Moist Bulk Unit Weight, γ_b (kN/m^3)	17	Low clay – BS 8002 (BSI, 2015)
Undrained Shear Strength, c_u (kN/m^2)	40	Field description & engineering judgement
Cohesive Glacial Till		
Moist Bulk Unit Weight, γ_b (kN/m^3)	21.7	Mean of laboratory testing
Undrained Shear Strength, c_u (kN/m^2)	c_u = 60kN/m^2 at 0.5m bgl then increasing linearly to 125kN/m^2 at 3.0m BGL c_u = 100kN/m^2 between 3m BGL and 6m BGL c_u = 200kN/m^2 between 6m and 10.0m BGL	Figure 7.4
Stiffness, E' (MN/m^2)	E' = 12MN/m^2 at 0.5m BGL then increasing linearly to 35MN/m^2 at 3.0m BGL. E' = 35MN/m^2 between 3.0m BGL and 6.0m BGL E' = 35MN/m^2 at 6.0m BGL then increasing linearly to 55MN/m^2 at 10.0m BGL.	Figure 7.5
California Bearing Ratio (%)	3	Appraisal of testing methods
Weathered Chester Formation Sandstone		
Moist Bulk Unit Weight, γ_b (kN/m^3)	20	Dense to very dense sand – BS 8002 (BSI, 2015)
Peak angle of internal friction, φ'_{peak} (°)	42	SPT $N1_{60}$ testing (Stroud, 1989) and engineering judgement
Stiffness, E' (MN/m^2)	250	SPT N_{60} testing (Clayton, 1995) and engineering judgement
Intact Chester Formation Sandstone		
Moist Bulk Unit Weight, γ_b (kN/m^3)	21.3	Mean of laboratory testing
UCS, σ_c (MN/m^2)	4.5	Figure 7.7

Parameter	Characteristic Value	Justification
Stiffness, *E'* (MN/m^2)	580	*E'* = 275√UCS (Whitworth & Turner, 1989)

8 GENERIC QUANTITATIVE RISK ASSESSMENT

8.1 INTRODUCTION

Legislation and guidance on the assessment of potentially contaminated sites acknowledges the need for a tiered risk based approach. This assessment represents a generic quantitative risk assessment (GQRA). It incorporates a comparison of site contaminant levels against generic assessment criteria (GAC) including a qualitative assessment of risk using the source-pathway-receptor model.

8.2 HUMAN HEALTH RISK ASSESSMENT

8.2.1 METHODOLOGY

In order to provide a consistent methodology for the assessment of contaminants, a series of soil GAC screening values have been calculated by WSP. Further detail of the risk assessment approach and methodology for the derivation of GAC is provided in Appendix G.

Based on the CSM, the reported soil concentrations were compared against the GAC for commercial land use. A conservative soil organic matter content of 1% was adopted for screening purposes. Appendix H presents a summary of the chemical data and screening reports.

8.2.2 HUMAN HEALTH RISK ASSESSMENT – SOILS

The screening assessment identified no exceedances of the adopted GAC for the contaminants of concern analysed as part of this investigation. Therefore, the reported soil concentrations are considered unlikely to present significant health risk to site users based on a commercial end use.

8.2.3 ASBESTOS

A total of 10 topsoil / Made Ground samples were screened for the presence of asbestos. No asbestos or asbestos containing material was identified in the samples submitted for screening.

It is noted additional areas of localised Made Ground may be present onsite (associated with infilled ponds / farm track). Therefore, it would be prudent to take precautions to minimise dust generation during the ground disturbance works. If suspected ACM is encountered during the ground works, professional advice should be sought.

8.3 CONTROLLED WATERS RISK ASSESSMENT

8.3.1 METHODOLOGY

The generic controlled waters risk assessment was conducted in accordance with the principles of EA 'Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination' 2006 (EA 2006) and the 'prevent and limit' approach of the 'Water Framework Directive' (2000/60 EC). Generic controlled waters risk assessments compare directly measured concentrations with standard assessment criteria. In this case, the following assessment was undertaken:

> **Level 2**- evaluates the concentrations of chemicals within the saturated zone immediately underlying a source area (i.e. taking dilution and attenuation in to account, in this case, groundwater analysis.

Appropriate water quality standards (WQS) are selected based on both a hierarchy of relevance to England and Wales and the receptors. Based on the CSM, the controlled water receptors include shallow perched/groundwater within the Till, underlying principal aquifer, onsite surface water features and off-site watercourses including a tributary of Whittle Brook. Therefore, the following hierarchies of WQS were considered to be appropriate.

Aquifers

- UK Drinking Water Quality Standards (DWS) from The Water Supply (Water Quality) Regulations 2000 (amended 2004)
- World Health Organisation Guidelines for Drinking Water Quality, Fourth Edition, Volume 1, (2011)
- World Health Organisation Petroleum Products in Drinking Water (2008)
- Environment Agency (EA) Supplementary Guidance on Hydrocarbons 2009)

Surface Waters

- Environmental Quality Standards (EQS) from The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

A summary of the groundwater samples in which exceedances of the water standards were identified are presented below. A summary of the chemical analysis in addition to screening output reports are provided in Appendix H.

8.3.2 GROUNDWATER AND SURFACE WATER

In total, three groundwater samples were taken from boreholes; BH8A06 and BH8B03 installed within the Till and BH8A03 installed within the Sandstone bedrock.

Relatively low/trace dissolved concentrations in exceedance of the adopted WQS protective of groundwater and surface water were identified in the wells as summarised below:

Groundwater

- Sulphate
- PAHs (benzo(a)pyrene)

Surface Water

- Metals (cadmium, chromium, copper, lead, nickel zinc)
- Aromatics and Aliphatics (Aromatic C12-16, Aromatic C16-21 and Aromatic C21-35) and;
- PAHs (benzo(a)pyrene and fluoranthene)

The above WQS are not considered to represent potentially unacceptable risks to controlled waters due to the following:

- The exceedances are considered to be marginal.
- The absence of historical potential sources of soil contamination onsite.
- Absence of evidence of mobile contamination within soil and groundwater during the investigation.
- The TPH fractions predominantly comprise heavy end aromatics (C12 -C35) which characteristically have limited solubility and mobility in groundwater.
- The limited hydraulic connectivity with the underlying Principal Aquifer and surface water receptors.

Based on the above, the overall risk to controlled waters is considered to be low.

8.4 PRELIMINARY GROUND GAS ASSESSMENT

Monitoring well response zones were predominantly installed within the Till due to an absence of a significant thickness of Made Ground or organic material. Two locations were installed within the sandstone bedrock. A review of the groundwater depths compared to the monitoring well response zones indicates a number of the wells were fully flooded during the monitoring. Gas monitoring results from these locations are not considered to be representative of the ground gas regime on site and therefore were not included in the ground gas risk assessment. In addition, the ground gas monitoring results from BH8A03 and BH8B03 during round 3 are considered to be anomalous and have been discounted. Three monitoring rounds are currently outstanding; the gas risk assessment shall be updated upon completion of the monitoring programme.

Table 8-1 presents the gas screening values (GSV) for each type of strata in accordance with C665. The GSV is the maximum volume of methane or carbon dioxide gas that could be produced each hour and is calculated as follows:

GSV = maximum steady carbon dioxide concentrations or methane concentrations (%) / 100 x maximum steady flow rate (l/hr).

As no methane was detected, the GSV has been calculated based on carbon dioxide concentrations.

Table 8-1 – Summary of Ground Gas Monitoring Results

Strata	Max Steady Flow Rate (l/hr)	Max Steady Carbon Dioxide (%v/v)	GSV	Characteristic Situation
Till	2.00	1.60	0.032	1 (very low risk)
Sandstone	3.70	3.10	0.1147	2 (low risk)

Based on the above the GSV for the Till was 0.032/hr which classifies the site as Characteristic Situation 1 (very low risk) with no gas protection measures required. The GSV for the sandstone was 0.1147l/hr which classifies the site as Characteristic Situation 2 (low risk) with gas protection measures indicated to be required.

It is considered that due to the significant thickness of the low permeability Till overlying the sandstone, this will inhibit and/or provide a barrier to gas migration from the bedrock. Therefore, a classification of CS1 for the site is considered to be appropriate (no gas protection measures required). This preliminary ground gas assessment shall be updated following completion of the required number of monitoring visits.

8.5 UNDERGROUND SERVICES ASSESSMENT

Based on the chemical laboratory testing undertaken it is considered unlikely that there will be any exceedances of the PE threshold criteria provided by United Utilities. A pipeline risk assessment should be undertaken to confirm this once detailed service plans and finished surface levels are available.

9 REVISED CONCEPTUAL SITE MODEL

The following section provides a revised conceptual model for the site as a result of the generic assessment of the analytical results and their risk to human health and controlled waters based on a commercial end use. Table 9-1 presents a summary of the potential pollutant linkages.

Table 9-1 – Summary of Potential Pollutant Linkages

Source	Pathway	Receptor	Comments
Human Health			
Shallow impacted soil (non- volatile chemical contamination)	Direct contact, ingestion, or inhalation of soil-bound contaminants	Onsite future commercial workers	**Linkage Not Active** Low/trace concentrations of contaminants detected.
		Construction workers	
		Future maintenance workers	
Free asbestos in soil	Inhalation of asbestos fibres	Onsite future commercial workers	**Linkage Not Active** No ACM or asbestos fibres detected in topsoil or Made Ground
		Construction workers	
		Future maintenance workers	
Shallow impacted soil (volatile contamination)	Vapour inhalation of volatile compounds	Onsite future commercial workers	**Linkage Not Active** No impact identified.
		Construction workers	
		Future maintenance workers	
Hazardous ground gases	Vapour inhalation of ground gases	Onsite future commercial workers	**Linkage Not Active (preliminary)** Preliminary data indicates the site is CS1 and ground gas protection measures are not required – the assessment shall be updated upon completion of required number of monitoring rounds.
		Construction workers	
		Future maintenance workers	
Controlled Waters			
Dissolved phase impacted groundwater	Migration to the wider environment	Secondary Undifferentiated aquifer (Till)	Whilst marginal exceedances of metals, TPH, sulphate and PAH have been detected, the risk to controlled waters is considered to be low.
		Principal Aquifer	

Source	Pathway	Receptor	Comments
Human Health			
		Onsite surface water features	
		Offsite surface water features (tributary of Whittle Brook)	
Building Infrastructure			
Shallow impacted soil	Permeation of contamination into unprotected water pipes	Building infrastructure	**Linkage to Be Confirmed** Water pipeline risk assessment to be completed

9.1 RISK EVALUATION

Based on the conditions encountered during the geo-environmental investigations, risks to the key receptors are summarised below:

Risks to Human Health: The detected soil and groundwater concentrations are not considered to present an unacceptable health risk to future commercial workers and construction and maintenance workers.

Risks to Controlled Waters: The exceedances of the adopted screening criteria for dissolved phase metals, petroleum hydrocarbons and sulphate are not considered to present an unacceptable risk to controlled waters given:

- The exceedances are considered to be marginal.
- The absence of historical potential sources of contamination onsite.
- Absence of evidence of mobile contamination within soil and groundwater during the investigation.
- The TPH fractions predominantly comprise heavy end aromatics (C12 -C35) which characteristically have limited solubility and mobility in groundwater.
- The limited hydraulic connectivity with the underlying Principal Aquifer and surface water receptors.

Risks to Building Infrastructure: The detected soil concentrations are unlikely to exceed PE threshold criteria provided by United Utilities. A pipeline risk assessment should be undertaken to confirm this once detailed service plans and finished surface levels are available.

10 CONCLUSIONS

10.1 GROUND CONDITIONS

The investigation has confirmed that ground conditions comprise a general sequence of topsoil overlying predominantly cohesive Till deposits over the Sherwood Sandstone, which was encountered from between 7.60m and 14.20m bgl. Made Ground was observed locally and, limited in thickness and generally associated within land drains.

Two groundwater bodies were encountered during the investigation; a shallow perched water within the Till, considered to be in limited vertical and lateral connectivity with the wider groundwater environment and a deeper regional groundwater body within the bedrock.

10.2 ENVIRONMENTAL

Based on the findings of this investigation, the potential health risk associated with chemical contamination are considered to be low and acceptable based on a proposed commercial development at the site.

No asbestos or asbestos containing material was identified. It is noted additional areas of localised Made Ground may be present onsite. Therefore, it would be prudent to take precautions to minimise dust generation during the ground disturbance works. If suspected ACM is encountered during the ground works, professional advice should be sought.

Elevated exceedances of metals, sulphate, TPH and PAHs were recorded from groundwater in samples when compared with WQS protective of groundwater and surface waters. Groundwater samples collected from the Till are considered to represent perched bodies of water and are considered unlikely to be in connectivity with the underlying sandstone (Principal Aquifer) and surface water features. Based on the surface water and groundwater assessments, there is considered to be a low risk posed to controlled waters.

The preliminary ground gas risk assessment classifies the site as Characteristic Situation 1 based on the assessment of ground gas monitoring data. As such, no ground gas protective measures are considered to be required. A final report with an updated gas risk assessment will be submitted upon completion of the required number of gas monitoring visits.

A pipeline risk assessment should be undertaken to confirm drinking water pipeline requirements once detailed service plans and finished surface levels are available.

In order to support the redevelopment at the site, a Remediation Strategy has been prepared and is detailed within the following section.

11 REMEDIATION STRATEGY

11.1 REMEDIATION WORKS

11.1.1 UNANTICIPATED GROUND CONDITIONS

During site redevelopment, construction workers shall remain vigilant to the possible risk of encountering isolated areas of contaminated material.

Should potentially contaminated material be encountered works in this area must immediately cease, a phased programme of assessment should be established and the local authority should be notified. It is recommended that advice from an environmental consultant be sought in this event. Examination and possible further testing of the soils shall be completed to assess the risk to health and safety of site workers and the environment, which should be carried out by a competent person. The Remediation Strategy may need to be modified if additional areas of contamination are encountered, which will also need to be documented in validation reports.

11.1.2 MATERIALS MANAGEMENT PLAN

The management of large volumes of the reuse of site won materials should be undertaken under a Materials Management Plan (MMP). The MMP is a document which seeks to simplify reuse of materials in accordance with Waste Regulations while maintaining adequate management to ensure that the practices undertaken on site are suitable and documented.

The CL:AIRE document 'Definition of Waste: Development Industry Code of Practice' (DoW CoP) details the requirements for an MMP and provides a declaration form to ensure the appropriate documentation is in place. Such a form should be completed by a Qualified Person and be registered with the EA via CL:AIRE.

11.2 VERIFICATION AND VALIDATION

Any further investigation and remedial works undertaken during the Remediation Phase shall be fully documented and which will be forwarded to the Contaminated Land Officer at Warrington Council for approval following completion of this phase.

11.2.1 VALIDATION REPORTING

Following completion of the development, a final validation report shall be completed by the contractor's appointed environmental consultant for all stages of remedial works, which shall include the following:

- Summary of pre-development conditions at the site;
- Summary of land regrading / raising exercise including details and nature of any contamination encountered that was not identified in the site investigation;
- Description of remedial measures completed at the site to include obstructions encountered, cover system placement (if required) and waste disposal records;
- Information on waste disposal will include details on the movement of vehicles taking any waste material off-site and copies of any Waste Transfer Notes; and
- Records of any consents, permits authorisation and/or licences held or obtained by the Contractor (and sub-contractors) relevant to the Works.

The final report will be submitted to the regulators to confirm that remedial measures have been taken and no further remedial action is required. This will enable the sign-off of the outstanding contaminated land planning conditions.

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