



EARTH ENVIRONMENTAL
& GEOTECHNICAL



GeoEnvironmental Investigation

Bentley Street

Rochdale

September 2022

On behalf of



Earth Environmental & Geotechnical Ltd
Houldsworth Mill Business & Arts Centre
Houldsworth Street
Stockport
SK5 6DA

Tel : 0161 975 6088

Email info@earthenvironmental.co.uk
www.earthenvironmental.co.uk

**GEOENVIRONMENTAL
SITE INVESTIGATION
REPORT**

BENTLEY STREET

ROCHDALE

Report Ref: A4575/22/SI

SEPTEMBER 2022

Prepared on Behalf of:

Koplar Group Ltd

By:

Earth Environmental & Geotechnical Ltd
Houldsworth Mill Business & Arts Centre
Houldsworth Street
Stockport
SK5 6DA

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Prepared for: Koplar Group Ltd

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Houldsworth Mill Business & Arts Centre
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Stockport
SK5 6DA

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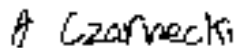
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Written by:



A Ellams
Senior GeoEnvironmental Consultant

Approved by:



Adam Czarnecki
Managing Director

TABLE OF CONTENTS

1.0	EXECUTIVE SUMMARY	1
2.0	INTRODUCTION	2
2.1	BACKGROUND	2
2.2	PREVIOUS INVESTIGATIONS.....	2
2.3	TERMS OF REFERENCE	3
2.4	REPORT SCOPE.....	4
2.5	LIMITATIONS OF THE STUDY	4
3.0	SITE LOCATION & DESCRIPTION.....	5
3.1	PROPOSED DEVELOPMENT	7
4.0	SITE INVESTIGATION.....	9
4.1	EXPLORATORY FIELDWORK.....	9
4.2	LABORATORY TESTING	11
4.2.1	<i>Geotechnical Testing</i>	11
4.2.2	<i>Environmental Testing</i>	12
5.0	GROUND CONDITIONS ENCOUNTERED.....	13
5.1	SOIL PROFILE ENCOUNTERED	13
5.2	OBSERVABLE INDICATIONS OF CONTAMINATION	13
5.3	OBSTRUCTIONS.....	14
5.4	GROUNDWATER	14
5.5	LAND GAS.....	14
6.0	ENGINEERING PROPERTIES OF SOILS ENCOUNTERED.....	15
6.1	GENERAL.....	15
6.2	MADE GROUND.....	15
6.2.1	<i>Cohesive</i>	15
6.2.2	<i>Granular</i>	16
6.3	SUPERFICIAL DEPOSITS	16
6.3.1	<i>Clay</i>	16
6.3.2	<i>Sand</i>	21
7.0	GEOTECHNICAL ASSESSMENT	22
7.1	PROPOSED DEVELOPMENT	22
7.2	GROUND CONDITIONS ENCOUNTERED	22
7.3	FOUNDATION CONSIDERATIONS.....	22
7.3.1	<i>Ground Improvement</i>	23
7.3.2	<i>Piled Foundations</i>	23
7.4	PAVEMENT DESIGN.....	23
7.5	CHEMICAL ATTACK ON BURIED CONCRETE.....	24
7.6	SUITABILITY OF EXCAVATED MATERIALS.....	24
7.7	TEMPORARY WORKS.....	25
8.0	SOIL CONTAMINATION RISK ASSESSMENT	26
8.1	TIER I HUMAN HEALTH SOIL RISK ASSESSMENT – GROUNDWORKERS DURING DEVELOPMENT.....	26
8.2	TIER I HUMAN HEALTH SOIL RISK ASSESSMENT – FUTURE SITE USERS.....	26
8.3	SOIL WASTE ASSESSMENT	29
9.0	GROUNDWATER CONTAMINATION RISK ASSESSMENT.....	31
10.0	GROUND GAS AND RADON GAS CONTAMINATION RISK ASSESSMENT	33
10.1	RADON GAS	33
10.2	ANALYSES OF MONITORING RESULTS	33

11.0	CONCLUSIONS & RECOMMENDATIONS	36
11.1	SOIL CONTAMINATION	36
11.2	ASBESTOS	36
11.3	FOUNDATIONS	36
11.4	EASTERN BOUNDARY	36
11.5	SOIL DISPOSAL	36
11.6	LAND GAS.....	36
11.7	PAVEMENT DESIGN.....	37
11.8	GROUNDWATER	37
11.9	RISK TO BURIED (WATER) SERVICES.....	37
11.10	SITE PERSONNEL	37
11.11	OTHER MATTERS.....	37

LIST OF FIGURES

Figure 1	Aerial Photograph Showing Site Location
Figure 2	General Site Photographs
Figure 3	Proposed Development Plan
Figure 4	Exploratory Hole Location Plan
Figure 5	SPT v Depth Plot
Figure 6	Strength v Depth Plot
Figure 7	Plasticity Chart

TABLES

Table 1	Shear Strength Definitions
Table 2	Summary of Exploratory Holes Undertaken
Table 3	Summary of Laboratory Geotechnical Tests Undertaken
Table 4	Summary of Ground Conditions Encountered
Table 5	Summary of Laboratory Geotechnical Test Results
Table 6	Summary of Design Parameters (Clay)
Table 7	Soil Desiccation Indicators in the Clay
Table 8	Summary of Design Parameters (Sand)
Table 9	Comparison of Capping Thickness with and without Geotextile
Table 10	Summary of Guideline Values for Protection of Workers and the General Public During Development of Contaminated Land
Table 11	Soil Results Comparison with C4SL/S4UL Values
Table 12	Summary of Asbestos Encountered
Table 13	Waste Classification of Soils
Table 14	Summary of WAC Test Results
Table 15	Groundwater Results Comparisons with EQS/Drinking Water Quality Values
Table 16	Characteristic Situations
Table 17	Gas Protection Point Score Required

APPENDICES

Appendix 1	Exploratory Hole Logs
Appendix 2	Ground Gas Monitoring Results
Appendix 3	Geotechnical Testing Results
Appendix 4	Chemical Testing Results
Appendix 5	Water Chemical Testing Results
Appendix 6	Soil Waste Assessment
Appendix 7	Report Limitations

1.0 EXECUTIVE SUMMARY

Appointment	A Site Investigation has been commissioned by Tang & Associates Ltd on behalf of Koplar Group Ltd (the Client), to examine ground conditions for a proposed new residential development at a site off Bentley Street, Rochdale.
The Investigation	The investigation comprised five cable percussive boreholes with associated sampling and in situ testing, laboratory geotechnical and contamination testing. Following visits were made to acquire water samples and for gas monitoring.
The Site	The site is located in Rochdale, Greater Manchester approximately 2.07km from Rochdale Town Centre. The approximate National Grid Reference for the centre of the site is SD 89479 14911 (X: 389479, Y: 414911) The site is underlain by Devensian Till Deposits and the solid geology beneath the site is the Pennine Lower Coal Measures Formation (Carboniferous Age).
Site History	Historically the site was undeveloped open land in a generally rural area. By 1893 the centre of the site was occupied by a pond and a footpath was present on the west of the site. By 1910, the pond on site has reduced in size and additional embankments present suggest fill had been placed on the site and several smaller structures were also located on site. By 1929 the pond is assumed to have been backfilled and the 1939 map indicates the site had undergone further filling. The 1959 map indicated further filling onsite with several smaller structures present. There were no significant changes on the site between mapping records dated 1974 to 2006 and a site visit conducted in 2012 identified that the site remained vacant and undeveloped.
Ground Conditions Encountered	The exploratory holes generally encountered Made Ground to a maximum depth of 8.00m. Underlying the Made Ground in all exploratory boreholes were superficial deposits of variable Clay and Sand with clay bands to a maximum depth of 10.00m bgl. Groundwater was encountered at depths between 4.10m and 5.20m bgl during the fieldwork and encountered during subsequent monitoring visits.
Geotechnical Assessment	Shallow strip/pad foundations are not considered appropriate for the proposed development. Other foundation options may need to be considered such as ground improvement or piles. Pavement Design – preliminary design value = 1% in Made Ground. Design Sulphate Class = DS-1 ACEC Site Classification = AC-1s
Contamination Assessment	Risk from contamination to groundworkers during development – Moderate to Low Risk from contamination to future site users – Moderate to Low Asbestos identified in one sample. Soil Waste Assessment: Eight samples classified as Non-Hazardous. Exceedances identified in ground water samples.
Ground Gas Assessment	Site classified as Characteristic Situation 2 – 'low risk'. Ground gas protection measures are considered necessary.
<i>This sheet is intended to provide a summary only of the report. It does not provide a definitive engineering analysis for the purposes of costing or construction and is subject to the limitation of the agreed brief.</i>	

2.0 INTRODUCTION

2.1 Background

A Site Investigation has been commissioned by Tang & Associates Ltd on behalf of Koplar Group Ltd (the Client), to examine ground conditions for a proposed new residential development at a site off Bentley Street, Rochdale.

2.2 Previous Investigations

2.2.1 Planning Application to Rochdale Borough Council, 12/55738/OUT, dated July 2012.

A planning application was submitted to Rochdale Borough Council (Reference: 12/55738/OUT) for an Outline Planning Application for the access and siting of 9 dwellings (landscaping, scale and appearance reserved for subsequent approval). The planning application was granted subject to conditions in February 2013.

2.2.2 Planning Application to Rochdale Borough Council, 13/01023/REM, dated September 2013.

A planning application was submitted to Rochdale Borough Council (Reference: 13/01023/REM) for a Reserved matters application following outline approval 12/55738/OUT for the appearance, landscape, and scale for the erection of 9 dwellings. The planning application was granted subject to conditions in December 2013.

A Phase I Desk Study was prepared by Chandos Remediation Services to supplement the planning application. The desk study identified the following:

Historically the site was undeveloped open land (from 1851) located adjacent to the Rochdale & Burnley Tramway, in a generally rural area northeast of the village of Shaw Clough.

By 1893 the centre of the site was occupied by a pond, noted to possibly be a clay pit associated with the nearby brickworks.

A small structure, indicated to be a blacksmiths 'smithy', was also located in the southwest corner of the site (in the location of the existing garage).

A footpath was present on the west of the site (located in its modern-day position) providing access between the tram line (now Whitworth Street) and an unnamed road (now Bentley Street). By 1910, the pond on site has reduced in size and additional embankments present suggest fill had been placed on the site.

Several smaller structures were also located adjacent to the smithy in the southwest corner of the site.

By 1929 the pond is assumed to have been backfilled and the 1939 map indicates the site had undergone further filling.

A small pond or depression is also shown in the northeast corner of the site. The 1959 map indicated further filling onsite with several smaller structures, possibly sheds or private garages located in the west of the site adjacent to the footpath. There were no significant changes on the

site between mapping records dated 1974 to 2006 and a site visit conducted in 2012 identified that the site remained vacant and undeveloped.

A footpath was evident in the west of the site and the remainder of the site was occupied by vegetation including mature trees, scrub, and knotweed. It was noted that other than fly tipped materials there was no obvious indication of potential contaminants on site.

Potential on-site sources of contamination were identified as Ground Gas associated with onsite fill material and two historical landfills located within 50m of the site. However, the desk study states 'Nearly 50 years have passed since the last recorded filling took place onsite and it is anticipated that by now any significant gas generation will have ceased. However, the fill materials could still have the potential to generate some residual carbon dioxide and possibly methane at concentrations that might require remedial measures to be incorporated within the proposed structure'.

Another potential source of ground gas was identified to be the nearby landfill to the south and southwest of the site, in the location of a historical brickworks. However, the material deposited in the landfill was reported as inert construction waste and again deemed by the desk study report 'unlikely to generate significant volumes of ground gas'.

Further potential sources of contamination were identified as a rail cutting to the north, backfilled with unknown material and the small buildings/garage located along the southern boundary.

No other significant, potentially contaminative land uses were identified on site.

An intrusive investigation was recommended to establish geotechnical parameters for the design of foundations, floor slabs and pavement construction. As part of the geotechnical investigation, it was recommended that samples are recovered for contamination testing, as well as installing ground gas monitoring standpipes to assess ground gas risk.

2.2.3 Planning Application to Rochdale Borough Council, 22/00185/FUL, dated April 2022.

A planning application was submitted to Rochdale Borough Council (Reference: 22/00185/FUL) for the Erection of 9 no. two-storey detached and semi-detached dwellings together with associated parking and landscaping. The planning application was withdrawn in July 2022.

2.3 Terms of Reference

Earth Environmental and Geotechnical Ltd (EEG) have been commissioned by the Client, to undertake a Site Investigation of the site in accordance with proposal A4575/22 dated 20th May 2022. The objectives of this investigation are as follows:

- *Provide factual information on the work undertaken including sampling location plan, borehole logs, geotechnical and chemical testing.*
- *Tier 1 (semi-quantitative) risk assessment will be undertaken. This will compare the concentrations of soil, ground gas and groundwater contaminants identified against current and appropriate published guidelines, in relation to identified receptors, e.g., existing/ future end users and site neighbours.*
- *Classification of potential surplus soils for offsite disposal.*
- *Assessment of ground conditions for foundation design.*

2.4 Report Scope

This report presents full factual records of the site work carried out, the ground conditions encountered in the exploratory holes, the in situ and laboratory test results. All information collected has been used to provide an interpretation of the ground conditions, with recommendations on geotechnical design and potential ground contamination risks for the proposed development.

2.5 Limitations of the Study

The report is written in the context of an agreed scope of work and budget and should not be used in a different context. New information, improved practices or changes in legislation may require a reinterpretation of the report in whole or in part. EEG reserve the right to amend either conclusions or recommendations in light of any further information that may become available. The report is provided for the sole use by the client and is confidential to them.

Recommendations within this report are also based on exploratory records and examination of samples and, where applicable, laboratory tests. No liability can be accepted for conditions not revealed by the boreholes particularly at intervening locations. Whilst every effort is made to ensure accuracy of data supplied, all opinions expressed as to the spatial distribution of strata between sampling locations is for guidance only and no responsibility is accepted as to its accuracy.

3.0 SITE LOCATION & DESCRIPTION

The site is located in Rochdale, Greater Manchester approximately 2km from Rochdale Town Centre. The approximate National Grid Reference for the centre of the site is SD 89479 14911 (X: 389479, Y: 414911), with the closest postcode being OL12 6EU.

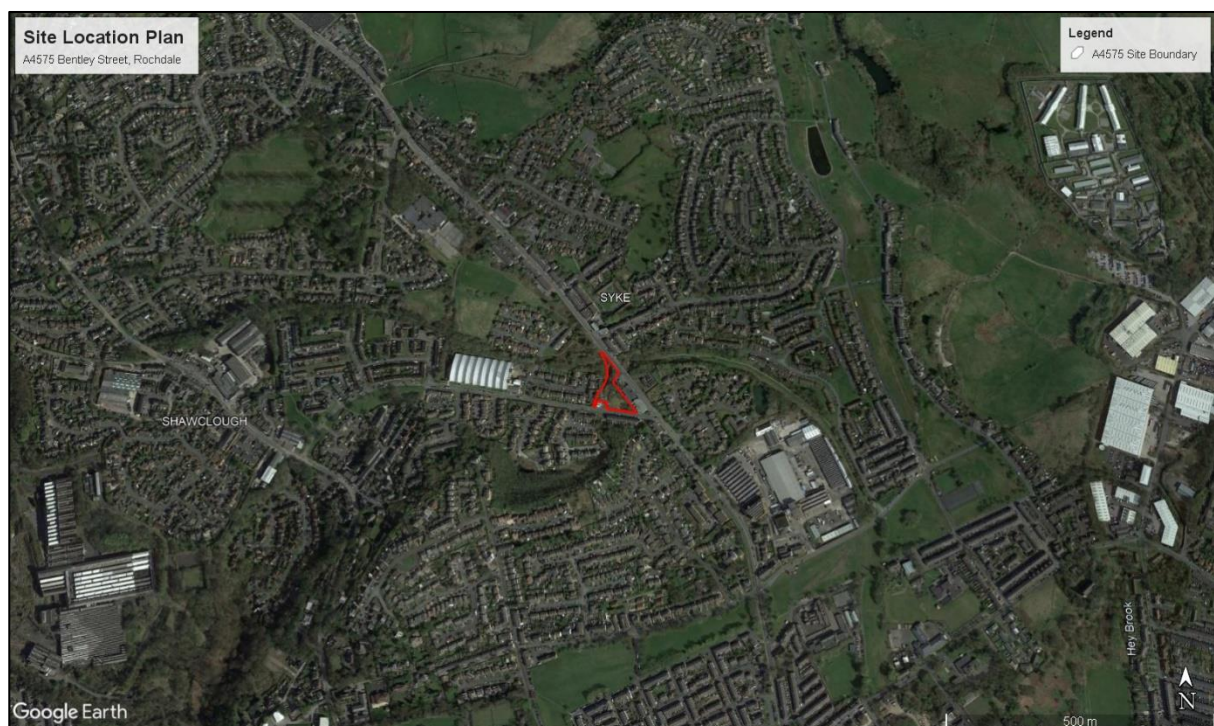
The site is an irregular shaped parcel of land with current access either via footpath in the southwest corner of the site or via heras fencing along the southern boundary, both off Bentley Street to the south of the site. The maximum dimensions of the proposed site are 111m north to south and 92m east to west. The site occupies an area of approximately 0.34 hectares.

The site is currently vacant land, occupied only by users of the footpath along the western boundary of the site. The site has recently undergone earthworks to level out the site, prior to the site investigation and construction beginning.

The surrounding area comprises predominantly of residential properties with a small vehicle garage located adjacent to the site in the southwest corner as well as a Tesco Express store and car wash are located adjacent to the eastern boundary of the site.

The site location is shown in the aerial photograph presented as Figure 1, below.

Figure 1: Aerial Photograph Showing Site Location



General site photographs are presented in Figure 2 overleaf.

Figure 2: General Site Photographs

Photograph taken viewing east showing the eastern part of the site



Photograph taken viewing north showing the central part of the site.



Photograph taken viewing north showing the north-western part of the site



Photograph taken viewing south showing the south-western part of the site



3.1 Proposed Development

It is understood that the client wishes to construct nine detached and semi-detached residential properties with associated parking and soft landscaping.

Site access will be retained via Bentley Street to the south of the site, via a new access road.

The proposed development layout details are shown in Figure 3 below.

Figure 3: Proposed Development Plan



4.0 SITE INVESTIGATION

4.1 Exploratory Fieldwork

The fieldwork was carried out by EEG on the 11th and 12th July 2022 and comprised:

- Five 150mm diameter boreholes (designated CP1 to CP5 inclusive) were sunk to a depth of 10.00m below existing ground level, using a light cable percussion boring rig. With this type of rig boreholes are advanced by the percussive action of drill tools suspended on a winch-driven steel cable. The tools generally include a clay-cutter for penetrating fine-grained soils, and a shell for use in coarse-grained, or “granular”, soils. Representative disturbed samples were recovered as boring proceeded. In addition, “undisturbed” 100mm diameter samples (U100’s) were recovered, as appropriate, using standard thick-walled, open-drive samplers, with a steel cutting shoe, dynamically driven by a sliding hammer. Standard Penetration Tests (SPTs) were undertaken in the boreholes in accordance with BS EN ISO 22476-3. Chiselling techniques, using a chisel or shell, were employed where necessary, to advance the boreholes through obstructions or into hard strata. Details of groundwater conditions were noted and are indicated on the attached borehole logs. These observations relate only to the time of boring, and do not necessarily reflect possible seasonal fluctuations. They may have been affected by the installation of casing, or the addition of water to aid boring. Borehole logs are included in Appendix 1.
- 50mm diameter standpipes were installed in all the exploratory boreholes to a maximum depth of 5.00m below ground level. Installation and backfill details are shown with the appropriate borehole log sheet. EEG carried out groundwater/ground gas monitoring in standpipes after the fieldwork period, the results of which are presented in Appendix 2.

Exploratory hole locations were selected prior to the site works by the Client, based on the proposed development layout.

Prior to excavation, each exploratory location was scanned using a Cable Avoidance Tool (CAT) in order to locate unrecorded underground services, and the exploratory locations were repositioned if necessary.

On completion, samples recovered from the site were taken to specialist laboratories for chemical and geotechnical testing.

Soil samples were recovered in 250g glass amber jars and 1kg plastic tubs. All the samples were labelled and stored in cool boxes prior to being collected by courier at the end of the day for delivery to the DETS laboratory.

If collection was not possible the same day, then samples were stored in the sample storage fridge at the EEG offices below 4°C.

Samples were tracked using appropriate Chain of Custody forms provided by DETS.

It should be noted that hexavalent chromium soil is analysed using the USEPA recommended method of alkaline leach. This method limits chromium (VI) reduction to chromium (III).

All site investigation work was supervised full time by a representative of EEG. The logging of soils and rocks has been carried out in accordance with BS5930^(2015+A1:2020) except where superseded by the soil and rock description methodology in BS EN14688-1⁽²⁰⁰²⁾, BS EN 14688-2⁽²⁰⁰⁴⁾ and BS EN 14689-1⁽²⁰⁰³⁾.

All sampling locations were surveyed by use of a hand-held Trimble GeoXH GPS instrument that is capable of surveying to an accuracy of less than 10mm depending on satellite coverage, proximity to trees and building structures.

The descriptive terminologies such as firm, etc formerly used within older versions of BS5930 to describe strength now solely relate to consistency. Shear strength is now defined related to results obtained in the field (using a hand vane for example) or in the laboratory (from triaxial tests), as detailed in Table 1 below.

Table 1: Shear Strength Definitions

Term based on measurement	Undrained Strength (c_u) definition in kN/m ² (from BS EN ISO 14688-2: 2004, 5.3, Table 5)
Extremely Low Strength	<10
Very Low Strength	10 to 20
Low Strength	20 to 40
Medium Strength	40 to 75
High Strength	75 to 150
Very High Strength	150 to 300
Extremely High Strength	300 to 600

An Exploratory Hole Location Plan is presented as Figure 4, overleaf.

Figure 4: Exploratory Hole Location Plan



A summary of exploratory holes undertaken during the investigation are presented in Table 2 below.

Table 2: Summary of Exploratory Holes Undertaken

Hole	Type*	Depth (m)	Date Started	Date Finished	Easting (m)	Northing (m)	Backfill Details**
CP1	CP	10.00	11/08/2022	11/08/2022	389508	414855	SP
CP2	CP	10.00	11/08/2022	11/08/2022	389490	414897	SP
CP3	CP	10.00	12/08/2022	12/08/2022	389466	414894	SP
CP4	CP	10.00	11/08/2022	12/08/2022	389479	414925	SP
CP5	CP	10.00	12/08/2022	12/08/2022	389459	414929	SP
*CP = Cable Percussive Borehole							
**SP = Standpipe							

4.2 Laboratory Testing

4.2.1 Geotechnical Testing

A programme of laboratory testing was carried out on samples taken from the various strata to assist in classification and determine the engineering properties of the materials underlying the site. The tests were scheduled by EEG and carried out by Murray Rix. The test procedures used were generally in accordance with the methods described in BS1377:1990. Details of the specific tests used in each case are given in Table 3, overleaf.

Table 3: Summary of Laboratory Geotechnical Tests Undertaken

TEST	STANDARD	No.
Moisture Content	BS1377:1990 Part 2, Clause 3.2	15
Liquid Limit, Plastic Limit, Plasticity Index	BS1377:1990 Part 2, Clause 4/5	10
Particle size distribution (wet)	BS1377:1990 Part 2, Clause 9.2	4
Sulphate content of 2:1 soil: water extract	BS1377:1990 Part 3, Clause 5	5
pH value	BS1377:1990 Part 3, Clause 9	5
Triaxial tests		
“Quick” undrained with multistage loading	BS1377:1990 Part 7, Clause 9	5

The results of the laboratory geotechnical tests are discussed in Section 6 and included in Appendix 3.

4.2.2 Environmental Testing

The environmental chemistry of the ground was investigated by specialist chemical analysis of selected samples, scheduled by EEG, and carried out by DETS, a UKAS and MCERTS accredited laboratory.

Chemical analyses were carried out on eight soil samples and were submitted for the following suite of determinants:

Asbestos Screen, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc, Cyanide, Phenol, Sulphate (SO₄), Sulphide, pH, Soil Organic Matter, Extractable Petroleum Hydrocarbons (EPH), Speciated Petroleum Hydrocarbon and Speciated Polyaromatic Hydrocarbons (PAH).

Waste Acceptance Criteria Testing (WAC) was also carried out on two soil samples.

Full results of the laboratory contamination tests are discussed in Section 8 and included in Appendix 4.

Chemical analyses were also carried out on three groundwater samples and were submitted for the following suite of determinants:

Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc, Cyanide, Phenol, Sulphate (SO₄), Sulphide, pH, Total Organic Carbon (TOC), Extractable Petroleum Hydrocarbons (EPH), Speciated Petroleum Hydrocarbon and Speciated Polyaromatic Hydrocarbons (PAH).

Full results of the laboratory contamination tests are discussed in Section 9 and included in Appendix 5.

5.0 GROUND CONDITIONS ENCOUNTERED

5.1 Soil Profile Encountered

BGS digital mapping shows the site is underlain by superficial deposits of Devensian Till, comprising Diamicton. The solid geology beneath the site is recorded as the Pennine Lower Coal Measures Formation, comprising mudstone, siltstone, and sandstone (Carboniferous Age). The sequence of strata encountered beneath the site was as follows:

- **Made Ground** – Variable Made Ground was encountered in all of the exploratory holes to a maximum depth of 8.00m bgl, comprising:
 - Sandy gravelly CLAY containing gravel of sandstone, ash and redbrick
 - Sandy GRAVEL containing gravel of sandstone
 - COBBLES of sandstone

- **Superficial Deposits** –

Clay was encountered in exploratory holes CP01, CP02, CP04 and CP05 to a maximum depth of 10.00m bgl, comprising:

- Sandy CLAY
- Sandy gravelly CLAY containing gravel of sandstone

Sand was encountered only in exploratory hole CP03 to a maximum depth of 10.00m bgl, comprising:

- Clayey gravelly SAND containing gravel of sandstone

The depths of the various materials encountered in the exploratory holes are summarised in Table 4, below.

Table 4: Summary of Ground Conditions Encountered

Hole	Depth to Stratum (m bgl)				GROUNDWATER (m bgl)
	MADE GROUND		SUPERFICIAL DEPOSITS		
	Cohesive	Granular	CLAY	SAND	
CP01	GL – 6.00	-	6.00 – 10.00+	-	-
CP02	GL – 4.50	4.50 – 5.90	5.90 – 10.00+	-	4.50
CP03	0.40 – 4.00	GL – 0.40	-	4.00 – 10.00+	-
CP04	GL – 4.00	4.00 – 7.00	7.00 – 10.00+	-	5.20
CP05	GL – 3.00	3.00 – 8.00	8.00 – 10.00+	-	4.10

5.2 Observable Indications of Contamination

Gravel/cobbles of sandstone and red brick were observed in the Made Ground encountered on site, but these materials are generally considered inert.

However, gravel of ash was also encountered in the Made Ground.

A strong hydrocarbon odour was observed in the Made Ground of CP02, CP04 and CP05.

No other visual or olfactory indications of contamination were observed.

5.3 Obstructions

No Man-Made obstructions were encountered in any of the exploratory hole locations.

5.4 Groundwater

Groundwater was encountered in CP02, CP04 and CP05 at depths between 4.10m and 5.20m bgl during the fieldwork.

Subsequent monitoring in the standpipes encountered groundwater at depths between 2.40m bgl and 5.80m bgl.

On the first monitoring visit, samples of water were recovered for chemical testing from CP2, CP3 and CP5.

5.5 Land Gas

Results obtained during six monitoring visits on the 28th July 5th, 11th, 18th and 25th of August and 1st September 2022, indicated Methane (CH₄) levels ranging from 0.0% and 0.2% by volume, Carbon Dioxide (CO₂) levels ranging from 0.1% to 12.1% by volume, and Oxygen (O₂) levels ranging from 0.4% to 21.1% by volume. Gas flows of -0.1l/hr to 0.1l/hr were recorded, together with atmospheric pressures between 995 mb and 1006 mb.

It should be noted that the concentrations and levels of mobile liquid and gaseous materials are likely to vary with time. The results obtained may therefore be representative of the conditions only at the time of sampling.

Full monitoring results are discussed in Section 10 and included as Appendix 2.

6.0 ENGINEERING PROPERTIES OF SOILS ENCOUNTERED

6.1 General

The following sections discuss the engineering properties of the strata encountered, based on results of in situ testing and laboratory testing obtained during this investigation.

The results of laboratory geotechnical testing are summarised in the following table.

Table 5: Summary of Laboratory Geotechnical Test Results

Location	Depth (m)	Strata*	CLASSIFICATION											STRENGTH	CHEMICAL	
			Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Modified Plasticity Index (%)	PSD Gravel (%)	PSD Sand (%)	PSD Silt/ (%)	PSD Clay (%)	Bulk Density Mg/m ³	Dry Density (Mg/m ³)	Shear Strength (kN/m ²)	pH Value	Water Soluble Sulphate SO ₄ (mg/l)
CP01	3.00-3.45	MG	22.7	28	12	16	12	-	-	-	-	1.95	1.59	25/26/27	-	-
CP01	6.00-6.45	CLAY	16.3	29	12	17	12	-	-	-	-	2.21	1.90	50/54/60	-	-
CP01	7.50-7.95	CLAY	16.3	32	14	18	13	17	21	46	16	-	-	-	7.4	200
CP02	6.00-6.45	CLAY	16.9	29	13	16	10	-	-	-	-	-	-	-	-	-
CP02	7.50-7.95	CLAY	16.2	27	12	15	9	-	-	-	-	2.12	1.82	33/38/44	-	-
CP02	9.00-9.45	CLAY	12.2	31	12	19	16	9	20	56	15	-	-	-	7.4	280
CP03	6.00-6.45	CLAY	18.3	31	13	18	12	26	18	40	16	-	-	-	7.5	180
CP04	1.50-1.95	MG	16.4	27	13	14	7	-	-	-	-	2.12	1.82	35/37/41	-	-
CP04	10.00	CLAY	18.6	30	12	18	14	17	13	57	13	-	-	-	7.4	100
CP05	8.00	CLAY	16.6	30	12	18	13	-	-	-	-	-	-	-	7.7	90

6.2 Made Ground

Variable Made Ground was encountered in all of the exploratory hole locations between ground level and 8.00m below ground level.

6.2.1 Cohesive

SPT tests carried out in the cohesive Made Ground were corrected for drilling energy efficiency and overburden pressure and resulted in **N1(60) values** of between 1 and 24, as shown on the SPT v Depth Plot in Figure 5 (overleaf).

The **undrained shear strength** in triaxial compression (U100) was carried out on two samples of the cohesive Made Ground. Results of the tests showed shear strength values in the range 25kN/m² to 41kN/m² at depths of 1.50m to 1.95m and 3.00m to 3.45m.

Atterberg Limit tests were also carried out on two samples of the cohesive Made Ground. Results of the tests reported **liquid limit** values of 27% and 28% and **plastic limit** values of 12% and 13%, resulting in values of **plasticity index** of 14% and 16%. These results suggest the samples of cohesive Made Ground tested are of **low plasticity** as shown on the Plasticity Chart in Figure 7, overleaf.

Made Ground is not typically considered to be a suitable founding material, and as such, no further geotechnical testing was carried out on the material.

6.2.2 Granular

SPT tests carried out in the granular Made Ground were corrected for drilling energy efficiency and overburden pressure and resulted in **N1(60) values** of between 3 and 12, as shown on the SPT v Depth Plot in Figure 5 (overleaf).

Made Ground is not typically considered to be a suitable founding material, and as such, no further geotechnical testing was carried out on the material.

6.3 Superficial Deposits

As discussed in Section 5, soils interpreted to represent the Devensian Till Deposits were encountered as variable CLAY and SAND in all of the exploratory hole locations.

6.3.1 Clay

Clay was encountered in all of the exploratory holes between 5.90m and 10.00m below ground level.

SPT tests carried out in the clay were corrected for drilling energy efficiency and overburden pressure and resulted in **N1(60) values** of between 11 and 24, as shown on the SPT v Depth Plot in Figure 5 (overleaf). The results suggest the clay is firm to stiff.

The **undrained shear strength** in triaxial compression (U100) was carried out on two samples of the clay. Results of the test showed shear strength values in the range 33kN/m² to 60kN/m² at depths of 6.00m to 6.45m and 7.50m to 7.95m bgl, suggesting the clay tested is low to medium strength.

Figure 6, overleaf, shows the **shear strength** of the clay soils based on undrained shear strength test results alongside equivalent shear strength from SPT N values based on correlations by Stroud and Butler ⁽¹⁹⁷⁵⁾.

Recommended N values and derived design values for the cohesive soils are summarised in Table 6, below.

Table 6: Summary of Design Parameters (Clay)

Depth	SPT N1(60) Value Range	Average N1(60) Value	Design N1(60) Value*	Equivalent Shear Strength** (kN/m ²)	Coefficient of Volume Compressibility** (mv)
6.00	11	11	11	64 (Medium Strength)	0.16 (Medium Compressibility)
7.50	16	16	16	93 (High Strength)	0.11 (Medium Compressibility)
9.00	16 - 25	21	18	102 (High Strength)	0.10 (Medium Compressibility)
*Based on lower quartile N value and correlations by Peck Hanson and Thornburn ⁽¹⁹⁷⁴⁾					
**Based on correlation by Stroud & Butler ⁽¹⁹⁷⁵⁾					

It is recommended that for assessing ultimate bearing capacities, where the lower values are critical, the lower quartile value of N values is used. Based on the N Values in the above table, the equivalent shear strength values range between 64kN/m² and 102kN/m², suggesting the clay is medium strength to high strength at the depths tested, in accordance with Table 1.

Figure 5: SPT v Depth Plot

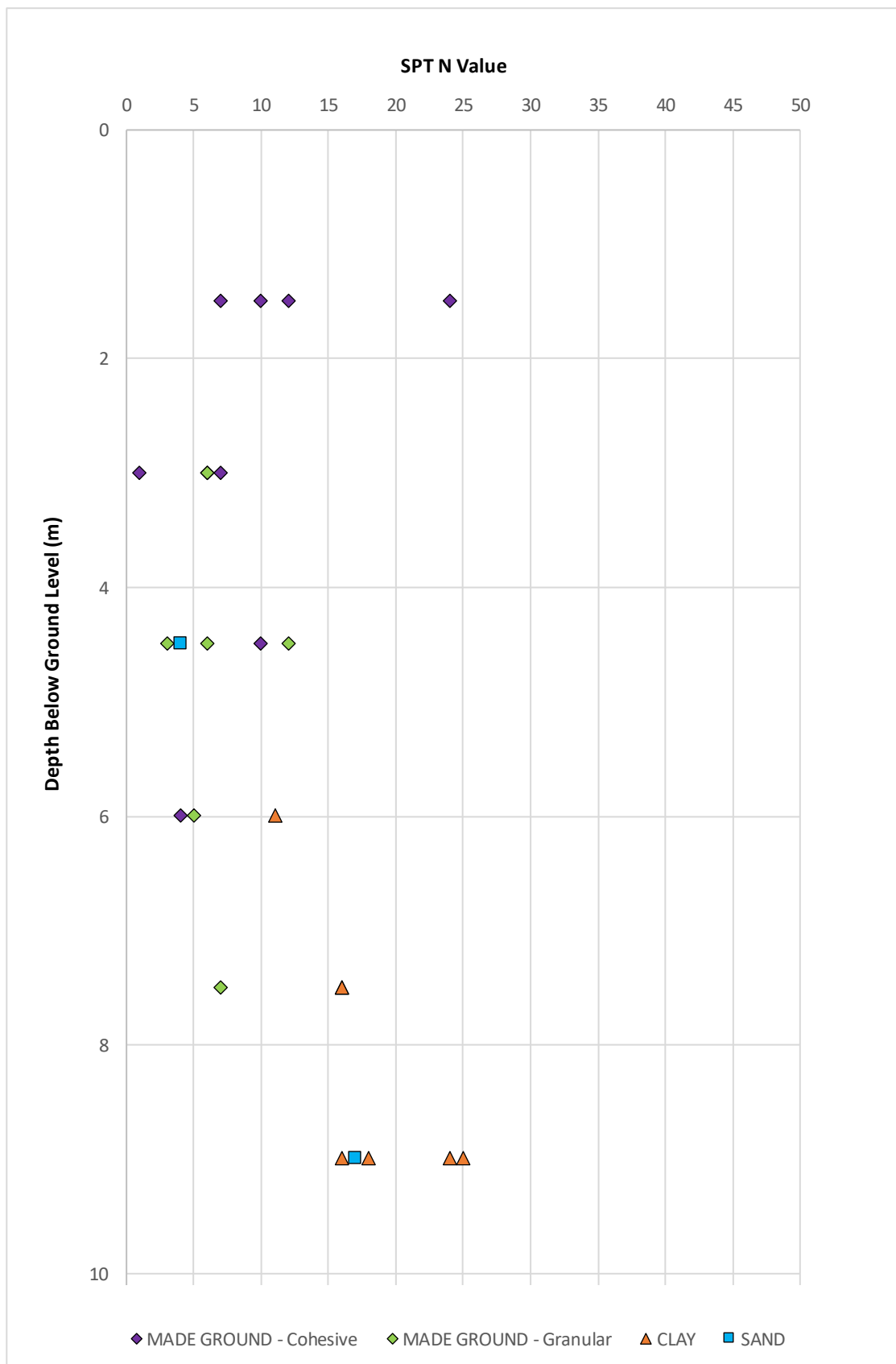
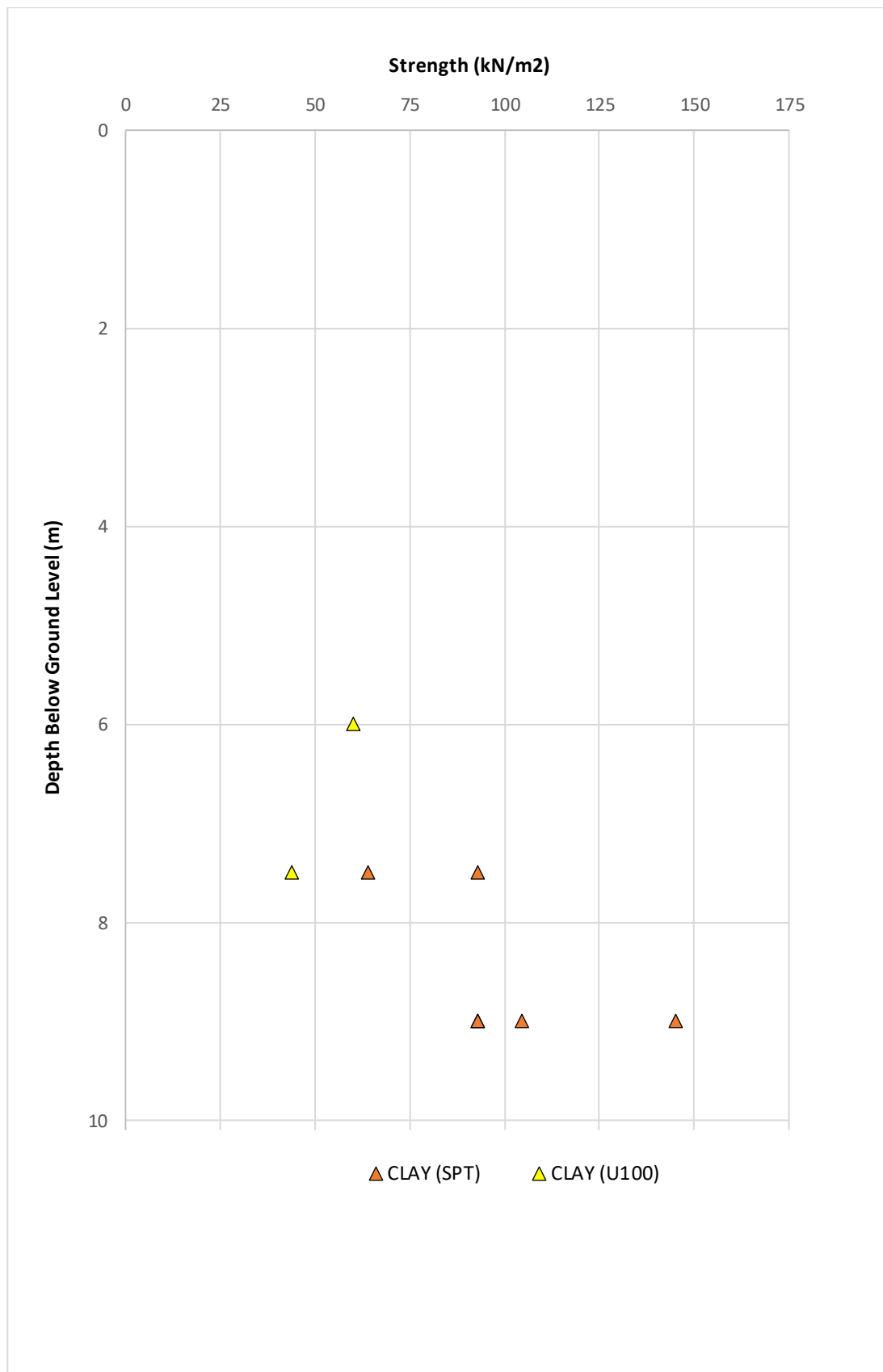
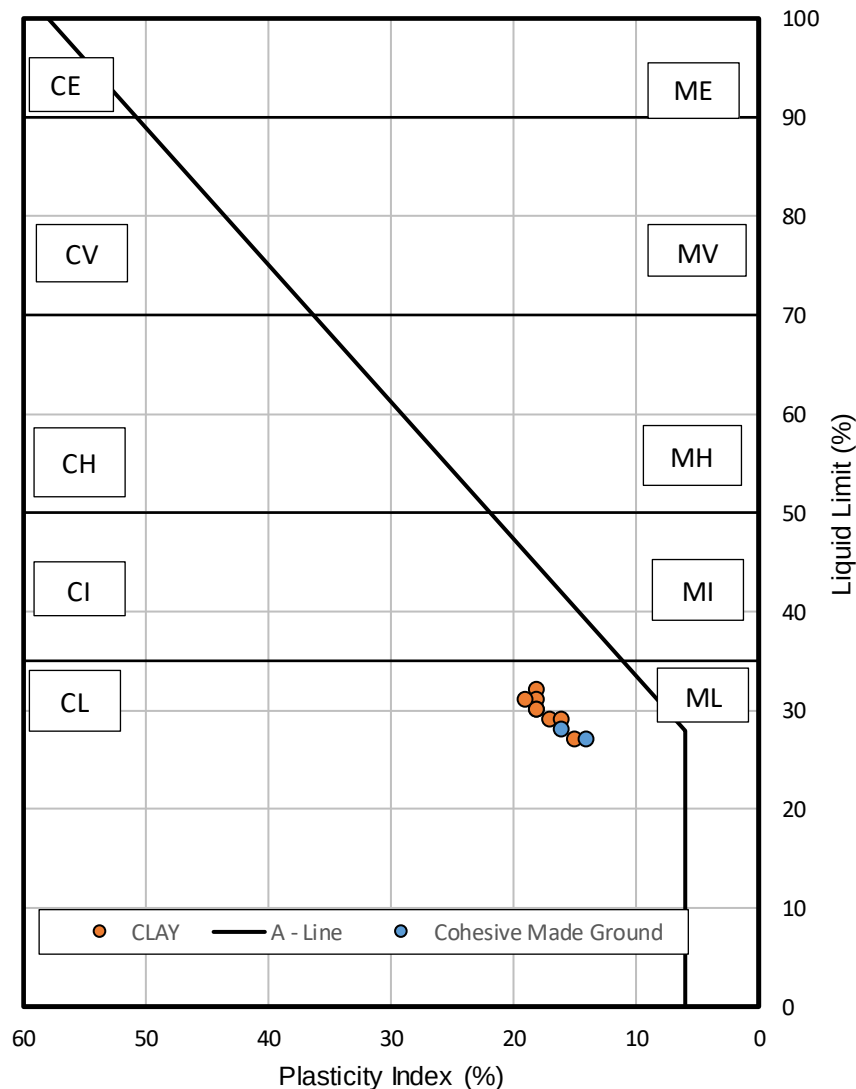


Figure 6: Strength v Depth Plot



Atterberg Limit tests were carried out on eight samples of the clay. Results of the tests reported **liquid limit** values in the range 27% to 32% and **plastic limit** values in the range 12% to 14%, resulting in values of **plasticity index** in the range 15% to 19%. These results suggest the samples of clay tested are of **low plasticity** as shown on the Plasticity Chart in Figure 7, below.

Figure 7: Plasticity Chart



For design purposes, a value of plasticity index = 18% is recommended, based on the upper quartile of the results.

The **coefficient of volume compressibility (mv)** has been estimated using the following correlation by Stroud and Butler ⁽¹⁹⁷⁵⁾: for a clay with a plasticity index of 18%, $mv = 1 / (0.580 \times N \text{ value})$.

This correlation gives values of the coefficient of volume compressibility of between 0.10m²/MN and 0.16m²/MN, as shown in Table 6, above. The results suggest the clay has **medium compressibility**.

In accordance with NHBC Chapter 4.2 Building Near Trees ⁽²⁰⁰³⁾ soils can be classified in terms of volume change potential, using the relationship:

$$I_{p'} = I_p \times \frac{\% \text{ less than } 425\mu\text{m}}{100\%}$$

$I_{p'}$ = modified plasticity index,

I_p = plasticity index.

Based on the laboratory test results, the above relationship and Table 1 of NHBC Chapter 4.2, the samples of Clay are shown to have a **low volume change potential**.

The **Natural Moisture Content** (NMC) and **Liquid Limit** (LL) of the soil can be used to give an indication of **soil desiccation**, i.e., where the NMC is less than 40% of the LL, the soil is inferred to be desiccated, as summarised in Table 7, below.

Table 7: Soil Desiccation Indicators in the Clay

Location	Depth (m)	Liquid Limit (%)	40% Liquid Limit (%)	Natural Moisture Content (%)	Desiccation
CP01	6.00-6.45	29	12	16.3	No
CP01	7.50-7.95	32	13	16.3	No
CP02	6.00-6.45	29	12	16.9	No
CP02	7.50-7.95	27	11	16.2	No
CP02	9.00-9.45	31	12	12.2	No
CP03	6.00-6.45	31	12	18.3	No
CP04	10.00	30	12	18.6	No
CP05	8.00	30	12	16.6	No

The results in the above table show that the samples tested show no evidence of desiccation.

6.3.2 Sand

Sand was encountered in exploratory hole location CP03 at depths between 4.00m and 10.00m

SPT tests carried out in the sand were corrected for drilling energy efficiency and overburden pressure and resulted in **N1(60) values** of between 4 and 11, as shown on the SPT v Depth Plot in Figure 5 (above).

Recommended N values and derived design values for the granular soils are summarised in Table 8, below.

Table 8: Summary of Design Parameters (Sand)

Depth	SPT N1(60) Value Range	Average N1(60) Value	Design N1(60) Value*	Equivalent Soil Density	Angle of Internal Friction (degrees°)**
4.50	4	4	4	Loose	27.9
9.00	17	17	17	Medium Dense	32.2
*Based on lower quartile N value **Based on the correlation by Peck, Hanson and Thornburn ⁽¹⁹⁷⁴⁾					

It is recommended that for assessing ultimate bearing capacities, where the lower values are critical, the lower quartile value of N values is used

Based on the correlation by Peck, Hanson and Thornburn ⁽¹⁹⁷⁴⁾, this gives an **angle of shearing resistance** ranging between $\phi=27.9$ and $\phi=32.2$.

For assessing settlements average ground conditions will give a more realistic value of settlements, and the average of N values should be used.

7.0 GEOTECHNICAL ASSESSMENT

7.1 Proposed Development

It is understood that the client wishes to construct nine detached and semi-detached residential properties with associated parking and soft landscaping. Site access will be retained via Bentley Street to the south of the site, via a new access road.

Detailed information regarding structural loadings and proposed foundation type was not available, however, we anticipate the loadings of the houses to be similar to those of a typical two-storey house (up to 75kN/m²).

7.2 Ground Conditions Encountered

The exploratory holes generally encountered Made Ground to a maximum depth of 8.00m (CP05). Underlying the Made Ground in all exploratory boreholes were superficial deposits of variable Clay and Sand with clay bands to a maximum depth of 10.00m bgl.

The deep Made Ground encountered is anticipated to be associated with a backfilled pond (identified in a previous report by Chandos Remediation Services, summarised in Section 2.2.1 of this report). The report states the pond was backfilled over a number of years between 1893 and 1929 when the pond is assumed to have been completely backfilled. By 1939, mapping records indicate the site has undergone further filling until 1974 where no significant changes were made on site between 1974 and 2006. A site visit conducted in 2012 identified that the site remained vacant and undeveloped.

It is assumed the site has also recently undergone earthworks to flatten out the slope and remove vegetation prior to any construction works associated with the proposed development plan.

Groundwater was encountered in CP02, CP04 and CP05 at depths between 4.10m and 5.20m bgl during the fieldwork.

Subsequent monitoring in the standpipes encountered groundwater at depths between 2.40m bgl and 5.80m bgl.

During the ground investigation it was noted a large cutting has been made along the western boundary to level the ground within areas of construction across the site. It should be noted that this slope will need to be secured and made safe prior to construction.

7.3 Foundation Considerations

Based on the ground conditions encountered, conventional shallow strip/pad foundations are not considered suitable for the proposed development, due to the depths of encountered Made Ground across the site. Alternative foundation options will need to be considered, such as ground improvement and piles.

These foundation options are discussed below in sections 7.3.1 and 7.3.2.

7.3.1 Ground Improvement

Ground treatment (e.g., vibro displacement) may be an option, subject to environmental and noise/vibration constraints.

For example, vibro stone columns are often used to solve a wide range of static, dynamic, and seismic foundation problems by using powerful depth vibrators to densify soils of form stone columns that compact or reinforce soils in situ. Vibro systems can be used to treat granular deposits, fills, made ground and soft clays/silts.

Soils treated by vibro could offer an allowable bearing pressure in the range 100kN/m² to 200kN/m², depending on column spacings and ground encountered.

Once the treatment has been carried out, spread foundations may be adopted across the site, and designed to the loadings given above. Providing that any imported fill material between the tops of the columns and the underside of the floor slab is placed in a controlled manner, floor slabs may be ground bearing. Positive assurances should be sought from an experienced specialist contractor that the proprietary system proposed can provide the required working loads in the ground conditions encountered, with a guarantee on maximum settlement for both footings and floor slabs.

7.3.2 Piled Foundations

In areas of deep made ground or unfavourable bearing capacities, foundation loading may be transferred via piles taken down to depth to a suitable founding stratum.

A variety of pile types may be used, including bored and continuous flight auger (CFA) piles. Driven piles may be suitable, subject to environmental and noise/vibration constraints.

Because of the various advantages and limitations of each pile type, and the cost implications, advice should be sought from specialist piling contractors to determine the most suitable and cost-effective type. They should also be able to give recommended pile diameters and depths and likely pile capacities, with guaranteed performance. It is recommended a pile test be carried out to confirm pile capacities. In assessing the pile capacities, contractors should make an allowance for the effects of negative skin friction, particularly in the made ground and soft clays.

There may be differential settlement between piled structures and the surrounding ground level. Provision should, therefore, be made to make up ground levels at threshold positions, loading bays, vehicle access doorways, etc. Alternatively, these materials should be removed and replaced in a controlled manner by suitable existing materials or imported engineered fill.

It is essential the advice of a specialist piling contractor is sought and that positive assurances are provided by the piling contractor that their proprietary system can provide the required working loads in the ground conditions encountered.

7.4 Pavement Design

The ground investigation identified the soil type at the subgrade level to typically be Made Ground.

A conservative design CBR value of 1% should be adopted in areas where Made Ground is encountered at subgrade level, where encountered.

Consideration should be given to the potential differing ground conditions near surface, which could cause pavements to be constructed on variable made ground. In this context a flexible pavement design may be required.

Consideration should also be given to the use of geotextiles to allow reduction of capping thickness. For examples biaxial geogrids such as Tensar SSLA20 and SSLA30 are often used to reduce capping thickness. The advice of a suitable contractor should be sought as to the most appropriate type of geotextile to use in the ground conditions encountered at this site. For guidance, the following table gives a comparison of granular layer thickness with and without the use of a geotextile, in accordance with the requirement of HA25/94 Part 2.

It should be noted the type of construction will depend on proposed finished pavement levels across the site and it is recommended the pavement design is reviewed once these levels are known. In this context, it is essential further in situ CBR testing is carried out once formation levels are known to confirm design CBR values.

Table 9: Comparison of Capping Thickness with and without Geotextile

CBR	Unreinforced			Reinforced with Tensar Geogrid				
	Sub-base	Capping	Total	Sub-base	Capping	No. of grids	Total	Thickness saving
0.5%	Design not suitable			200mm	400mm	2	600mm	-
1.0%	150mm	600mm	750mm	400mm	0	1	400mm	350mm
1.5%	150mm	600mm	750mm	310mm	0	1	310mm	440mm
2.0%	150mm	600mm	750mm	260mm	0	1	260mm	490mm
3.0%	150mm	350mm	500mm	210mm	0	1	210mm	290mm
4.0%	150mm	300mm	450mm	175mm	0	1	175mm	275mm
5.0%	150mm	250mm	400mm	160mm	0	1	160mm	240mm
These figures are suitable for light access roads and car parks, based on 1000 standard axles. For heavier loaded pavements, the advice of specialist contractor should be sought.								

All formation excavations should be examined by a suitably experienced engineer or inspector to check for soft or unsuitable material, which should be removed and replaced with compacted granular fill. Also, to ensure good compaction and remove unevenness, the formation should be compacted with equipment suitable for use in the ground conditions encountered. Careful inspection of this work will also help identify any soft spots at or just below formation level.

7.5 Chemical Attack on Buried Concrete

Chemical tests (see Appendices) show low levels of water-soluble sulphates and near neutral conditions. Based on these conditions, it is recommended that for concrete placed in natural strata the Design Sulphate Class for the site, as defined in BRE Special Digest 1⁽²⁰⁰⁵⁾, be taken as DS-1, and the Aggressive Chemical Environment for Concrete (ACEC) site classification be taken as AC-1s. The recommendations of BRE Special Digest 1 should be followed for concrete foundations and ground bearing floor slabs.

7.6 Suitability of Excavated Materials

Acceptability criteria and testing, and methods of compaction/placement will depend on the type of contract and specification used for the construction of the proposed development and it is recommended that earthworks specifications are reviewed by a suitably qualified engineer once these have been prepared by the relevant parties.

Granular Made Ground and natural sand could be suitable for re-use as structural fill, providing it is not contaminated and does not contain excessive amounts of clay and providing moisture

contents are controlled during placement. The control of moisture contents will be important as the cohesive content of this stratum is likely to be sensitive to moisture content changes.

7.7 Temporary Works

Formations will be susceptible to damage both by weather and trafficking, and should be protected immediately on exposure, particularly in areas where construction plant will access the site.

Excavations in Made Ground are likely to be unstable and should be battered back to an angle of 1 in 2, or a system of close sheeting and shoring adopted to ensure stability, and in particular where personnel are required to enter excavations. All excavations should be adequately supported where personnel are required to enter.

Groundwater seepages could be encountered near surface within excavations, particularly during the wetter months of the year. Pumping of excavations from a suitable located sump is likely to be required to keep excavations dry.

All natural materials on site should be capable of being excavated using conventional excavating machinery.

8.0 SOIL CONTAMINATION RISK ASSESSMENT

8.1 Tier I Human Health Soil Risk Assessment – Groundworkers During Development

To assess the risk of soil contamination to construction and ground workers during development, guidelines from the HSE Document 'Protection of workers and the general public during development of contaminated land' ⁽¹⁹⁹¹⁾ are used. The document assesses soil contamination test results and classifies the site as being uncontaminated or contaminated with varying degrees of contamination from 'slight' to 'unusually heavy'. The guideline values and laboratory test results are summarised in the following table:

Table 10: Summary of Guideline Values for Protection of Workers and the General Public During Development of Contaminated Land

Contaminant	Typical Values* for:					Test Results	Class
	Uncontaminated Soils	Slight Contamination	Contaminated	Heavy Contamination	Unusually Heavy Contamination		
	Class A	Class B	Class C	Class D	Class E		
pH (acid)	6 - 7	5 - 6	4 - 5	2 - 4	<2	6.4	A
pH (alkaline)	7 - 8	8 - 9	9 - 10	10 - 12	12	7.2 – 7.9	A
Arsenic	0 - 30	30 - 50	50 - 100	100 - 500	500	6 – 31	A - B
Cadmium	0 - 1	1 - 3	3 - 10	10 - 50	50	< 0.2 – 0.8	A
Chromium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	18 – 46	A
Copper	0 - 100	100 - 200	200 - 500	500 - 2500	2500	34 – 588	A - D
Lead	0 - 500	500 - 1000	1000 - 2000	2000 – 1%	1.0%	32 – 227	A
Mercury	0 - 1	1 - 3	3 - 10	10 - 50	50	< 1 – 1	A - B
Nickel	0 - 20	20 - 50	50 - 200	200 - 1000	1000	21 – 35	A - B
Zinc	0 - 250	250 - 500	500 - 1000	1000 - 5000	5000	60 – 222	A
Boron	0 - 2	2 - 5	5 - 50	50 - 250	250	< 1	A
Selenium	0 - 1	1 - 3	3 - 10	10 - 50	50	< 3	A
Barium	0-500	500-1000	1000-2000	2000-1.0%	1.0%	82 – 181	A
Beryllium	0 - 5	5 - 10	10 - 20	20 - 50	50	0.6 – 1.6	A
Vanadium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	26 – 90	A
Sulphate	0 - 2000	2000 - 5000	5000 – 1%	1% - 5%	5.05%	299 – 2044	A - B
Sulphide	0 - 10	10 - 20	20 - 100	100 - 500	500	< 5 – 9	A
Cyanide (free)	0 - 1	1 - 5	5 - 50	50 - 100	100	< 2	A
Phenol	0 - 2	2 - 5	5 - 50	50 - 250	250	< 2	A

Based on the above results, the soils are ranging from heavily contaminated to uncontaminated. A heavily contaminated concentration of copper was observed as well as slightly contaminated concentrations of arsenic, mercury, nickel, and sulphate. The remaining values are present in uncontaminated concentrations.

Therefore, there is a **MODERATE to LOW** potential risk from soil contamination to construction workers, ground workers and members of the public during construction. Appropriate measures, such as PPE, site health plans, and appropriate disposal of material arisings will further mitigate this risk.

8.2 Tier I Human Health Soil Risk Assessment – Future Site Users

The following section provides a Human Health Soil Assessment for future site users. Based on the proposed development type, the following section compares the results of contamination analyses to residential types of end development as specified by Defra/LQM/CIEH. As part of

the contamination assessment, the chemical results obtained by EEG have been screened against accepted compliance criteria, namely:

- Defra C4SL Health Criteria Values (March 2014), where available; and
- Tier 1 assessment values - based on LQM/CIEH Suitable 4 Use Levels ⁽²⁰¹⁵⁾ (S4ULs).

The soil chemical testing results are summarised in Table 11, overleaf.

Table 11: Soil Results Comparison with C4SL/S4UL Values

Determinand	C4SL/S4UL Levels Residential (mg/kg)	CP01 0.40m	CP01 1.00m	CP02 0.50m	CP02 0.90m	CP02 4.50m	CP03 1.20m	CP04 0.75m	CP05 0.35m	No of Exceedances
Metals										
Arsenic	37	12	13	28	10	15	31	6	8	0
Beryllium	1.7	1	1.6	0.7	0.7	0.6	0.7	1.1	0.9	0
Boron	290	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Cadmium	22	0.8	0.4	< 0.2	< 0.2	< 0.2	0.4	0.2	< 0.2	0
Chromium	910	27	20	46	22	18	42	20	22	0
Chromium VI	21	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0
Copper	2400	313	113	73	34	588	378	37	40	0
Lead	200	227	115	35	38	180	178	32	37	1
Mercury	40	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Nickel	180	31	34	35	21	21	34	25	25	0
Selenium	250	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	0
Vanadium	410	32	35	90	28	42	76	27	26	0
Zinc	3700	212	102	62	60	222	184	66	77	0
Petroleum Hydrocarbons										
Benzene	0.87	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
Toluene	660	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0
Ethylbenzene	260	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
o-xylenes	310	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
m-xylenes	310	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
p-xylenes	310	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
Aliphatic EC >5-6	160	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Aliphatic EC >6-8	530	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Aliphatic EC >8-10	150	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0
Aliphatic EC >10-12	760	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0
Aliphatic EC >12-16	4300	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	0
Aliphatic EC >16-21	110000	< 3	5	< 3	< 3	< 3	< 3	< 3	< 3	0
Aliphatic EC >21-35	110000	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	0
Aromatic EC >5-7	300	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Aromatic EC >7-8	660	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Aromatic EC >8-10	190	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0
Aromatic EC >10-12	380	< 2	< 2	< 2	4	< 2	< 2	< 2	< 2	0
Aromatic EC >12-16	660	5	< 2	< 2	5	3	2	< 2	< 2	0
Aromatic EC >16-21	930	26	< 3	< 3	8	5	14	7	4	0
Aromatic EC >21-35	1700	29	< 10	< 10	< 10	< 10	< 10	< 10	< 10	0
Polycyclic Aromatic Hydrocarbons										
Naphthalene	2.3	0.16	0.59	0.87	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthylene	210	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthene	170	0.47	0.62	0.67	0.14	< 0.1	0.23	0.15	< 0.1	0
Fluorene	170	0.29	0.38	0.48	< 0.1	< 0.1	0.18	< 0.1	< 0.1	0
Phenanthrene	95	3.23	3.24	3.53	0.87	0.51	1.69	0.81	0.27	0
Anthracene	2400	0.66	0.66	0.74	0.17	< 0.1	0.34	0.13	< 0.1	0
Fluoranthene	280	5.61	4.02	3.25	1.12	0.48	2.21	1.07	0.35	0
Pyrene	620	4.92	3.47	2.60	0.94	0.40	1.88	0.92	0.31	0
Benzo(a)anthracene	7.2	2.71	2.01	1.35	0.39	0.16	0.79	0.42	0.14	0
Chrysene	15	2.40	1.85	1.22	0.47	0.16	0.80	0.47	0.17	0
Benzo(a)pyrene	5	1.96	1.55	0.82	0.32	< 0.1	0.59	0.33	< 0.1	0
Benzo(b)fluoranthene	2.6	2.40	1.87	1.06	0.38	< 0.1	0.76	0.42	0.14	0
Benzo(k)fluoranthene	77	0.81	0.61	0.34	0.14	< 0.1	0.26	0.13	< 0.1	0
Indeno(1,2,3-cd) pyrene	27	1.09	0.88	0.43	0.15	< 0.1	0.28	0.17	< 0.1	0
Dibenz (a, h) anthracene	0.24	0.24	0.19	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Benzo(ghi)perylene	320	0.96	0.75	0.33	0.15	< 0.1	0.31	0.17	< 0.1	0
Phenols										
Phenol	280	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0

Based on the above tables, only one contaminant concentration was found in exceedance of the screening criteria relevant to a Residential End Use.

The sample taken from CP01 at 0.40m identified an exceedance in the contaminant lead.

Asbestos was also identified in this sample. Table 12 below presents the details and quantification.

Table 12: Summary of Asbestos Encountered

Location	Depth (m bgl)	Asbestos Type	Sample Matrix	Quantification
CP01	0.40	Chrysotile	Bundles of Fibres	<0.001

8.3 Soil Waste Assessment

An assessment of the disposal characteristics of the soil in accordance with Environment Agency guidance WM3.1, edition of June 2018, "Guidance on the classification and assessment of waste" has been carried out on soils recovered from the site, using HazWasteOnline.

The results are summarised in Table 13 below and presented in full in Appendix 6.

Table 13: Waste Classification of Soils

Location	Depth (m bgl)	WM3.1 Classification	Comments
CP01	0.40	Non-Hazardous	-
CP01	1.00	Non-Hazardous	-
CP02	0.50	Non-Hazardous	-
CP02	0.90	Non-Hazardous	-
CP02	4.50	Non-Hazardous	-
CP03	1.20	Non-Hazardous	-
CP04	0.75	Non-Hazardous	-
CP05	0.35	Non-Hazardous	-

Table 13 above shows that the eight soil samples collected from the exploratory boreholes were classified as **Non-Hazardous** in accordance with WM3.1.

Further Waste Acceptance Criteria (WAC) testing may prove that this material is acceptable as inert waste.

Asbestos can affect the waste classification of soil, if the concentration is greater than 0.1%, the soil will automatically be classified as Hazardous waste. As asbestos quantification of the sample taken from CP01 at 0.40m revealed a value of <0.001%, therefore this does not affect the Waste Classification as stated above.

For Waste Acceptance Criteria (WAC) testing, EEG have compared solid waste and leachate values with guideline values in Landfill Regulations. Table 14 overleaf, summarises the results of the solid waste analysis and leachate testing, together with limit values for Non-Hazardous waste and Hazardous waste as described in the Landfill Regulations.

The results of this further Waste Acceptance Criteria (WAC) testing (Table 14) revealed that the sample from CP01 at 0.40m has been classified as Stable Non-reactive Hazardous waste (in non-hazardous landfill).

The other results of this further Waste Acceptance Criteria (WAC) testing (Table 14) revealed that the sample from CP05 at 0.35m can be classified as inert material and will be accepted at an Inert Waste Facility.

Table 14: Summary of WAC Test Results

Determinand	Landfill Regulations Limits (mg/kg unless otherwise indicated)			CP01 0.40m (mg/kg)	CP05 0.35m (mg/kg)
	Inert Waste	Stable Non- Reactive non-hazardous waste	Hazardous Waste		
TOC (%)	3%	5%	6%	3.9	1.4
Loss on ignition (%)	-	-	10%	6.10	4
BTEX (mg/kg)	6	-	-	< 0.05	< 0.05
Sum of PCBs (mg/kg)	1	-	-	< 0.1	< 0.1
Mineral Oil (mg/kg)	500	-	-	< 10	< 10
Total PAH (mg/kg)	100	-	-	28.1	< 1.7
pH (units)	-	>6	-	7.9	7.4
Acid Neutralisation Capacity (mol/kg)	-	To be evaluated		< 1	< 1
Arsenic	0.5	2	25	< 0.2	< 0.2
Barium	20	100	300	0.5	0.2
Cadmium	0.04	1	5	< 0.02	< 0.02
Chromium	0.5	10	70	< 0.20	< 0.20
Copper	2	50	100	< 0.5	< 0.5
Mercury	0.01	0.2	2	< 0.005	< 0.005
Molybdenum	0.5	10	30	< 0.1	< 0.1
Nickel	0.4	10	40	< 0.2	< 0.2
Lead	0.5	10	50	< 0.2	< 0.2
Antimony	0.06	0.7	5	< 0.05	< 0.05
Selenium	0.1	0.5	7	< 0.05	< 0.05
Zinc	4	50	200	< 0.2	< 0.2
Chloride	800	15000	25000	22	54
Fluoride	10	150	500	5.9	< 1
Sulphate	1000	20000	50000	129	73
Total Dissolved Solids	4000	60000	100000	1030	546
Phenol Index	1	-	-	< 0.5	< 0.5
DOC	500	800	1000	170	196

9.0 GROUNDWATER CONTAMINATION RISK ASSESSMENT

In the absence of specific UK guidelines regarding groundwater quality in the UK, chemical results obtained by EEG have been compared with the following statutory and non-statutory standards:

- Environmental Quality Standards (EQS); and
- UK Drinking Water standards ⁽²⁰⁰⁰⁾.

Many of the EQS values lie just above the method detection limit for parameters and as such, are extremely conservative. In the absence of EQS values, Drinking Water Standards have been used for comparison of results. Again, these standards are highly conservative, especially in this site context.

A direct comparison was made between the groundwater analyses results and the EQS and Drinking Water Standards, and the results are summarised in Table 15, overleaf.

From the below table there are 6 contaminants in exceedance of either or both EQS and Drinking Water Standards in the groundwater samples taken on 28th July 2022.

Given there are no identified water bodies nearby and the contaminants are all identified to be heavy metals, the risk to groundwater from contamination is considered **low**.

Further detail on the water chemical testing results can be found in Appendix 5.

Table 15: Groundwater Results Comparisons with EQS/Drinking Water Quality Values

Determinand	EQS Value (A)	Drinking Water Quality (DWQ) Value (B)	CP02	CP03	CP05	No. of Exceedances
Arsenic	50	10	7	14	18	2 (B)
Cadmium	0.9	5	1.7	1.6	< 0.4	2 (A)
Chromium	50	-	< 5	6	25	0
Copper	10	2000	386	358	< 5	2 (A)
Lead	1.2 - 14	10	442	528	144	3 (A+B)
Mercury	0.07	1.0	< 0.05	< 0.05	< 0.05	0
Selenium	-	10	< 5	< 5	< 5	0
Nickel	50 - 200	20	28	228	83	1 (B), 2 (A+B)
Zinc	75	-	524	399	562	3 (A)
Cyanide	-	50	< 5	< 5	< 5	0
Phenol	7.7 - 46	-	< 10	< 10	< 10	0
Sulphate	400000	250000	4	21	30	0
pH	6 - 9	-	7.1	6.9	6.9	0
Naphthalene	10	-	0.26	0.03	< 0.01	0
Anthracene	0.1	-	< 0.01	< 0.01	< 0.01	0
Benzo(a)pyrene	0.27	0.01	< 0.01	< 0.01	< 0.01	0
Benzo(b)fluoranthene	0.017	0.10	< 0.01	< 0.01	< 0.01	0
Benzo(k)fluoranthene	0.017	-	< 0.01	< 0.01	< 0.01	0
Indeno(123cd) pyrene	-	0.10	< 0.01	< 0.01	< 0.01	0
Fluoranthene	0.12	-	0.03	< 0.01	< 0.01	0
Benzene	10 - 50	1	< 1	< 1	< 1	0
Toluene	50 - 380	-	< 5	< 5	< 5	0
Ethylbenzene	20 - 200	300 (WHO)	< 5	< 5	< 5	0
Xylenes	30	-	< 25	< 25	< 25	0
Total Petroleum Hydrocarbons Aro C6-C8	-	10	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Aro C8-C10	-	700	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Aro C10-C12	-	300	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Aro C12-C16	-	90	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Aro C16-C21	-	90	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Aro C21-C35	-	90	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Ali C6-C8	-	15000	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Ali C8-C10	-	15000	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Ali C10-C12	-	300	< 10	< 10	< 10	0
Total Petroleum Hydrocarbons Ali C12-C16	-	300	< 10	< 10	< 10	0
All values in µg/l unless otherwise stated WHO=World Health Organization guide values.						

10.0 GROUND GAS AND RADON GAS CONTAMINATION RISK ASSESSMENT

10.1 Radon Gas

The site is not located within a Radon Affected Area as defined by the Health Protection Agency, and therefore radon protection measures are not necessary.

10.2 Analyses of Monitoring Results

The potential risk associated with gases being generated in the ground (whether from natural or man-made sources) depends on the concentrations of gas and its flow rate to the surface. These factors are assessed by monitoring of the gas installations in the boreholes. The variable nature of gas generation and the effect of barometric pressure on gas flow, means that the volume of gas potentially reaching the ground surface is normally inconsistent over time.

A total of six gas monitoring visits have been completed by Earth Environmental & Geotechnical Ltd. The monitoring visits were carried out between the 28th July and 1st September 2022. The results recorded methane (CH₄) levels ranging from 0.0% and 0.2% (v/v) and carbon dioxide (CO₂) levels of 0.1% to 12.1% v/v. Oxygen concentrations of between 0.4% to 21.1% v/v were also recorded.

Regarding flow rates, for the purposes of the ground gas risk assessment BS8485 2015+A1 2019 states that *'steady state flow rates, rather than brief peak values on opening, should be used in screening risk assessment if these are representative of the conceptual site model'*.

Gas flow rates were recorded between -0.1l/hr to 0.1l/hr and a maximum flow rate of 0.1l/hr has been adopted for the below calculations. Atmospheric pressure was recorded to be between 995mb and 1006mb.

Full results of the monitoring are presented in Appendix 2.

Table 16 overleaf, adapted from CIRIA C665 "Assessing risks posed by hazardous ground gases to buildings", shows a summary of the current UK practice with respect to appropriate gas protection measures based upon a Gas Screening Value (GSV).

A GSV for the site has been obtained by multiplying the maximum concentration of gas by the steady flow rate of 0.1l/h adopted for assessment purposes.

- Carbon dioxide: steady flow rate = 0.1l/hr, max concentration = 12.1%
- Methane: steady flow rate = 0.1l/hr, max concentration = 0.2%.

Based on the above figures, the GSV is calculated as:

- **Carbon dioxide:** $GSV = 0.1 \times 12.1 / 100 = 0.0121$ litres/hr
- **Methane:** $GSV = 0.1 \times 0.2 / 100 = 0.0002$ litres/hr

Table 16: Characteristic Situations (Wilson et al 2006/2007 modified from Wilson and Card, 1999)

<i>Characteristic Situation (CS)</i>	<i>Risk Classification</i>	<i>Gas Screening Value CH₄ or CO₂ (l/hr)</i>	<i>Additional Factors</i>	<i>Typical source of generation</i>
1	Very Low	<0.07	Typically, < 1% methane Typically, < 5% carbon dioxide	Typical made ground
2	Low	<0.7	Borehole air flow rate to not exceed 70l/hr otherwise consider increase to Characteristic Situation 3	Typical made ground
3	Moderate	<3.5		Old landfill, inert waste, flooded mineworkings
4	Moderate to High	<15	Quantitative risk assessment	Mineworkings susceptible to flooding, completed landfill
5	High	<70		Mineworking unflooded inactive with shallow workings near surface
6	Very High	>70		Recent landfill site

The CIRIA guidance document notes that ‘...the GSV is a guideline value and not an absolute threshold’.

The above results suggest the site can be given a Characteristic Situation 2, i.e., ‘low risk’, in accordance with Table 16, above.

Protection Measures

Based on the foregoing preliminary assessment, ground gas protection measures are considered necessary at the site in accordance with BS8485:2015 + A1 2019.

Table 17: Gas Protection Point Score Required (BS8485:2015 + A1 2019)

Characteristic Situation	Minimum gas protection score (points)			
	High Sensitivity		Medium	Low
	Type A building (private housing)	Type B building (multiple occupancy private or commercial)	Type C building (single occupancy commercial)	Type D building (large industrial)
1	0	0	0	0
2	3.5	3.5	2.5	1.5
3	4.5	4.0	3.0	2.5
4	6.5	5.5	4.5	3.5

The proposed development is for Type A buildings (private housing), a high sensitivity risk. Therefore, a score of 3.5 for gas protection is required.

The required 3.5 points must be achieved by installation of a suitable combination of measures. Reference should be made to **BS8485:2015 + A1 2019** for details. These should include a combination of two or more of the following three types of protection measures, which should be used to achieve the required score:

- The structural barrier of the floor slab, or of the basement slab and walls if a basement is present;
- Ventilation measures; and
- Gas resistant membrane.

11.0 CONCLUSIONS & RECOMMENDATIONS

11.1 Soil Contamination

There is a **MODERATE TO LOW** potential risk from soil contamination to construction workers and ground workers during development, and appropriate measures such as PPE, site health plans, appropriate disposal of material arisings will be required to mitigate this risk. The groundworks contractor must provide a soil management plan including methods of dealing with unanticipated soil contamination encountered during groundworks.

Based on the results of the chemical testing, one exceedance in contaminants was observed in the soil samples analysed. Therefore, there is a **MODERATE TO LOW** potential risk from soil contamination to residential end users.

To break potential pollutant linkages to future residential end users, it is recommended that landscaped areas should be capped with imported clean cover soils.

The exceedance in contamination found should be further delineated and any impacted material removed offsite.

A Remediation Strategy is recommended to specify the design of the capping system and any following validation work.

11.2 Asbestos

Asbestos was identified in one of the samples tested with a quantification of <0.001%.

11.3 Foundations

Shallow strip/pad foundations are not considered suitable for the proposed development plan.

Other foundation options may need to be considered such as ground improvement or piles.

11.4 Eastern Boundary

A large cutting has been identified along the eastern boundary of the site to level the ground across the site. This slope will need to be secured and made stable prior to construction.

11.5 Soil Disposal

Soils should be disposed of at a suitable site, registered to take the levels of contamination encountered. The soils collected from eight borehole locations have been classified as Non-Hazardous for the purpose of off-site disposal in accordance with Environment Agency guidance WM3.1.

11.6 Land Gas

Based on results of the gas monitoring, the risk of ground gas is low and protection against the ingress of ground gas will be required at the site.

11.7 Pavement Design

Based on the findings of the site investigation, the soil type at subgrade level was typically Made Ground. Based on the recommendations for design CBR values provided in Interim advice note 73/06, Revision 1 (2009), a conservative design CBR value of 1% should be adopted in areas where Made Ground is encountered at subgrade level, where encountered.

11.8 Groundwater

Groundwater was encountered in CP02, CP04 and CP05 at depths between 4.10m and 5.20m bgl during the fieldwork.

Subsequent monitoring in the standpipes encountered groundwater at depths between 2.40m bgl and 5.80m bgl.

Chemical testing was carried out on three groundwater samples and numerous exceedances in contaminants were observed. However, given there are no identified water bodies nearby, the risk to groundwater from contamination is considered **LOW**.

11.9 Risk to Buried (Water) Services

It is considered that, due to the presence of hydrocarbon contamination in TP1, non-standard materials may be required for new water pipes. Further advice should be sought from the local water company.

Previous guidance on buried water pipes was contained in Water Regulations Advisory Scheme (WRAS) Guidance Note No. 9-04-03⁽²⁰⁰²⁾, however this has been superseded by the UK Water Industry Research Report 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites' Ref 10/WM/03/21 (January 2011).

11.10 Site Personnel

As with all construction sites, personnel working on the site during the construction period should be encouraged to maintain a high standard of personal hygiene and on-site washing facilities should be available.

11.11 Other Matters

Due diligence is required during the construction period, and should any further evidence of contamination be found, appropriate investigation and / or action should be taken. The significance of any contamination not discovered by this investigation is outside the scope of this report.

APPENDIX 1

EXPLORATORY HOLE LOGS

APPENDIX 2

GROUND GAS MONITORING RESULTS

APPENDIX 3

GEOTECHNICAL TESTING RESULTS

APPENDIX 4

CHEMICAL TESTING RESULTS

APPENDIX 5

WATER CHEMICAL TESTING RESULTS

APPENDIX 6

SOIL WASTE ASSESSMENT

APPENDIX 7

REPORT LIMITATIONS

REPORT LIMITATIONS

This contract was completed by Earth Environmental & Geotechnical Ltd on the basis of a defined programme and scope of works and terms and conditions agreed with the client. This report was compiled with all reasonable skill, and care, bearing in mind the project objectives, the agreed scope of works, the prevailing site conditions, the budget, and staff resources allocated to the project.

Other than that, expressly contained in the above paragraph, Earth Environmental & Geotechnical Ltd provides no other representation or warranty whether express or implied, is made in relation to the services. Unless otherwise agreed this report has been prepared exclusively for the use and reliance of the client in accordance with generally accepted consulting practices and for the intended purposes as stated in the agreement under which this work was completed. This report may not be relied upon, or transferred to, by any other party without the written agreement of a Director of Earth Environmental & Geotechnical Ltd.

If a third party relies on this report, it does so wholly at its own and sole risk and Earth Environmental & Geotechnical Ltd disclaims any liability to such parties.

It is Earth Environmental & Geotechnical Ltd understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was an important factor in determining the scope and level of the services. Should the purpose for which the report is used, or the proposed use of the site change, this report will no longer be valid and any further use of, or reliance upon the report in those circumstances by the client without Earth Environmental & Geotechnical Ltd review and advice shall be at the client's sole and own risk.

The report was written in 2022 and should be read in light of any subsequent changes in legislation, statutory requirements, and industry best practices. Ground conditions can also change over time and further investigations, or assessment should be made if there is any significant delay in acting on the findings of this report. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of Earth Environmental & Geotechnical Ltd. In the absence of such written advice of Earth Environmental & Geotechnical Ltd, reliance on the report in the future shall be at the client's own and sole risk. Should Earth Environmental & Geotechnical Ltd be requested to review the report in the future, Earth Environmental & Geotechnical Ltd shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between Earth Environmental & Geotechnical Ltd and the client.

The observations and conclusions described in this report are based solely upon the services that were provided pursuant to the agreement between the client and Earth Environmental & Geotechnical Ltd. Earth Environmental & Geotechnical Ltd has not performed any observations, investigations, studies or testing not specifically set out or mentioned within this report.

Earth Environmental & Geotechnical Ltd is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, Earth Environmental & Geotechnical Ltd did not seek to evaluate the presence on or off the site of electromagnetic fields, lead paint, radon gas or other radioactive materials.

The services are based upon Earth Environmental & Geotechnical Ltd observations of existing physical conditions at the site gained from a walkover survey of the site together with Earth Environmental & Geotechnical Ltd interpretation of information including documentation, obtained from third parties and from the client on the history and usage of the site. The findings and recommendations contained in this report are based in part upon information provided by third parties, and whilst Earth Environmental & Geotechnical Ltd have no reason to doubt the accuracy and that it has been provided in full from those it was requested from, the items relied on have not been verified.

No responsibility can be accepted for errors within third party items presented in this report. Further Earth Environmental & Geotechnical Ltd was not authorised and did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the services. Earth Environmental & Geotechnical Ltd is not liable for any inaccurate information, misrepresentation of data or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to Earth Environmental & Geotechnical Ltd and including the doing of any independent investigation of the information provided to Earth Environmental & Geotechnical Ltd save as otherwise provided in the terms of the contract between the client and Earth Environmental & Geotechnical Ltd.

Where field investigations have been carried out these have been restricted to a level of detail required to achieve the stated objectives of the work. Ground conditions can also be variable and as investigation excavations only allow examination of the ground at discrete locations. The potential exists for ground conditions to be encountered which are different to those considered in this report. The extent of the limited area depends on the soil and groundwater conditions, together with the position of any current structures and underground facilities and natural and other activities on site. In addition, chemical analysis was carried out for a limited number of parameters [as stipulated in the contract between the client and Earth Environmental & Geotechnical Ltd] based on an understanding of the available operational and historical information, and it should not be inferred that other chemical species are not present.

The groundwater conditions entered on the exploratory hole records are those observed at the time of investigation. The normal speed of investigation usually does not permit the recording of an equilibrium water level for any one water strike. Moreover, groundwater levels are subject to seasonal variation or changes in local drainage conditions and higher groundwater levels may occur at other times of the year than were recorded during this investigation.

Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan but is (are) used to present the general relative locations of features on, and surrounding, the site.