



EARTH ENVIRONMENTAL
& GEOTECHNICAL

GeoEnvironmental Site Investigation Report

Waterfold Lane

Heywood

June 2024

On behalf of

DMG Contracts Ltd

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**GEOENVIRONMENTAL
SITE INVESTIGATION
REPORT**

WATERFOLD LANE

HEYWOOD

Report Ref: A4301/21/SI

JUNE 2024

Prepared on Behalf of:

DMG Contracts Ltd

By:

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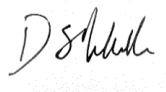
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1.0 EXECUTIVE SUMMARY

Appointment	A site investigation has been commissioned by John Stephens & Co. on behalf of DMG Contracts Ltd (the Client), to examine ground conditions for a proposed new residential development at the land off Waterfold Lane, Heywood.
The Investigation	The investigation comprised five windowless sample boreholes and two cable percussive boreholes, with associated sampling, in situ testing, laboratory geotechnical and contamination testing.
The Site	The site is a vacant plot of land located off Waterfold Lane, approximately 420m southwest of Heap Bridge and approximately 1.7km east of Bury town centre. The approximate National Grid Reference for the centre of the site is SD 82112 10338 (X: 382112, Y: 410338), with the closest postcode being BL9 7JY. The site is recorded to be underlain by superficial river terrace deposits comprising sand and gravel. The solid geology beneath the site is recorded as the Pennine Lower Coal Measures Formation, comprising coal seams, mudstone, siltstone and sandstone.
Ground Conditions Encountered	The exploratory holes generally encountered variable made ground between ground level and a maximum depth of 3.40m bgl, excluding WS2 which encountered topsoil and no made ground, underlain by superficial deposits of variable sand, gravel, clay and silt. Mudstone rockhead was encountered within 4 of the boreholes between 4.00m and 6.00m bgl. Groundwater was encountered during the ground investigation in all exploratory borehole locations, excluding WS4 and CP2, between 2.00m - 3.00m bgl. During subsequent monitoring visits, groundwater was encountered in all installed boreholes between 1.77 - 2.87m bgl.
Geotechnical Assessment	Shallow strip/pad foundations placed in the natural superficial deposits are considered appropriate for the townhouse section of the current proposed development, dependent on allowable bearing pressures and tolerance of structures to settlement. Due to the deep made ground encountered below the footprint of the apartment block, a shallow foundation solution is not considered appropriate and an alternative foundation solution such as piles will be required. Pavement Design - preliminary design value = 1% in Made Ground. Design Sulphate Class = DS-1 ACEC Site Classification = AC-1s
Soil Contamination Assessment	Risk from contamination to groundworkers during development - MODERATE to LOW . Risk from contamination to future residential end users - MODERATE . No Asbestos identified in the tested samples. Soil Waste Assessment: 10 samples tested; 1 classified as Hazardous, 9 classified as Non-Hazardous. 3 WAC tests conducted; 1 classified as Hazardous, 2 exceeds hazardous classification. Remediation strategy required for the proposed development.
Water Contamination Assessment	4 groundwater samples tested. Heavy metal exceedances above EQS/DWQ guidelines identified in 3 samples. Risk from water contamination to future residential end users - LOW . Risk to controlled waters - MODERATE to LOW . Additional sampling of surface water from River Roch recommended to assess potential migration of contaminants.
Ground Gas Assessment	Initial assessment of the ground gas monitoring data suggests that the site would be classified as CS1 "very low risk". However, due to slightly elevated carbon dioxide and methane levels across multiple site visits, the classification should be increased to CS2 "low risk".

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.

2.0 INTRODUCTION

2.1 Background

A site investigation has been commissioned by John Stephens & Co. on behalf of DMG Contracts Ltd (the Client), to examine ground conditions for a proposed new residential development on land off Waterfold Lane, Heywood.

2.2 Existing Planning Applications

2.2.1 Planning Application to Rochdale Borough Council, 22/01085/OUT, dated September 2022.

A planning application has been submitted to Rochdale Borough Council (Reference: 22/01085/OUT) as an outline application for the erection of two, three storey apartment blocks, comprising a total of 36 units. The application was rejected in December 2022.

2.3 Previous Investigations

2.3.1 Earth Environmental & Geotechnical Ltd, Phase I GeoEnvironmental Desk Study (A4301/21/FDS), dated July 2022.

Historically the site has been partially occupied by a woollen mill and a small reservoir, however all buildings were demolished, and the reservoir infilled by 1980. The site has been a vacant plot of undeveloped land since.

The site is underlain by superficial river terrace deposits comprising sand and gravel (Secondary A Aquifer), with a small section of alluvium along the northern boundary. The solid geology below the site is the Pennine Lower Coal Measures Formation, comprising coal seams, mudstone, siltstone and sandstone (Secondary A Aquifer).

There is potential for the presence of contamination on the site due to former land uses.

The risk from soil contamination to future end users and construction workers was considered to be **MODERATE**. The risk from ground gas to end users was considered to be **MODERATE** due to the previous industrial land use and likely extent of buried made ground.

The risk to controlled waters was concluded to be **HIGH** due to the underlying granular soils and the proximity to the River Roch.

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 the development of a ground gas risk assessment.

2.4 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 A4301/21 dated 7th January 2024. The objectives of this investigation are as follows:

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

2.5 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.

2.6 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 off Waterfold Lane, approximately 420m southwest of Heap Bridge and approximately 1.7km east of Bury town centre.

The approximate National Grid Reference for the centre of the site is SD 82112 10338 (X: 382112, Y: 410338), with the closest postcode being BL9 7JY.

The site is an irregular shaped parcel of land, with current access via Waterfold Lane to the south of the site. The maximum dimensions of the site are approximately 220m north to south, and 100m east to west. The site occupies an area of approximately 0.92 hectares.

The site comprises a vacant plot of land, generally surfaced by soft cover and relic roadways comprising tarmac and old cobbled paving.

The site is surrounded by agricultural land to the south, the River Roch to the north and east, with vacant land further north, and the M66 motorway to the west. Residential properties are located approximately 60m southeast 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 across the site, facing south



Photograph taken of relic cobbled path, facing east



Photograph taken of relic road, facing south



Photograph of representative soils (WS5)



3.1 Proposed Development

It is understood that the client wishes to develop a new row of townhouses and a residential apartment block, comprising six three-bedroom townhouses and twenty one, one-bedroom flats.

New site access with be developed from Waterfold Lane to the south of the site, with the existing road to be upgraded to accommodate the additional traffic.

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 21st of March and the 18th - 19th of April 2024 and comprised:

- Five window sample boreholes (designated WS1 - WS5 inclusive) were each sunk to a maximum depth of 6.00m below existing ground level. All the boreholes were drilled with the intention of reaching 6.00m bgl however two were terminated early due to the boreholes collapsing multiple times. Window sampler boring is carried out with a small, track-mounted rig, which uses a chain-driven trip hammer to drive sampling tubes or penetrometers into the ground. These tools are coupled to the anvil of the hammer by solid drill rods. Sampling tubes comprise “windowless samplers,” which are plain sampler tubes in which a continuous disturbed sample is recovered within a semi-rigid plastic liner. In order to reduce friction within the borehole, sampling tubes of progressively smaller diameter are used as the borehole depth increases. Sampler diameters generally range from between approximately 90mm to 50mm. Standard Penetration Tests (SPTs) were undertaken in the boreholes in accordance with BS EN ISO 22476-3. Groundwater observations were noted where possible. These observations relate to the time of the investigation only, and do not necessarily reflect seasonal fluctuations. Exploratory hole logs are included in Appendix 1.
- 50mm diameter standpipes were installed in all the window sample 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 and ground gas monitoring in standpipes after the fieldwork period, the results of which are presented in Sections 9 and 10 respectively.
- Two 150mm diameter boreholes (designated CP1 and CP2) were sunk to depths of 5.65m and 6.45m below existing ground level, using a cable percussion boring rig. Both boreholes were drilled with the intention of reaching 15.00m bgl however were terminated early due to SPT refusals in suspected bedrock. 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.
- Exploratory hole locations were selected prior to the site works by EEG Ltd based on the proposed development and avoiding known services.

Table 1 below indicates the appropriate features targeted.

Table 1: Sampling Location Justification

Exploratory Hole	Sampling Location
WS1 & WS2	Within proposed new car parking court
WS3	Within proposed private amenity space
WS4 & WS5	Within proposed footprint of new townhouse area
CP1 & CP2	Within proposed footprint of new apartment block

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. 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 2 overleaf.

Table 2: 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 and tests undertaken during the investigation are presented in Table 3 below.

Table 3: Summary of Exploratory Holes Undertaken

Hole/ Test	Type*	Depth (m)	Date Started	Date Finished	Easting (m)	Northing (m)	Backfill Details**
WS1	WS	6.00	21/03/2024	21/03/2024	382089	410295	MW
WS2	WS	4.00	21/03/2024	21/03/2024	382106	410311	MW
WS3	WS	6.00	21/03/2024	21/03/2024	382121	410341	MW
WS4	WS	4.00	21/03/2024	21/03/2024	382133	410329	MW
WS5	WS	6.00	21/03/2024	21/03/2024	382147	410334	MW
CP1	CP	6.45	19/04/2024	19/04/2024	382116	410371	A
CP2	CP	5.65	19/04/2024	19/04/2024	382084	410325	A

*WS = Window Sample Borehole, CP = Cable Percussive Borehole
**MW = Monitoring Well, A = Arisings

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 4, below.

Table 4: Summary of Laboratory Geotechnical Tests Undertaken

TEST	STANDARD	No.
Particle size distribution (wet)	BS1377:1990 Part 2, Clause 9.2	6
Moisture Content	BS1377:1990 Part 2, Clause 3.2	7
Liquid Limit, Plastic Limit, Plasticity Index	BS1377:1990 Part 2, Clause 4/5	7
Sulphate content of 2:1 soil: water extract	BS1377:1990 Part 3, Clause 5	8
pH value	BS1377:1990 Part 3, Clause 9	8

The results of the laboratory geotechnical tests are discussed in Section 6 and included in Appendix 2.

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 ten soil samples and were submitted for the following suite of determinants:

Asbestos Screen, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Hexavalent Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc, Cyanide, Phenol,

Sulphate (SO₄), Sulphide, pH, Soil Organic Matter, Speciated Petroleum Hydrocarbons (TPH) and Speciated Polyaromatic Hydrocarbons (PAH).

Three of the soil samples were also submitted for Waste Acceptance Criteria (WAC) testing.

Full results of the laboratory contamination tests are discussed in Section 8 and included in Appendix 3.

Additionally, chemical analyses were also carried out on four groundwater samples and were submitted for the following suite of determinants:

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

The results of the laboratory contamination tests are discussed in Section 8 and 9 and included in Appendix 5.

5.0 GROUND CONDITIONS ENCOUNTERED

5.1 Soil Profile Encountered

BGS digital mapping shows the site is recorded to be generally underlain by superficial river terrace deposits, comprising sand and gravel.

The solid geology beneath the site is recorded as the Pennine Lower Coal Measures Formation, comprising coal seams, mudstone, siltstone and sandstone. The sequence of strata encountered beneath the site was as follows:

- **Made Ground** - was encountered in all exploratory hole locations, excluding WS2, between ground level and to a maximum depth of 2.35m bgl, comprising:
 - GRAVEL of sandstone, red brick, concrete, clinker and tarmac/asphalt, with variable quantities of clay and sand.
 - SAND, with variable quantities of silt and gravel of red brick, concrete, red brick, ash and clinker.
 - CLAY, with variable quantities of silt, sand and gravel of red brick, sandstone, slate and clinker.
- **Topsoil** - was encountered exclusively in WS2, between ground level and to a maximum depth of 0.30m bgl, comprising:
 - Silty, sandy, slightly gravelly CLAY, containing gravel of sandstone and rare red brick.
- **Superficial Deposits** - Variable superficial deposits were encountered in all exploratory holes, to a maximum depth of 6.00m bgl, comprising:
 - SAND, with variable quantities of clay, silt and gravel of sandstone.
 - GRAVEL of sandstone, mudstone and coal, with variable quantities of clay, silt and sand.
 - CLAY, with variable quantities of silt, sand and gravel of sandstone, mudstone and coal.
 - SILT, with variable quantities of clay and sand.
- **Mudstone** - was encountered exclusively in in WS3 between 4.70m and to a maximum depth of 6.00m bgl, and within the 6.00m SPT test in WS1.

The depths of the various materials encountered in the exploratory holes are summarised in Table 5, overleaf.

5.2 Observable Indications of Contamination

Clinker was observed throughout the made ground across the site, with ash also identified within WS5.

5.3 Obstructions

No man-made obstructions were observed during the investigation.

5.4 Groundwater

Groundwater was encountered during the ground investigation in all exploratory borehole locations, excluding WS4 and CP2, between 2.00m - 3.00m bgl.

During subsequent monitoring visits, groundwater was encountered in all installed boreholes between 1.77 - 2.87m bgl.

5.5 Rockhead

Suspected weathered mudstone rockhead was encountered in WS1 at 6.00m bgl and in WS3 at 4.70m bgl.

Table 5: Summary of Ground Conditions Encountered

Hole	Depth to Stratum (m bgl)							Groundwater (Investigation) (m bgl)	Groundwater (Monitoring) (m bgl)
	MADE GROUND	TOPSOIL	SUPERFICIAL DEPOSITS				MUDSTONE		
			SAND	GRAVEL	CLAY	SILT			
WS1	GL - 2.35	-	-	-	2.35 - 4.00	4.00 - 6.00	6.00+	2.80	1.77 - 2.87
WS2	-	GL - 0.30	0.30 - 1.00 2.40 - 3.40	1.00 - 2.40 3.90 - 4.00	-	3.40 - 3.90	-	2.00	1.86 - 2.23
WS3	GL - 0.60	-	0.60 - 1.95	1.95 - 2.50 3.00 - 4.50	2.50 - 3.00 4.50 - 4.70	-	4.70 - 6.00+	3.00	2.12 - 2.85
WS4	GL - 0.40	-	0.40 - 1.00	1.50 - 2.00	1.00 - 1.50 2.00 - 3.00	3.00 - 4.00	-	-	2.21 - 2.86
WS5	GL - 0.70	-	0.70 - 1.00	1.85 - 2.50 3.00 - 3.40	1.00 - 1.85 2.50 - 3.00	3.40 - 5.00	-	3.00	2.04 - 2.34
CP1	GL - 3.40	-	-	-	3.40 - 5.00	-	5.00 - 6.45+	2.45	-
CP2	GL - 0.60	-	0.60 - 3.50	-	-	3.50 - 4.00	4.00 - 5.65+	-	-

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 6: 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)
WS1	2.95	CLAY	28.2	32	14	18	18	-	-	-	-	-	-	-	6.9	170
WS2	3.60	SILT	-	-	-	-	-	0	4	89	7	-	-	-	-	-
WS3	2.70	CLAY	13.5	29	13	16	11	-	-	-	-	-	-	-	7.4	230
WS4	1.10	CLAY	13.2	27	12	15	11	-	-	-	-	-	-	-	7.2	280
WS4	3.50	SILT	-	-	-	-	-	0	3	93	4	-	-	-	-	-
WS5	1.30	CLAY	23.3	29	13	16	13	-	-	-	-	-	-	-	7.4	110
CP1	4.00	CLAY	12.6	27	14	13	9	-	-	-	-	-	-	-	7.2	200
CP2	2.00	SAND	-	-	-	-	-	0	63	30	7	-	-	-	-	-
CP2	2.70	CLAY	17.3	29	17	12	9	-	-	-	-	-	-	-	7.2	180
CP2	3.70	SILT	27.9	29	22	7	7	-	-	-	-	-	-	-	7.0	70

6.2 Made Ground

Made Ground was encountered in all exploratory boreholes, excluding WS2, between ground level and a maximum depth of 2.35m below ground level. Due to the thickness of the made ground within WS1, SPT tests were conducted and resulted in **SPT N values** of 10 and 12.

Due to the material encountered, no geotechnical testing was carried out in the Made Ground.

6.3 Superficial Deposits

As discussed in Section 5, superficial material was encountered as variable SAND, GRAVEL, CLAY and SILT in all of the exploratory hole locations.

6.3.1 Granular

Granular material comprising sand and gravel, was encountered in all exploratory hole locations, excluding CP1, below the Made Ground or topsoil at depths between 0.30m and 4.50m below ground level.

A **Particle Size Distribution** (PSD) test was carried out on one sample of sand. The laboratory generally described the material as a slightly clayey silty SAND. A breakdown of the test results is shown in Table 6 above and in Appendix 2.

SPT tests carried out in the granular material resulted in **SPT N values** of between 7 and 50, as shown on the SPT v Depth Plot, in Figure 5 (above). The results suggest the sand is loose to very dense.

Recommended N values and derived design values for the granular soils are summarised in Table 7, below.

Table 7: Summary of Design Parameters (Granular)

Depth	SPT N Value Range	Average N Value	Design N Value*	Equivalent Soil Density	Angle of Internal Friction (degrees)**
1.20	7 - 37	22	15	Medium Dense	31.6
2.00	12 - 50	34	30	Medium Dense to Dense	36
3.00	7 - 23	15	11	Medium Dense	30.3
4.00	20 - 42	31	26	Medium Dense	34.9
*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 a range of **angles of shearing resistance** of between $\phi=30.3^\circ$ and 36° .

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

6.3.2 Cohesive

Cohesive material comprising clay and silt, was encountered in all exploratory hole locations, below the made ground and topsoil at depths between 1.00m and 6.00m bgl.

SPT tests carried out in the cohesive material resulted in **SPT N values** of between 8 and 50, as shown on the SPT v Depth Plot in Figure 5 (overleaf). This result suggests the cohesive material is soft to very stiff.

Atterberg Limit tests were carried out on six samples of the clay and one sample of silt. Results of the test reported **liquid limit** values in the range of 27% to 32% and **plastic limit** values in the range of 12% to 22%, resulting in values of **plasticity index** in the range of 7% to 18%. These results suggest the clay to be of **low plasticity**. Results are shown on the Plasticity Chart in Figure 6, overleaf.

The **water-soluble sulphate** content of the six clay samples and one silt sample ranged from 70mg/l to 280mg/l SO_4 , together with **pH values** of 6.9 to 7.4.

Particle Size Distribution (PSD) tests were carried out on two silt samples. A breakdown of the test results is shown in Table 6 above and in Appendix 2.

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

Table 8: Summary of Design Parameters (Cohesive)

Depth	SPT N Value Range	Design N Value*	Equivalent Shear Strength** (kN/m ²)	Coefficient of Volume Compressibility** (mv)
1.00	17 - 20	17.75	112.71 (High Strength)	0.09 (Low Compressibility)
2.00	43	43	273.05 (Very High Strength)	0.04 (Very Low Compressibility)
3.00	8 - 50	14.75	93.66 (High Strength)	0.13 (Medium Compressibility)
4.00	9 - 33	11	69.85 (Medium Strength)	0.17 (Medium Compressibility)
5.00	16 - 17	16.25	103.19 (High Strength)	0.12 (Medium Compressibility)
6.00	26	26	165.10 (Very High Strength)	0.07 (Low 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 were between 69 and 273kN/m².

For design purposes, a value of plasticity index = 16% is recommended, based on the upper quartile value 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 16%, $mv = 1 / (0.635 \times N \text{ value})$. This correlation gives a value of coefficient of volume compressibility of 0.17 to 0.04m²/MN, as shown in Table 7, above. The results suggest the clay has a **medium to very low 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 **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 9, overleaf.

Table 9: Soil Desiccation Indicators in the Clay

Location	Depth (m)	Liquid Limit (%)	40% Liquid Limit (%)	Natural Moisture Content (%)	Desiccation
WS1	2.95	32	13	28.2	No
WS3	2.70	29	12	13.5	No
WS4	1.10	27	11	13.2	No
WS5	1.30	29	12	23.3	No
CP1	4.00	27	11	12.6	No
CP2	2.70	29	12	17.3	No
CP2	3.70	29	12	27.9	No

The results in the above table show that none of the clay/silt samples tested show evidence of desiccation.

6.4 Bedrock

Mudstone bedrock was encountered at the base of exploratory boreholes WS1, WS3, CP1 and CP2, with rockhead between 4.00m - 6.00m bgl.

SPT tests carried out in the mudstone resulted in **SPT N values** of 25 - 50 as shown on the SPT v Depth Plot in Figure 5 (overleaf).

Figure 5: SPT v Depth Plot

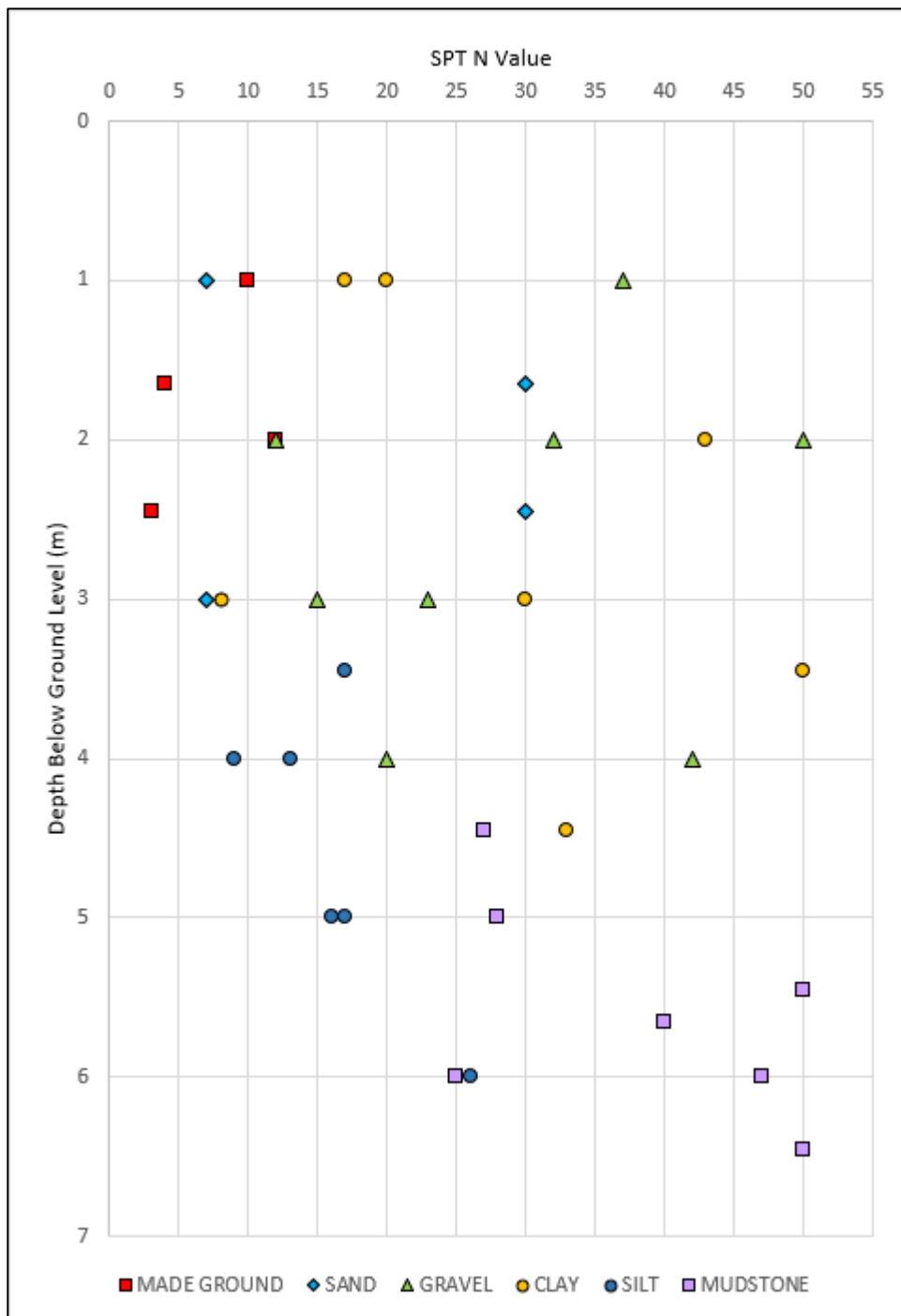
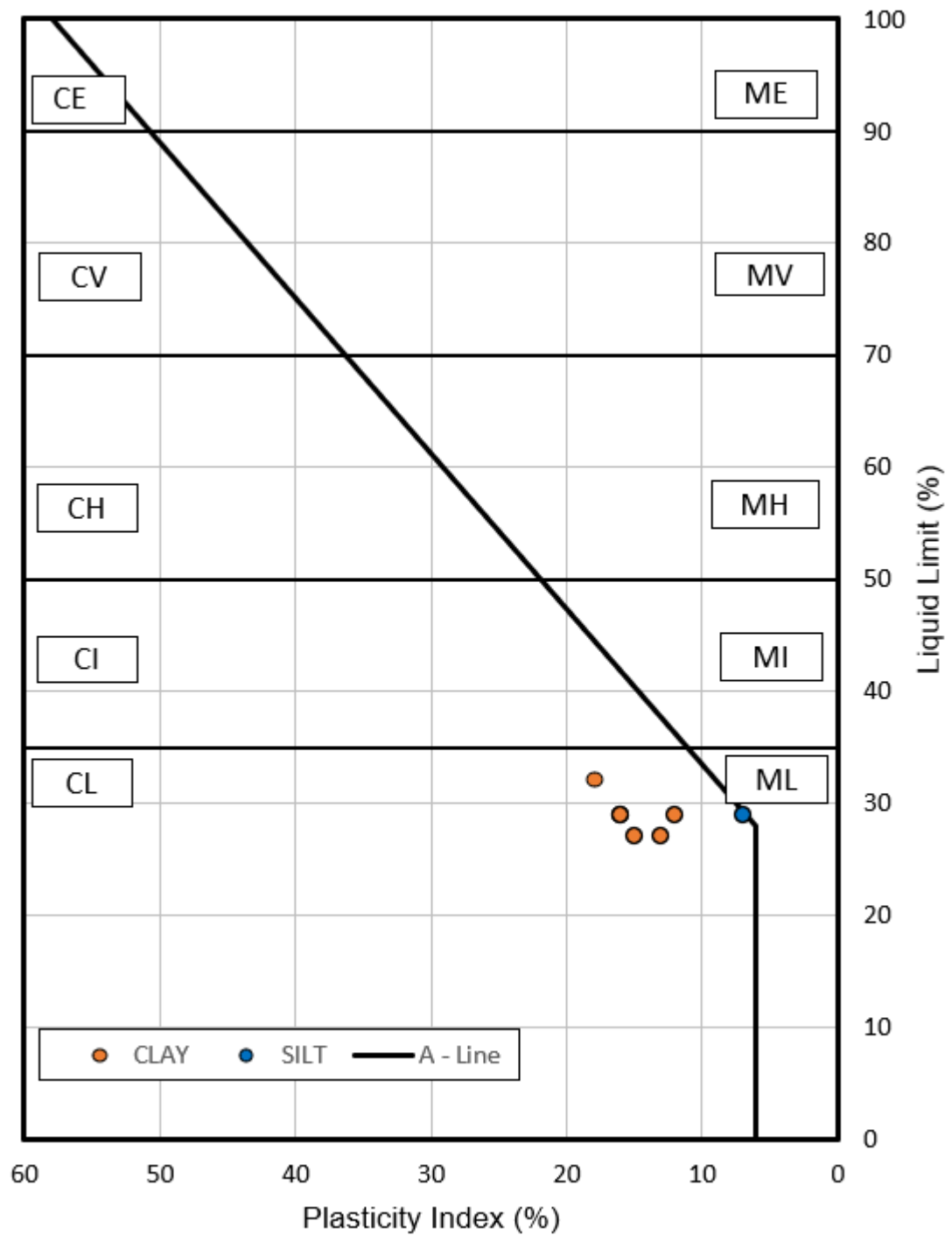


Figure 6: Plasticity Chart



7.0 GEOTECHNICAL ASSESSMENT

7.1 Proposed Development

It is understood that the client wishes to develop a new row of townhouses and a residential apartment block, comprising six three-bedroom townhouses and 21 one-bedroom flats.

Detailed information regarding structural loadings and proposed foundation type was not available at the time of authoring this report.

7.2 Ground Conditions Encountered

The exploratory holes generally encountered variable made ground between ground level and a maximum depth of 3.40m bgl (CP1), underlain by superficial river terrace deposits of sand, gravel, clay and silt. Mudstone rockhead was encountered between 4.00m and 6.00m bgl.

It should be noted that deep made ground was only identified within WS1 and CP1, with WS1 located in a proposed car parking area and has therefore been disregarded for the following calculations.

Groundwater was encountered in all exploratory boreholes, excluding WS4 and CP2, during the ground investigation, with water encountered between 2.00m and 3.00m bgl. Subsequent monitoring visits to the site identified groundwater in all of the installed boreholes ranging from 1.77 - 2.87m bgl.

7.3 Foundation Considerations

Based on the ground conditions encountered, conventional shallow depth foundations (strip/pad), placed in the superficial deposits, should be suitable for the townhouse portion of the development, providing the anticipated structural loadings are relatively low and subject to tolerance of structure to settlement.

Should the allowable bearing pressure and settlement prove unfavourable, then alternative foundations options will need to be considered, such as ground improvement and piles.

Due to the deep made ground (3.40m) encountered within CP1, a shallow foundation solution would not be appropriate for the apartment block portion of the development, therefore a ground improvement or piled solution should be considered.

7.3.1 *Conventional Shallow Depth Strip/Pad Foundations*

Strip/pad foundations should be taken down below any Topsoil or Made Ground and placed in the natural superficial deposits. If any Made Ground, particularly loose or soft material, is encountered at foundation level this should be excavated and replaced with suitable granular fill or the foundation extended at least 150mm into suitable natural strata.

Foundations should be placed in materials of similar bearing and consolidation characteristics to avoid potential differential settlement occurring. Should foundations cross from cohesive to granular soils, nominal reinforcement should be incorporated to avoid the effects of differential settlement.

Table 10 below, summarises anticipated allowable bearing pressures for strip/pad foundations placed in the superficial deposits. The bearing capacities are calculated based on Hansen's⁽¹⁹⁷⁸⁾ method and assuming a factor of safety against bearing capacity failure of 3. For the purpose of the calculation, groundwater has been assumed to be at 1.77m bgl, as this was the shallowest groundwater depth encountered during both the investigation and subsequent monitoring visits.

Table 10: Summary of Allowable Bearing Pressures

Foundation Strata	Design Value (Section 8)	Foundation Depth (m bgl)	Foundation Type	Foundation Size (m)	Allowable Bearing Pressure (kN/m ²)
GRANULAR	$\phi = 31.6^\circ$	1.0	Strip	0.4	201
				0.9	217
			Pad	1.0 x 1.0	296
				2.0 x 2.0	300
	$\phi = 31.6^\circ$	1.5	Strip	0.4	295
				0.9	297
			Pad	1.0 x 1.0	435
				2.0 x 2.0	422
	$\phi = 36^\circ$	2.0	Strip	0.4	592
				0.9	598
			Pad	1.0 x 1.0	966
				2.0 x 2.0	941
	$\phi = 36^\circ$	2.5	Strip	0.4	666
				0.9	673
			Pad	1.0 x 1.0	1097
				2.0 x 2.0	1070
COHESIVE	$c_u=112.71 \text{ kN/m}^2$	1.0	Strip	0.4	291
				0.9	264
			Pad	1.0 x 1.0	309
				2.0 x 2.0	279
	$c_u=112.71 \text{ kN/m}^2$	1.5	Strip	0.4	304
				0.9	282
			Pad	1.0 x 1.0	330
				2.0 x 2.0	299
	$c_u=273.05 \text{ kN/m}^2$	2.0	Strip	0.4	737
				0.9	695
			Pad	1.0 x 1.0	818
				2.0 x 2.0	746
	$c_u=273.05 \text{ kN/m}^2$	2.5	Strip	0.4	745
				0.9	711
			Pad	1.0 x 1.0	838
				2.0 x 2.0	772

Tables 11 and 12 overleaf summarise anticipated settlements of the above foundations in granular and cohesive soils based on design values discussed in Section 6. Settlement in cohesive soils typically comprises a small amount of immediate settlement as loads are applied and a larger proportion of consolidation settlement, which will occur over a longer period, whereas settlement in granular soils typically comprises a large amount of immediate settlement as loads are applied and a smaller proportion of consolidation settlement, which will occur over a longer period of time.

As the proposed foundation loading is not known, for the purposes of these calculations a foundation loading of 75kN/m² has been used.

Table 11: Summary of Anticipated Settlement (Granular)

Foundation Depth (m bgl)	Foundation Strata	Foundation Type	Foundation Size (m)	Pad Foundation Loading (kN/m²)	Settlement* (mm)		
					Lower Limit	Upper Limit	Best Estimate
1.0 - 1.5	SAND/ GRAVEL	Strip	0.4	75	1	2	1
			0.9	75	1	6	2
		Pad	1.0 x 1.0	75	1	4	2
			2.0 x 2.0	75	1	6	3
2.0 - 2.5		Strip	0.4	75	0	2	1
			0.9	75	1	3	1
		Pad	1.0 x 1.0	75	0	1	2
			2.0 x 2.0	75	1	1	3
*Immediate settlement							

*Immediate settlement

Table 12: Summary of Anticipated Settlement (Cohesive)

Foundation Depth (m bgl)	Foundation Strata	Foundation Type	Foundation Size (m)	Pad Foundation Loading (kN/m²)	Settlement (mm)		
					At Centre	At Corner	Average
1.0	CLAY	Strip	0.4	75	-	-	6
			0.9	75	-	-	10
		Pad	1.0 x 1.0	75	9	2	7
			2.0 x 2.0	75	17	4	12
1.5		Strip	0.4	75	-	-	6
			0.9	75	-	-	10
		Pad	1.0 x 1.0	75	9	2	7
			2.0 x 2.0	75	16	4	12
2.0		Strip	0.4	75	-	-	5
			0.9	75	-	-	9
		Pad	1.0 x 1.0	75	9	2	7
			2.0 x 2.0	75	17	4	12
2.5		Strip	0.4	75	-	-	6
			0.9	75	-	-	11
		Pad	1.0 x 1.0	75	10	3	8
			2.0 x 2.0	75	18	4	13

Floor slabs should be designed as suspended if Made Ground of 600mm thickness or greater is present. Made ground is not considered an appropriate bearing stratum due to its variable nature. Floor slabs may be designed as ground bearing where Made Ground is excavated and replaced with suitable granular fill.

All foundation excavations should be inspected by a suitable qualified engineer to prove that the founding strata is suitable and uniform along the length of the foundation, and capable of taking the anticipated structural loadings. If foundations cross from granular to cohesive soils, nominal reinforcement should be incorporated.

7.3.2 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 or 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 is capable of providing the required working loads in the ground conditions encountered, with a guarantee on maximum settlement for both footings and floor slabs.

7.3.3 Controlled Modulus Columns

Where traditional ground improvement techniques may not be suitable due to either poor soil strength, high loadings or tight settlement criteria, controlled modulus columns (CMCs) provide a fast and economical ground improvement alternative to piling.

The technique installs low strength concrete columns, 280mm to 500mm in diameter, up to 50m in depth using displacement tools.

The benefits are:

- Ground bearing foundation solution utilising a distribution mattress.
- The rig working platform can be used as part of the distribution mattress.
- No breaking down of CMCs. Trimming is undertaken while the CMCs are still wet.
- The vibration free displacement process creates minimal spoil.

The technique can be used for a wide range of structures including heavily loaded commercial/industrial floor slabs, road and rail embankments, silos, tanks and wind turbines and residential buildings traditionally founded on driven piles.

Positive assurances should be sought from an experienced specialist contractor that the proprietary system proposed is capable of providing the required working loads in the ground conditions encountered, with a guarantee on maximum settlement for both footings and floor slabs.

7.3.4 Piled Foundations

Due to the deep made ground below the proposed apartment block, driven or bored piles could be adopted. Driven piles would have the advantage of minimising the spoil that is generated, however, the noise and vibration associated with the installation of driven piles may prevent this type of pile from being selected. It should also be noted that driven piles can also potentially create preferential pollutant pathways.

Short bored (cast in-situ) piles installed using continuous flight auger (CFA) techniques may therefore be more appropriate but given 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 any Made Ground.

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 is capable of providing the required working loads in the ground conditions encountered.

Floor slabs should be designed as suspended if the piled solution is used.

7.4 Pavement Design

The exploratory boreholes generally encountered Made Ground or topsoil at a subgrade level. 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 a subgrade level.

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 13: 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 axes. 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 generally neutral or slightly alkaline 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.

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 14: 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	-	-
pH (alkaline)	7 - 8	8 - 9	9 - 10	10 - 12	12	7.4 - 11.3	A - D
Arsenic	0 - 30	30 - 50	50 - 100	100 - 500	500	3 - 45	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	8 - 25	A
Copper	0 - 100	100 - 200	200 - 500	500 - 2500	2500	9 - 130	A - B
Lead	0 - 500	500 - 1000	1000 - 2000	2000 - 1%	1.0%	10 - 132	A
Mercury	0 - 1	1 - 3	3 - 10	10 - 50	50	< 1	A
Nickel	0 - 20	20 - 50	50 - 200	200 - 1000	1000	6 - 56	A - C
Zinc	0 - 250	250 - 500	500 - 1000	1000 - 5000	5000	31 - 149	A
Boron	0 - 2	2 - 5	5 - 50	50 - 250	250	< 1	A
Selenium	0 - 1	1 - 3	3 - 10	10 - 50	50	< 2	A
Barium	0-500	500-1000	1000-2000	2000-1.0%	1.0%	25 - 412	A
Beryllium	0 - 5	5 - 10	10 - 20	20 - 50	50	< 0.5 - 3.2	A
Vanadium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	10 - 77	A
Sulphate	0 - 2000	2000 - 5000	5000 - 1%	1% - 5%	5.05%	< 200 - 10430	A - D
Sulphide	0 - 10	10 - 20	20 - 100	100 - 500	500	< 5	A
Cyanide (free)	0 - 1	1 - 5	5 - 50	50 - 100	100	< 1	A
Phenol	0 - 2	2 - 5	5 - 50	50 - 250	250	< 2	A

Based on the above results, the soils range from uncontaminated to heavily contaminated. 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 contaminated land guidance has recently changed the evaluation of risk from 'minimal' (SGVs) to 'low' (referred to as Lowest Level of Toxicological Concern (LLTCs)). The policy companion document and supporting letter by DEFRA, states that C4SLs 'could be used under the planning regime, as well as within Part 2A'.

Based on these comments EEG considers the justifications and assumptions used to generate 'low' risk are suitable for the planning regime.

Where no C4SLs have been generated EEG will use the LQM S4ULs. Similar assumptions and land use to C4SLs have been used. However, toxicological information has been based on 'minimal risk' as per previous guidelines and assumptions. If contaminants are not present as C4SLs or S4ULs then EEG will use CL:AIRE GACs. These follow the 'minimal' risk principal and more stringent exposure parameters and will be conservative.

EEG consider the main risk drivers for PAHs are benzo(a)pyrene (B(a)P) and naphthalene. This is due to B(a)P possibly being a carcinogen and most toxic of the PAHs and naphthalene the most volatile and soluble. The new C4SLs indicate B(a)P as a surrogate marker for carcinogenic PAHs, since the risk from other non-carcinogenic PAHs are considered negligible. Naphthalene will be treated separately using the LQM S4ULs.

As a preliminary screening assessment, all results have been compared to residential end use (with plant uptake) criteria. The average soil organic matter of the tested samples is 10%, therefore for the purpose of this assessment, a SOM of 6% has been used.

The soil chemical testing results are summarised in Table 15, overleaf.

Table 15: Soil Results Comparison with C4SL/S4UL Values

Determinand	C4SL/S4UL Levels Residential with plant uptake 6% SOM (mg/kg)	WS1 0.40m MG	WS2 0.50m SAND	WS3 0.30m MG	WS4 0.30m MG	WS4 0.80m SAND	No of Exceedances
Metals							
Arsenic	37	4	3	10	9	4	0
Beryllium	1.7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0
Boron	290	< 1	< 1	< 1	< 1	< 1	0
Cadmium	22	0.8	< 0.2	0.2	0.8	< 0.2	0
Chromium	910	8	8	10	11	11	0
Chromium VI	21	< 2	< 2	< 2	< 2	< 2	0
Copper	2400	21	9	35	39	15	0
Lead	200	61	10	71	118	16	0
Inorganic Mercury	40	< 1	< 1	< 1	< 1	< 1	0
Nickel	180	9	6	10	10	6	0
Selenium	250	< 2	< 2	< 2	< 2	< 2	0
Vanadium	410	14	10	17	19	13	0
Zinc	3700	60	31	50	59	31	0
Petroleum Hydrocarbons							
Benzene	0.87	<0.002	<0.002	<0.002	<0.002	<0.002	0
Toluene	660	<0.005	<0.005	<0.005	<0.005	<0.005	0
Ethylbenzene	260	<0.002	<0.002	<0.002	<0.002	<0.002	0
o-xylenes	330	<0.002	<0.002	<0.002	<0.002	<0.002	0
m-xylenes	320	<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
Aliphatic EC >5-6	160	< 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
Aliphatic EC >8-10	150	< 2	< 2	< 2	< 2	< 2	0
Aliphatic EC >10-12	760 ^{vap}	< 2	< 2	< 2	< 2	< 2	0
Aliphatic EC >12-16	4300 ^{sol}	24	< 3	< 3	< 3	< 3	0
Aliphatic EC >16-21	110000	31	< 3	< 3	< 3	< 3	0
Aliphatic EC >21-35	110000	213	< 10	< 10	< 10	< 10	0
Aromatic EC >5-7	300	< 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
Aromatic EC >8-10	190	< 2	< 2	< 2	< 2	< 2	0
Aromatic EC >10-12	380	< 2	< 2	< 2	< 2	< 2	0
Aromatic EC >12-16	660	11	< 2	4	< 2	< 2	0
Aromatic EC >16-21	930	83	< 3	18	< 3	< 3	0
Aromatic EC >21-35	1700	553	< 10	74	< 10	< 10	0
Polycyclic Aromatic Hydrocarbons							
Naphthalene	85	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthylene	920	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthene	1100	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Fluorene	860	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Phenanthrene	440	0.32	< 0.1	0.21	< 0.1	< 0.1	0
Anthracene	11000	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Fluoranthene	890	0.58	< 0.1	0.23	< 0.1	< 0.1	0
Pyrene	2000	0.55	< 0.1	0.2	< 0.1	< 0.1	0
Benzo(a)anthracene	13	0.22	< 0.1	< 0.1	< 0.1	< 0.1	0
Chrysene	27	0.27	< 0.1	0.12	< 0.1	< 0.1	0
Benzo(a)pyrene	5	0.27	< 0.1	< 0.1	< 0.1	< 0.1	0
Benzo(b)fluoranthene	3.7	0.24	< 0.1	< 0.1	< 0.1	< 0.1	0
Benzo(k)fluoranthene	100	0.12	< 0.1	< 0.1	< 0.1	< 0.1	0
Indeno(1,2,3-cd) pyrene	41	0.18	< 0.1	< 0.1	< 0.1	< 0.1	0
Dibenzo (a, h) anthracene	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Benzo(ghi)perylene	350	0.16	< 0.1	< 0.1	< 0.1	< 0.1	0
Phenols							
Phenol	380	< 2	< 2	< 2	< 2	< 2	0

Table 15: Soil Results Comparison with C4SL/S4UL Values, Continued

Determinand	C4SL/S4UL Levels Residential with plant uptake 6% SOM (mg/kg)	WS5 0.50m MG	CP1 1.00m MG	CP1 2.50m MG	CP2 0.50m MG	CP2 0.70m SAND	No of Exceedances
Metals							
Arsenic	37	45	27	25	9	7	1
Beryllium	1.7	3.2	1.7	2.2	0.7	0.7	3
Boron	290	< 1	< 1	< 1	< 1	< 1	0
Cadmium	22	< 0.2	0.6	< 0.2	0.6	0.5	0
Chromium	910	25	23	15	15	13	0
Chromium VI	21	< 2	< 2	< 2	< 2	< 2	0
Copper	2400	130	121	116	53	20	0
Lead	200	109	132	41	100	37	0
Inorganic Mercury	40	< 1	< 1	< 1	< 1	< 1	0
Nickel	180	56	35	42	16	14	0
Selenium	250	< 2	< 2	< 2	< 2	< 2	0
Vanadium	410	77	40	53	22	19	0
Zinc	3700	67	149	57	81	77	0
Petroleum Hydrocarbons							
Benzene	0.87	<0.002	<0.002	0.033	<0.002	<0.002	0
Toluene	660	<0.005	<0.005	<0.005	<0.005	<0.005	0
Ethylbenzene	260	<0.002	0.022	<0.002	<0.002	<0.002	0
o-xylenes	330	<0.002	0.027	0.002	<0.002	<0.002	0
m-xylenes	320	<0.002	0.043	0.004	<0.002	<0.002	0
p-xylenes	310	<0.002	0.043	0.004	<0.002	<0.002	0
Aliphatic EC >5-6	160	< 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
Aliphatic EC >8-10	150	< 2	5	< 2	< 2	4	0
Aliphatic EC >10-12	760 ^{vap}	< 2	53	< 2	14	16	0
Aliphatic EC >12-16	4300 ^{sol}	< 3	405	13	144	156	0
Aliphatic EC >16-21	110000	< 3	525	17	209	215	0
Aliphatic EC >21-35	110000	< 10	807	32	204	286	0
Aromatic EC >5-7	300	< 0.01	< 0.01	0.03	< 0.01	< 0.01	0
Aromatic EC >7-8	660	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Aromatic EC >8-10	190	< 2	5	< 2	< 2	< 2	0
Aromatic EC >10-12	380	< 2	61	2	< 2	< 2	0
Aromatic EC >12-16	660	< 2	1121	40	11	14	1
Aromatic EC >16-21	930	< 3	4751	213	45	35	1
Aromatic EC >21-35	1700	< 10	5962	283	54	29	1
Polycyclic Aromatic Hydrocarbons							
Naphthalene	85	< 0.1	28	0.82	0.54	< 0.1	0
Acenaphthylene	920	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthene	1100	< 0.1	131	3.51	1.25	0.36	0
Fluorene	860	< 0.1	70.9	1.92	0.9	< 0.1	0
Phenanthrene	440	0.23	563	19.9	3.87	0.57	1
Anthracene	11000	< 0.1	147	5.63	1.21	0.17	0
Fluoranthene	890	0.3	890	39.1	4.76	0.81	1
Pyrene	2000	0.27	733	31.6	4.54	0.84	0
Benzo(a)anthracene	13	0.14	286	11.7	1.56	0.31	1
Chrysene	27	0.21	262	10.9	2.04	0.41	1
Benzo(a)pyrene	5	< 0.1	188	10.4	2.37	0.44	2
Benzo(b)fluoranthene	3.7	0.14	236	9.52	2.39	0.48	2
Benzo(k)fluoranthene	100	< 0.1	96.6	4.08	0.87	0.15	0
Indeno(1,2,3-cd) pyrene	41	< 0.1	94.6	4.95	1.52	0.29	1
Dibenzo (a, h) anthracene	0.3	< 0.1	19.4	0.94	< 0.1	< 0.1	2
Benzo(ghi)perylene	350	< 0.1	67.2	3.4	1.36	0.26	0
Phenols							
Phenol	380	< 2	< 2	< 2	< 2	< 2	0

Based on the above table, 18no. contaminant concentrations from three soil samples were found in exceedance of the screening criteria relevant to a residential with plant uptake end use. Contaminant exceedances are summarised in Table 16 overleaf.

Table 16: Summary of Contaminant Exceedances

Borehole Location	Contaminant Exceedance
WS5 (0.50m)	Arsenic (45mg/kg), Beryllium (3.2mg/kg)
CP1 (1.00m)	Beryllium (1.7mg/kg), Aromatic EC >12-16 (1121mg/kg), Aromatic EC >16-21 (4751mg/kg), Aromatic EC >21-35 (5962mg/kg), Phenanthrene (563mg/kg), Fluoranthene (890mg/kg), Benzo(a)anthracene (286mg/kg), Chrysene (262mg/kg), Benzo(a)pyrene (188mg/kg), Benzo(b)fluoranthene (236mg/kg), Indeno(1,2,3-cd) pyrene (94.6mg/kg), Dibenzo (a, h) anthracene (19.4mg/kg)
CP1 (2.50m)	Beryllium (2.2mg/kg), Benzo(a)pyrene (10.4mg/kg), Benzo(b)fluoranthene (9.52mg/kg), Dibenzo (a, h) anthracene (0.94mg/kg)

Asbestos fibres and fragments were not identified in the soil samples analysed.

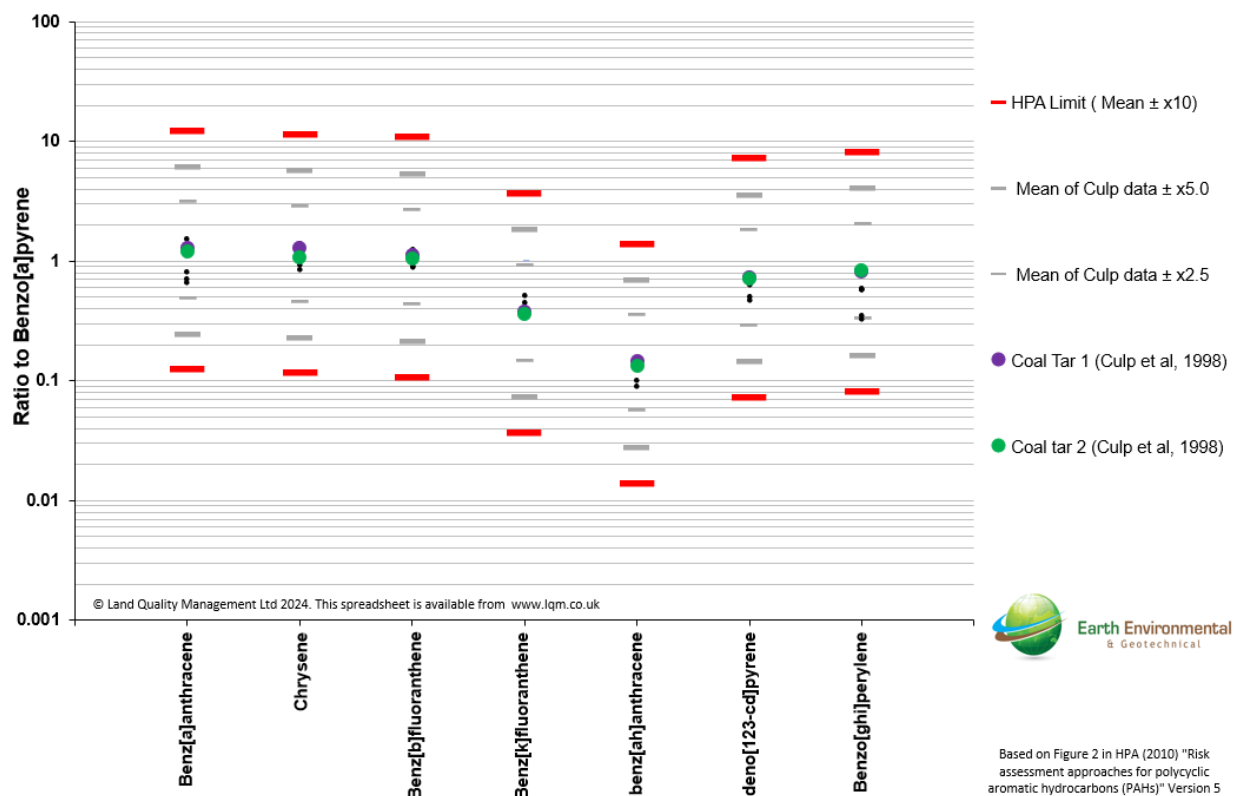
Benzo(a)pyrene as Surrogate Marker

The main risk drivers for PAHs are benzo(a)pyrene (B(a)P) and naphthalene. This is due to B(a)P possibly being a carcinogen and most toxic of the PAHs and naphthalene the most volatile and soluble. The C4SLs indicate B(a)P as a surrogate marker for carcinogenic PAHs, if it falls within appropriate limits, since the risk from other non-carcinogenic PAHs are considered negligible. For B(a)P to be used as a surrogate marker it should follow the profile described by the HPA (2010)i and CL:AIRE (2013). Naphthalene will be treated separately using the LQM S4ULs.

An assessment of the PAH data has been undertaken for the site, with regards to using B(a)P as a surrogate marker for carcinogenic PAHs as per HPA and CL:AIRE guidelines. The primary toxicological study related to Culp et.al, which was based on coal tar mixtures (>80,000mg/kg of total PAHs) fed in food to mice over a two-year carcinogenicity study.

Figure 7 summarises the study site data (where values were >LOD to allow the calculation of a ratio) with respect to how the ratios of carcinogenic PAHs relate to B(a)P, within the confidence limits provided in the HPA document.

Figure 7: PAH v Benzo(a)pyrene Plot



All the data points that could be used to calculate ratios fall inside the upper or lower limits.

Based on this distribution of data EEG Ltd considers B(a)P can be used as a surrogate marker for carcinogenic PAHs and the C4SL criteria is suitable for this dataset.

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 17 below and presented in full in Appendix 4.

Table 17: Waste Classification of Soils

Location	Depth (m bgl)	WM3.1 Classification	WAC Testing Classification	Comments
WS1	0.40	Non-Hazardous	Hazardous	Elevated TOC
WS2	0.50	Non-Hazardous	-	-
WS3	0.30	Non-Hazardous	-	-
WS4	0.40	Non-Hazardous	-	-
WS4	0.80	Non-Hazardous	-	-
WS5	0.50	Non-Hazardous	Exceeds Hazardous	Elevated TOC & Loss on Ignition
CP1	1.00	Hazardous	Exceeds Hazardous	Elevated TOC, Loss on Ignition, Mineral Oil & Total PAHs
CP1	2.50	Non-Hazardous	-	-
CP2	0.50	Non-Hazardous	-	-
CP2	0.70	Non-Hazardous	-	-

The above table shows that 1no. of the tested samples collected from the site have been classified as **Hazardous** in accordance with WM3.1, with the remainder classified as Non-Hazardous.

Three of the soil samples have been submitted for Waste Acceptance Criteria (WAC) testing. Two of the tested samples (WS5 at 0.50m and CP1 at 1.00m) are recorded to exceed the criteria for disposal at a hazardous waste facility, due to elevated TOC and Loss on Ignition, as well as Mineral Oil and Total PAHs in CP1. The third tested sample (WS1 at 0.40m) has been classified as **Hazardous**, due to elevated TOC.

Soils from the areas around WS5 and CP1 may need to be treated prior to disposal. Alternatively, as the Dissolved Organic Carbon (DOC) of both samples was less than 1000mg/kg at L/S=10l/kg, the Environment Agency may consider this material to be suitable for disposal at a hazardous waste facility. Further consultation with the Environment Agency is recommended prior to the disposal of this material.

For Waste Acceptance Criteria (WAC) testing, EEGL have compared solid waste and leachate values with guideline values in Landfill Regulations. The following table 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.

Further WAC testing on the remaining samples may prove that the material is acceptable as inert waste.

Table 18: Summary of WAC Test Results

Determinand	Landfill Regulations Limits (mg/kg unless otherwise indicated)			WS1 0.40m (mg/kg)	WS5 0.50m (mg/kg)	CP1 1.00m (mg/kg)
	Inert Waste	Stable Non- Reactive non-hazardous waste	Hazardous Waste			
TOC (%)	3%	5%	6%	5.8	15.4	16.7
Loss on ignition (%)	-	-	10%	7.30	11.80	16.20
BTEX (mg/kg)	6	-	-	< 0.05	< 0.05	0.09
Sum of PCBs (mg/kg)	1	-	-	< 0.1	< 0.1	< 0.1
Mineral Oil (mg/kg)	500	-	-	333	< 10	1819
Total PAH (mg/kg)	100	-	-	2.9	< 1.7	3830
pH (units)	-	< 6	-	8.8	7.4	7.6
Acid Neutralisation Capacity (mol/kg)	-	To be evaluated		1.5	< 1	< 1
Arsenic	0.5	2	25	0.025	0.016	0.065
Barium	20	100	300	1.350	0.624	0.520
Cadmium	0.04	1	5	< 0.002	< 0.002	< 0.002
Chromium	0.5	10	70	0.017	0.003	0.005
Copper	2	50	100	0.043	0.024	0.090
Mercury	0.01	0.2	2	< 0.0004	< 0.0004	< 0.0004
Molybdenum	0.5	10	30	0.044	0.074	0.097
Nickel	0.4	10	40	< 0.0002	< 0.0002	0.0060
Lead	0.5	10	50	0.026	0.017	0.008
Antimony	0.06	0.7	5	< 0.002	< 0.002	< 0.002
Selenium	0.1	0.5	7	0.0046	0.0044	0.0032
Zinc	4	50	200	0.13	0.28	0.05
Chloride	800	15000	25000	22	< 12	192
Fluoride	10	150	500	< 1	< 1	< 1
Sulphate	1000	20000	50000	110	109	895
Total Dissolved Solids	4000	60000	100000	1462	539	1579
Phenol Index	1	-	-	< 0.5	< 0.5	< 0.5
DOC	500	800	1000	145	113	228

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⁾.

EQS values have been derived to protect surface water. The nearest surface water feature is River Roch, located directly north of the site. For the purposes of this report, it is considered the most appropriate EQS data are those established for freshwater.

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 total of 4no. groundwater samples were retrieved from the monitoring wells installed across the site.

A direct comparison was made between the groundwater analyses results and the EQS and Drinking Water Standards, and the results are summarised in Table 19, overleaf.

In general, the laboratory analyses encountered low concentrations of contaminants which were below the EQS and Drinking Water Standards. However, 5no. contaminant exceedances were encountered within three of the samples, as summarised below.

- WS1 has elevated levels of arsenic (14.9 µg/l) above the DWQ value.
- WS2 has elevated levels of copper (1.4 µg/l) above the EQS value.
- WS4 has elevated levels of nickel (30.8 µg/l) above the DWQ value, and levels of zinc (17 µg/l) above the EQS value. This sample also had a pH (5.9) just outside the EQS value.

Given the EQS guidelines are particularly stringent and based on the type of proposed development and end use, the identified contamination within the groundwater samples does not pose a risk to future end users.

However, considering the site is located directly south of the River Roch, there is the potential for sub-surface migration of the contaminants into the local water course.

Table 19: Groundwater Results Comparisons with EQS/Drinking Water Quality Values

Determinand	EQS Value (a)	Drinking Water Quality (DWQ) Value (b)	WS1	WS2	WS4	WS5	No. of Exceedances
Arsenic	50 ^(A)	10	14.9	0.3	0.3	0.6	1 for (b)
Barium	-	700 (WHO)	575	96.7	52	73.8	0
Beryllium	-	-	< 0.2	< 0.2	< 0.2	< 0.2	0
Boron	2000 ^(A)	1000	59	20	50	48	0
Cadmium	0.9 ^(M)	5	< 0.2	< 0.2	< 0.2	< 0.2	0
Chromium	32 ^(M)	50	0.3	< 0.2	< 0.2	< 0.2	0
Chromium VI	3.4 ^(A)	-	< 20	< 20	< 20	< 20	0
Copper	1 ^(A)	2000	< 0.2	1.4	0.3	0.7	1 for (a)
Lead	14 ^(M)	10	< 0.2	< 0.2	< 0.2	< 0.2	0
Mercury	0.07 ^(M)	1	< 0.04	< 0.04	< 0.04	< 0.04	0
Selenium	-	10	0.5	0.2	< 0.2	4.8	0
Vanadium	20 ^(A)	-	0.4	< 0.2	< 0.2	< 0.2	0
Nickel	34 ^(M)	20	2.3	2.4	30.8	2.7	1 for (b)
Zinc	10.9 ^(A)	5000	3	3	17	< 1	1 for (a)
Cyanide	5 ^(M)	50	< 5	< 5	< 5	< 5	0
Phenol	46 ^(M)	5	< 10	< 10	< 10	< 10	0
Sulphate	400000 ^(A)	250000	0.005	0.004	0.02	0.011	0
pH	6 - 9 ^(M)	-	6.5	6.8	5.9	6.5	1 for (a)
Naphthalene	130 ^(M)	-	< 0.01	0.09	< 0.01	< 0.01	0
Anthracene	0.1 ^(M)	-	< 0.01	< 0.01	< 0.01	< 0.01	0
Benzo(a)pyrene	0.27 ^(M)	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Benzo(b)fluoranthene	0.017 ^(M)	0.1	< 0.01	< 0.01	< 0.01	< 0.01	0
Benzo(k)fluoranthene	0.017 ^(M)	0.1	< 0.01	< 0.01	< 0.01	< 0.01	0
Indeno(123cd) pyrene	-	0.1	< 0.01	< 0.01	< 0.01	< 0.01	0
Fluoranthene	0.12 ^(M)	-	< 0.01	< 0.01	< 0.01	< 0.01	0
Benzene	50 ^(M)	1	< 1	< 1	< 1	< 1	0
Toluene	380 ^(M)	700 (WHO)	< 5	< 5	< 5	< 5	0
Ethylbenzene	-	300 (WHO)	< 5	< 5	< 5	< 5	0
Xylenes	30 ^(A)	500 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aromatic C5-C7	-	10 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aromatic C7-C8	-	700 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aromatic C8-C10	-	300 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aromatic C10-C12	-	90 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aromatic C12-C16	-	90 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aromatic C16-C21	-	90 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aromatic C21-C35	-	90 (WHO)	< 10	< 10	< 10	84	0
TPH Aliphatic C5-C6	-	15000 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aliphatic C6-C8	-	15000 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aliphatic C8-C10	-	300 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aliphatic C10-C12	-	300 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aliphatic C12-C16	-	300 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aliphatic C16-C21	-	300 (WHO)	< 10	< 10	< 10	< 10	0
TPH Aliphatic C21-C35	-	300 (WHO)	< 10	< 10	< 10	< 10	0

*All values in µg/l unless otherwise stated, WHO=World Health Organization guide values.
*EQS Standards – (M) = Maximum Allowable Concentration Standard, (A) = Annual Average Standard.
Zinc EQS is based on bioavailability
Values in red are elevated above the recommended guidance value

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.

Six monitoring visits have been conducted between the 5th of April and the 3rd of May 2024. The results recorded methane (CH₄) levels of 0.0% to 3.2% v/v with carbon dioxide (CO₂) levels of 0.1% to 11.4% v/v. Oxygen concentrations of between 0.1% and 21.2% v/v were also recorded.

An absence of flow rates was detected during the monitoring period. For assessment purposes, a flow rate of 0.1 litres/hour has been used based on the limit of detection of the flow meter.

Atmospheric pressure was recorded to be between 986mb and 1005mb, therefore including a period of low pressure.

Full results of the monitoring are presented in Appendix 6.

Table 20 overleaf, adapted from Table 1 of the technical paper Risk and Reliability in Gas Protection Design by Card et al. 2019, 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 = 0.1 l/hr, max concentration = 11.4%
- Methane: Steady flow rate = 0.1 l/hr, max concentration = 3.2%.

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

- **Carbon Dioxide:** $GSV = 0.1 \times 11.4 / 100 = 0.0114 \text{ litres/hour}$
- **Methane:** $GSV = 0.1 \times 3.2 / 100 = 0.0032 \text{ litres/hour}$

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 1, i.e., ‘very low risk’, in accordance with Table 20 overleaf. However, due to the slightly elevated concentrations of carbon dioxide methane identified, the classification may need to be increased to CS2.

Table 20: Characteristic Situation (Wilson et al 2006/2007 modified from Wilson and Card, 1999)

Characteristic Situation	Risk Classification	Gas Screening Value CH₄ or CO₂ (l/hr)	Additional Factors	Typical source of generation
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 mine workings
4	Moderate to High	<15	Quantitative risk assessment	Mine workings susceptible to flooding, completed landfill
5	High Risk	<70		Mineworking unflooded inactive with shallow workings near surface
6	Very High Risk	>70		Recent landfill site

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.

Based on the results of the chemical testing, contaminant concentrations of arsenic and beryllium were found to exceed the screening criteria relevant to a residential with plant uptake end use in three samples across 2 locations (WS5 & CP1). Additionally, multiple PAHs including Benzo(a)pyrene, along with heavy fractions of TPH, were also found to exceed the screening criteria for residential development with plant uptake, exclusively within the made ground of CP1.

Therefore, the risk to future end users is **MODERATE** and a remediation strategy will be required for the proposed development.

11.2 Asbestos

Asbestos fibres and fragments were not identified in any of the soil samples tested.

11.3 Foundations

Shallow strip/pad foundations placed in/on the superficial deposits are considered appropriate for the townhouses section of the current proposed development, dependent on allowable bearing pressures and tolerance of structures to settlement.

Should the allowable bearing pressure and settlement prove unfavourable, then alternative foundations options will need to be considered, such as ground improvement and piles.

Due to the deep made ground encountered within the footprint of the proposed apartment block (up to 3.40m in CP1), conventional shallow foundations are not considered appropriate for the development. Therefore, alternative foundation solutions such as piles will be required for this section of the development. It is likely that piles driven into the local, shallow mudstone bedrock will be suitable.

It recommended that for foundations and ground floor slabs in contact with the made ground, the Design Sulphate Class should be taken as DS-1, and the Aggressive Chemical Environment for Concrete (ACEC) site classification be taken as AC-1.

11.4 Soil Disposal

Soils should be disposed of at a suitable site, registered to take the levels of contamination encountered. Soil samples collected have been classified mainly as Non-Hazardous for the purpose of off-site disposal in accordance with Environment Agency guidance WM3.1, with the exception being the sample tested from CP1 at 1.00m which was classified as Hazardous.

Further Waste Acceptance Criteria (WAC) testing was conducted on three of the collected samples, with the sample from WS1 at 0.40m classified as Hazardous waste and the samples

collected from WS5 at 0.50m and CP1 at 1.00m given a classification that exceeds Hazardous waste. This material will have to be treated before offsite disposal.

11.5 Groundwater Contamination

Based on the results of the chemical testing, in general low concentrations of contaminants were observed in the groundwater which were below the EQS values and Drinking Water Standards.

However, 5 exceedances were identified in three of the tested samples referring to heavy metals and a slightly acidic pH.

Whilst this type of contamination poses no risk to future end users, due to the presence of the River Roch directly north of the site, there is a **MODERATE to LOW** risk to controlled waters.

It is therefore recommended that sampling and testing of the surface water in the River Roch is conducted both upstream and downstream from the site, to assess the presence of contaminants leaching into the local watercourse.

11.6 Pavement Design

Based on the findings of the site investigation, the soil type at subgrade level was typically Made Ground or topsoil. 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.

11.7 Land Gas

Based on results of the gas monitoring, the risk of ground gas is considered “very low” with a characteristic situation of CS1. However, due to the slightly elevated concentrations of carbon dioxide and methane across all monitoring visits, this assessment should be increased to CS2 “low risk”.

Ground gas protection measures should be detailed within a remediation strategy.

11.8 Risk to Buried (Water) Services

It is considered that, due to the presence of hydrocarbons in the tested soils, standard materials are unlikely to be suitable 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).

11.9 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.

11.10 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

GEOTECHNICAL TESTING RESULTS

APPENDIX 3

SOIL CHEMICAL TESTING RESULTS

APPENDIX 4

SOIL WASTE ASSESSMENT

APPENDIX 5

WATER CHEMICAL TESTING RESULTS

APPENDIX 6

GROUND GAS MONITORING RESULTS

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 2024 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 of 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.