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SUMMARY

Site Details	
Site Location	<i>The site is located circa 1.6 miles South East of Bury Town Centre and is approximately centred on National Grid Reference 381974, 408609.</i>
Site Area	<i>The site shape is irregular in shape and covers an area of approximately 0.52 Hectares. The topography of the site slopes gently north to the south to a steep embankment. The development area is part of a wider site of Holchem Laboratories north of the site. The investigation area is generally covered by mature trees in the southern area of the site with light scrubland on the northern area of the site.</i>
Ground Model	
Made Ground Soils	<i>Made Ground was encountered across the site to a maximum depth of 6.5m bgl and comprised of brown clayey gravel and sand with low cobble content.</i>
Natural Soils	<i>The natural strata beneath the site generally consists of loose to medium dense Sand and firm to stiff medium strength to high strength sandy gravelly Clay.</i>
Bedrock	<i>No bedrock was encountered in this investigation.</i>
Groundwater	<i>Groundwater was encountered at depths between 7.0m bgl and 10.0m bgl.</i>
Ground Engineering Assessment	
Foundations	<i>The most appropriate foundation solution is considered to be CFA piles transferring loads through the Sand and Clay to between 12m and 16m bgl.</i>
Constraints	<i>Dense Vegetation is located in the southern area of the site which requires clearing. Deep Made Ground associated with sloping ground which contains obstructions for deep foundations. Requirement for retaining wall along south western corner.</i>
GQRA and Revised (PL) Assessment	
Human Health	<i>Geo-environmental testing indicates that there are no elevated Contaminants of Concern present within the Made Ground soils beneath the site. The site is to be predominantly covered with the extension and the risk to human health is considered to be Low.</i>
Controlled Waters	<i>No sources of mobile contamination have been identified onsite, therefore the risk to controlled waters is Very Low.</i>
Permanent Ground Gas	<i>Gas monitoring to date has recorded high concentrations of carbon dioxide and methane. The site is currently classified as being in CS2 and some gas protection measures will be required. This will be confirmed or otherwise on completion of the monitoring period.</i> <i>The site is not within an area requiring radon precautions within foundations</i>
Final Appraisal	



The following further work is considered necessary to progress the site to construction phase:

- *Completion of gas monitoring programme and issue the gas risk assessment.*
 - *Design of remedial specification.*
 - *Detailed foundation design.*
 - *Confirmation of the recommendations made within this report with the regulators.*
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Plans		
<i>Plan Reference</i>	<i>Revision</i>	<i>Title</i>
GRO-22216-P01	-	Site Location
GRO-22216-P02	-	Exploratory Hole Location Plan
GRO-22216-P03	-	Generalised Ground Model
GRO-22216-P04	-	Illustrative CSM

1.0 INTRODUCTION

1.1 Project Objectives

Groundtech Consulting Limited have been instructed by Brian Clancy Higby Partnership on behalf of Holchem Laboratories Ltd to undertake a Geo-Environmental Appraisal for a site at Pilsworth Industrial Estate in Bury.

A main investigation was undertaken in accordance with BS 5930:2015, BS 8576:2013, BS 10175:2017 and Eurocode 7. The Appraisal has been prepared in accordance with current UK Legislation and to discharge Land Quality pre-commencement planning conditions.

The report has been undertaken to fulfil the requirements of a preliminary risk assessment in accordance with LCRM "Land Contamination Risk Management".

1.2 Proposed Development

The proposed development is commercial end use comprising a warehouse extension to the main laboratory.

1.3 Limitations

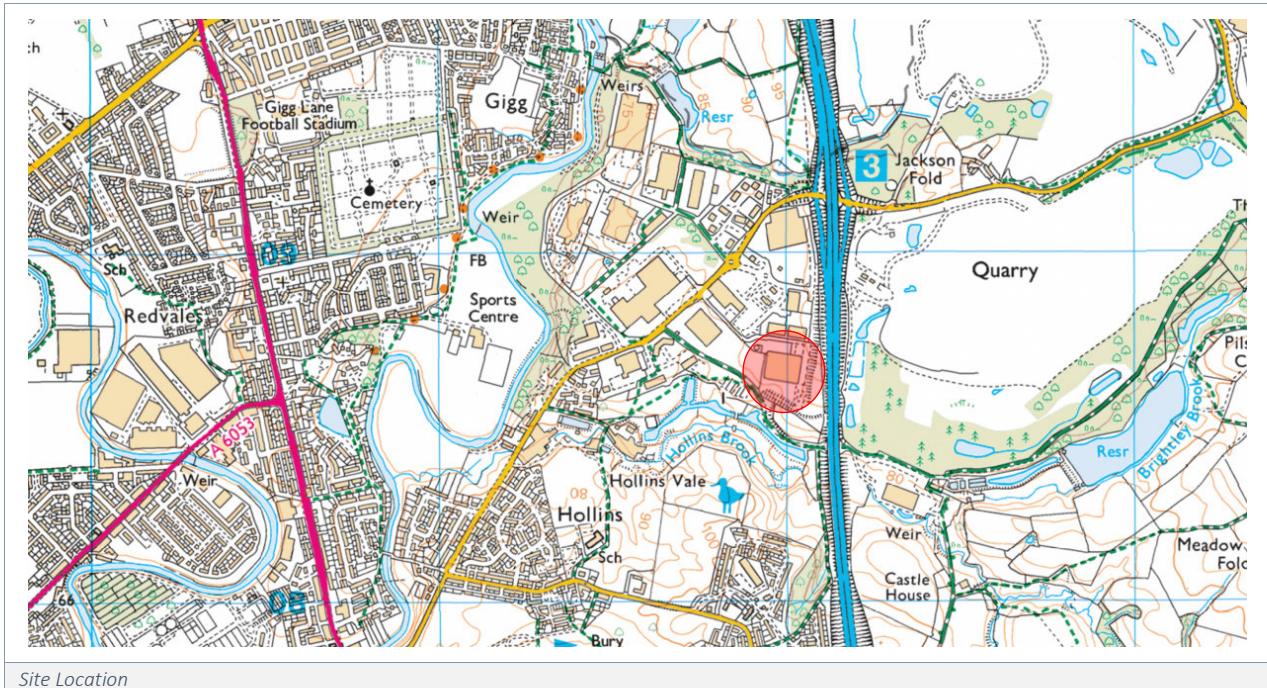
Other conditions may exist on the site that have not been taken into account in this assessment as they are outside the scope of works. Groundtech Consulting are not responsible for these circumstances that are not outlined in the report.

The assessment has been prepared for the exclusive use of the client. No third parties may rely on or reproduce the contents of the report without the written permission of Groundtech Consulting Limited. If any unauthorised third party comes into possession of the report, they rely on it at their own risk and Groundtech Consulting Limited will not be obliged to provide a duty of care.

2.0 SITE SETTING

2.1 Location

The site is located circa 2.1km south east of Bury Town Centre as shown on the Project Location Plan GRO-22216-P01 and is approximately centred on National Grid Reference 381974 408609.



Access to the site is gained off Pilsworth Road to the west.

2.2 Site Description

The development area is irregular in shape and covers an area of approximately 0.5 hectares. The topography of the proposed development area slopes gently north to the south to a steep embankment.

The development area forms part of the wider Holchem Laboratories site which lies to the north and east. The development area is generally covered with soft landscaping with mature trees in the southern area of the site and light scrubland in the northern area.

Site Boundaries and Surrounding Area

No delineating features form the northern and eastern boundaries. The southern area of the site is formed by mature trees and the western boundary is lined with mature trees and metal fencing.

The site is surrounded by following features/land uses:

- North - Holchem Laboratories (part of the wider site).
- East - Car park (part of the wider site) and M66 beyond.
- South - Aviation Road with Hollins Brook and farmland beyond.
- West - Industrial buildings.

Site photographs are presented in *Appendix 2*.

3.0 PREVIOUS INVESTIGATION SUMMARY

3.1 Introduction

Brian Clancy Higby Partnership produced a Ground Investigation Report (REF:1401-4246) in May 2014 and a summary of the relevant information is summarised below.

Superficial Deposits

The site is indicated to be underlain by superficial Hummocky (Moundy) Glacial Deposits which characteristically comprises clayey sand and gravel.

Solid Geology

The solid geology is the Pennine Lower Coal Measures Formation consisting of mudstone, siltstone and sandstone. The site is not underlain at shallow depth by any coal seam.

Coal Mining Risk Assessment

The site does not lie in a Development High Risk Area, however a Coal Authority Report is required.

Scope and Ground Conditions

Three cable percussive boreholes were drilled to depths of between 8.0m and 12.0m bgl.

Made Ground was encountered in all locations across the site to a maximum depth of 6.5m bgl and comprised cohesive clay fill with variable granular content of sand and subangular gravel. Slightly clayey fine to coarse sand was encountered between depths of 1.2m and 1.65m bgl within BH02, clayey fine to medium grained sand and gravel was present between depths of 1.98m and 4.8m bgl within BH03.

Alluvial Clay - Soft to firm dark brown slightly sandy Clay with occasional gravel was encountered between depths of 3.2m to 5.2m bgl in BH02.

Alluvial Sand – Loose and medium dense dark brown fine to medium grained Sand was observed between 4.9m to 10.45m bgl in all locations across the site.

Glacial Clay – Firm to stiff brown sandy silty Clay with thin bands of wet fine to medium grained sand was encountered between 7.0m to 12.0m bgl.

Bedrock was not encountered during the investigation.

Groundwater was observed in BH01 at 9.0m bgl.

Geo-Environmental Testing Results

No elevated Contaminants of Concerns were encountered based on the site having a commercial end use.

Geotechnical Testing Results

An undrained shear strength of 218kN/m² was recorded in BH01 at 10.5m bgl through laboratory testing.

4.0 SCOPE OF INVESTIGATION AND RATIONALE

4.1 Project Objectives

The aim of the fieldwork was to:

Determine the stratification beneath the site.
Maintain a watching brief for visual and olfactory evidence of contamination.
Obtain samples using methodology in current guidance for contamination analysis.
Obtain relevant geotechnical parameters for preliminary foundation design to address both ULS and SLS conditions.
Determine if targeted supplementary investigation in areas of concern is required and for remedial design.
Install monitoring standpipes for gas and groundwater monitoring.

4.2 Scope of Works

The following scope of works was completed between the dates of 13th June and 17th June 2022:

- *Four cable percussive boreholes (BH4 to BH7) were drilled to depths between 15.0m and 20.0m bgl using a Dando 2000 drilling rig.*
- *Three hand excavated trial pits (HP1 to HP3) were excavated to a depth of 0.5m bgl.*

The exploratory hole locations are presented on Groundtech Plan GRO-22216-P02 and the logs are in Appendix 3.

The exploratory holes were positioned to establish the stratification beneath the site, and target any areas of concern as summarised in the table below:

Location	Target Rationale
<i>HP1 to HP3</i>	<i>Made Ground mound</i>
<i>BH4 to BH7</i>	<i>Proposed extension footprint</i>

The exploratory holes were logged by a suitably experienced geo-environmental engineer in general accordance with the following current guidance:

- *BS 5930 'Code of Practice for Site Investigations' 2015.*
- *BS EN 14688-1:2002 'Geotechnical Investigation and Testing – Identification and classification of soil'.*

4.3 Soil Sampling

During the intrusive investigation, representative samples were taken at regular intervals, changes of strata and where evidence of contamination existed. Laboratory analysis was scheduled on the samples obtained.

The samples obtained are summarised in the table below:

Soil Sample	Number
<i>Environmental Sample</i>	<i>19</i>
<i>Disturbed Sample</i>	<i>18</i>
<i>Bulk Sample</i>	<i>25</i>
<i>Undisturbed U100 Sample</i>	<i>6</i>

The samples have been obtained in accordance with current environmental and geotechnical guidance. The sampling plan has been designed to obtain samples from all required strata using the correct methodology.

Disturbed samples of soil for geo-environmental testing were placed in the correct sampling containers as required by the laboratory in accordance with their MCERTS and UKAS Accreditation. Transportation was arranged in a timely manner and the samples were at the correct temperature.

The sample locations and depths are recorded on the exploratory logs.

4.4 Geo-Environmental Testing

To inform the Generic Quantitative Risk Assessment, the following geo-environmental testing was scheduled to assess the risk from contamination on the site. The testing is based on the potential sources identified in during the Ground Investigation.

Contaminants of Concern	Matrix	Number
<i>Arsenic, cadmium, chromium (total and hexavalent), copper, lead, mercury, nickel, selenium, zinc, speciated polycyclic aromatic hydrocarbons and pH.</i>	<i>Soil</i>	<i>6</i>
<i>Asbestos screening</i>	<i>Soil</i>	<i>6</i>
<i>Waste Acceptance Criteria (WAC)</i>	<i>Soil</i>	<i>2</i>

The Geo-Environmental Laboratory Testing Results are presented in *Appendix 4*.

Representative disturbed samples were obtained for all soil types encountered. Selected samples were scheduled for testing at an approved laboratory in accordance with BS 1377 'Method of Test for Soils for Civil Engineering Purposes' 1990. The following tests were scheduled:

British Standard	Test Method	Number
<i>Part 2</i>	<i>Water Content</i>	<i>4</i>
<i>Part 2</i>	<i>Plasticity Index</i>	<i>4</i>
<i>Part 2</i>	<i>Particle Size Distribution (Wet Sieve)</i>	<i>4</i>
<i>Part 3</i>	<i>Undrained Shear Strength in Triaxial Compression</i>	<i>6</i>
<i>Part 3</i>	<i>Determination of Asbestos Content</i>	<i>6</i>

The Geotechnical Laboratory Testing Results are presented in *Appendix 5*.

4.5 Gas and Groundwater Monitoring

Gas and groundwater monitoring installations were constructed in the boreholes. The standpipes consisted of high density polyethylene (HDPE) pipe - a bentonite seal was placed around the plain pipe and a clean gravel pack was placed around the slotted pipe. A summary of the installation construction is presented in the table below:

Location	Depth (m)	Response Zone (m bgl)	Targeted Strata	Reason
<i>BH4</i>	<i>3.0</i>	<i>1.0 – 3.0</i>	<i>Made Ground</i>	<i>Ground Gas</i>
<i>BH5</i>	<i>7.0</i>	<i>3.0 – 7.0</i>	<i>Made Ground</i>	<i>Ground Gas</i>
<i>BH7</i>	<i>3.0</i>	<i>1.0 – 3.0</i>	<i>Made Ground</i>	<i>Ground Gas</i>

Permanent gas and flow rate monitoring was carried out using GFM 436 infrared gas monitor with integral electronic flow analyser. The measurements taken are listed below:

- Oxygen (O₂), carbon dioxide (CO₂) and methane (CH₄) as the percentage volume in air (%v/v).
- Hydrogen sulphide (H₂S) and carbon monoxide (CO) as the percentage volume in air (%v/v).
- Lower Explosive Limit (%LEL) of methane.
- Atmospheric and borehole pressure, including pressure trend.
- Flow measurements (l/hr).
- Weather and ground surface conditions.

Both peak and steady state conditions were monitored to understand the behaviour of the permanent ground gas, the steady state conditions were recorded by allowing the gas monitor to run for a minimum of 3 minutes.

Permanent gas and groundwater monitoring results are presented in *Appendix 6*.

5.0 GROUND MODEL

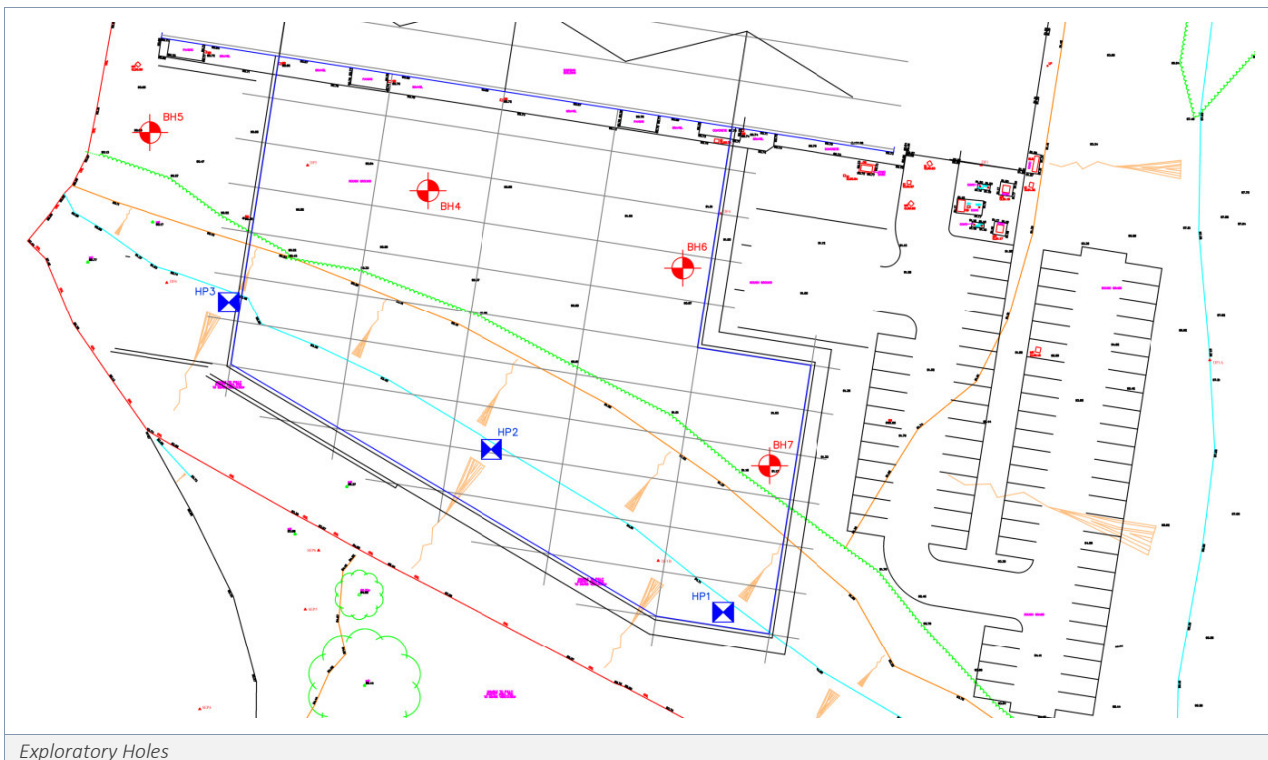
5.1 Made Ground

Made Ground was encountered in all three cable percussive boreholes to depths of between 2.5m and 6.5m bgl. The deepest Made Ground was present in the eastern part of the proposed development area.

The surfacing of the site comprised sandy cobbles of sandstone in BH4 to a depth of 0.5m bgl. Dark brown slightly sandy clayey topsoil was present in BH5 to BH7 and HP1 to HP3 to a depth of 0.5m bgl where the trial pits were terminated.

Three main populations of Made Ground were encountered during the investigation and are described below:

- *Dark brown clayey slightly gravelly sand with a low cobble content was present between depths of 0.3m to 3.3m bgl in BH4 to BH6.*
- *Firm brown sandy silty clay was observed between depths of 0.25m to 6.5m bgl in BH4 to BH7.*
- *Brown silty sandy gravel with a moderate cobble content was in HP1 to HP3 between depths of 0.1m and 0.5m bgl.*



5.2 Natural Ground

The natural strata encountered generally confirmed the published geological records. Two main natural stratification were encountered during the investigation are described below:

- *Firm to stiff brown sandy gravelly Clay was encountered between depths of 4.0m to 20.0m bgl in all of the borehole locations across the site.*
- *Loose to medium dense clayey gravelly Sand was encountered between depths of 2.5m to 15.7m bgl in BH4, BH5 and BH7 as bands of vary thickness.*

5.3 Bedrock

Bedrock was not encountered during this investigation.

5.4 Groundwater

Groundwater strikes were observed in all boreholes across the site and are presented below:

Location	Water Strike Depth (m bgl)	Strata
BH4	7.00	Silty gravelly SAND
BH5	8.00	Silty gravelly CLAY
BH6	9.00	Sandy CLAY
BH6	12.00	Gravelly sandy silty CLAY
BH7	10.00	Silty gravelly SAND

5.5 Watching Brief

A watching brief was maintained during the ground investigation for visual and olfactory evidence of contamination. No evidence of contamination was noted.

5.6 Excavation Stability

No evidence of spalling or collapse was noted during excavation of the hand dug trial pits.

5.7 Borehole Progress

Slow progress while drilling the boreholes was not experienced.

6.0 GROUND ENGINEERING

6.1 Geotechnical Testing Results

Comparison of water content and the value of 0.4 times the Liquid Limit in accordance with BRE Digest 412 'Desiccation in Clay Soils' suggests significant desiccation has taken place when 0.4 times the Liquid Limit is greater than the actual water measured water content. This is a rudimentary method but also a good guide.

Results of the plasticity testing and the volume change potential of the Clay is summarised in the table below:

Reference	Depth (m bgl)	Modified PI	Volume Change Potential	Significantly Desiccated
<i>BH4</i>	<i>2.6</i>	<i>Non-Plastic</i>	<i>-</i>	<i>-</i>
<i>BH5</i>	<i>4.5</i>	<i>8.2</i>	<i>Low</i>	<i>No</i>
<i>BH6</i>	<i>9.5</i>	<i>19.5</i>	<i>Low</i>	<i>No</i>
<i>BH7</i>	<i>3.0</i>	<i>12.3</i>	<i>Low</i>	<i>No</i>

Quick undrained triaxial testing was carried out on five samples of natural undisturbed Clay and the results of the triaxial test are summarised in the table below.

Reference	Depth (m bgl)	Undrained Shear Strength (kN/m ²)	Relative Strength
<i>BH4</i>	<i>6.00 – 6.40</i>	<i>40</i>	<i>Medium</i>
<i>BH4</i>	<i>8.50 – 8.95</i>	<i>83</i>	<i>High</i>
<i>BH4</i>	<i>11.50 – 11.95</i>	<i>147</i>	<i>High</i>
<i>BH5</i>	<i>4.00 – 4.45</i>	<i>89</i>	<i>High</i>
<i>BH6</i>	<i>9.00 – 9.45</i>	<i>90</i>	<i>High</i>
<i>BH6</i>	<i>12.00 – 12.45</i>	<i>41</i>	<i>Medium</i>

6.2 Assessment background

The ground engineering investigation has been undertaken to formulate an accurate ground model in order to undertake preliminary foundation design.

It is proposed to extend the existing building on site. At this stage, loading associated with the proposed structure are not available.

Made Ground has been encountered below the site to a maximum depth of 6.5m bgl and was generally underlain by firm to stiff medium to high strength Clay to a maximum depth of 20.0m bgl and bands of loose to medium dense clayey gravelly Sand to a maximum depth of 15.7m bgl.

Groundwater was encountered between 7.0m and 10.0m bgl in all borehole locations across the site.

No investigation was possible in the western area due to dense vegetation.

As part of the enabling works, the topsoil will need to be stripped and stockpiled separately.

The main constraint associated with the proposed development is the deep Made Ground that has been encountered to depths up to 6.5m and the loose Sand/soft Clay in BH7 to 8.0m bgl. In addition, the method of foundation installation should be considered such that vibrations etc. do not interfere with the existing sensitive laboratory procedures.

6.3 Geotechnical Parameters

The geotechnical test results have been evaluated to derive geotechnical parameters for the soils underlying the site. A 'depth to SPT N value' graph is presented on Plan GRO-21415-P03 in Appendix 7 to provide a generalised ground model for the site.

Characterisation of the geotechnical parameters above has been undertaken to select a characteristic value, which is a cautious estimate of the value affecting the occurrence of the limit state.

The characteristic values of the granular strata have been selected based on correlation with SPT values and the characteristic values for the cohesive deposits have been selected based on direct measurement through laboratory testing. The characteristic values for Ultimate Limit State (ULS) selected are presented in the table below.

Stratum	Parameter	Selected Characteristic Value
Loose Sand	Drained angle of friction (ϕ')	28°
Medium dense Sand	Drained angle of friction (ϕ')	31°
Low to Medium strength Clay	Undrained Shear Strength (C_u)	40kN/m ²
High strength Clay	Undrained Shear Strength (C_u)	90kN/m ²

6.4 Preliminary Foundation Design

Made Ground has been encountered to depths of up to 6.5m bgl and locally in WS7, loose Sand and soft Clay was present to 8.0m bgl. Therefore, a shallow foundation will not be a viable option for the proposed extension. In addition, foundations constructed in vibro treated ground and driven piles have not been considered due to vibrations during the installation process potentially affecting the existing laboratory procedures during the construction phase.

The most suitable foundations for the proposed extension are considered to be CFA piles so as to not disturb the ongoing laboratory works within Holchem laboratories. The pile foundations should be designed to transfer loads through the Made Ground, loose Sand and soft Clay to the high strength Clay. When permanent and variable actions are available, the utilisation factor can be confirmed or otherwise in accordance with EC7.

Continuous Flight Auger (CFA) bored piles are considered to be the most suitable type of pile for the development and this should be discussed with the preferred piling contractor. Good workmanship will be required when installing the piles to ensure the assumptions in the design by calculation are met.

Design by Calculation

Preliminary design by calculation has been carried out for BH4 to BH7.

For a 450mm diameter CFA pile 12m in length, an allowable load of between 170kN and 250kN has been calculated. If greater loads are required, the diameter of the piles should be increased and/or the piles installed in groups. Using BH4 ground model, a 450mm diameter pile 16m in length would increase the a vertical allowable load to 425kN. This should be considered by the detailed design when loadings are confirmed.

The end bearing strata may differ to the variable ground conditions, the resistance will depend on the end bearing strata, drilling technique and magnitude of disruption. A thin 0.2m band of peat was observed in BH6, this should be taken into consideration when forming the piles.

Obstructions were encountered in the Made Ground, and the requirement for pre boring should be discussed with the piling contractor in advance of the development.

Downdrag has not been included in the above allowable load and should be considered by the detailed design when the surcharge applied by finished site levels is confirmed. Beneath the southern area of the proposed development, the site levels will be significantly reduced due to the current topography. A retaining wall is proposed along the south western corner, an option is to install an embedded retaining wall using CFA piles in this area. This will be suitable due to the limited space, when the site levels have been reduced the structure will predominantly be retaining natural firm and firm to stiff Clay.

Effective stress testing has recorded an internal angle of friction (ϕ') value of 27.2° in the firm to stiff Clay at 8.5m bgl in BH4, this parameter should be used in the design of the retaining wall. The groundwater level is recorded at 7m to 10m bgl during the Ground Investigation, the variable ground conditions and groundwater level should be taken into consideration in the design when the finished development levels have been confirmed.

Pile design for the proposed extension should be designed so that they do not affect the foundations of the existing laboratory. In addition, it recommended that a movement joint is installed between the extension and the existing structure to mitigate the risk of differential settlement.

An appropriate working platform should be constructed in accordance with BR470 guidance.

Design Validation

The piling type, length, depth of reinforcement and design should be discussed with a specialist piling contractor. They can then undertake the detailed design including drawings and specifications to provide fitness for purpose design.

In accordance with EC7 and due to the variable strata, static load testing is recommended on 1 % of working piles to 1.5 times the characteristic load to validate the design.

The piling works should be carried out in accordance with Execution Standard EN 1536 for Bored Piles.

Construction Recommendations

The recommendations in this appraisal are preliminary and the detailed design should be developed in advance and during the construction phase. If the ground conditions or groundwater regime encountered during the construction phase differ significantly to the conditions encountered during the Ground Investigation, work should cease and Groundtech Consulting contacted for further advice.

During the construction phase, supervision by a suitably qualified geotechnical engineer should be on a continuous basis to check the design assumptions are correct and construction conforms to design in accordance with EC7. Supervision should include inspections, Control Ground Investigations and monitoring by a suitably qualified geotechnical engineer.

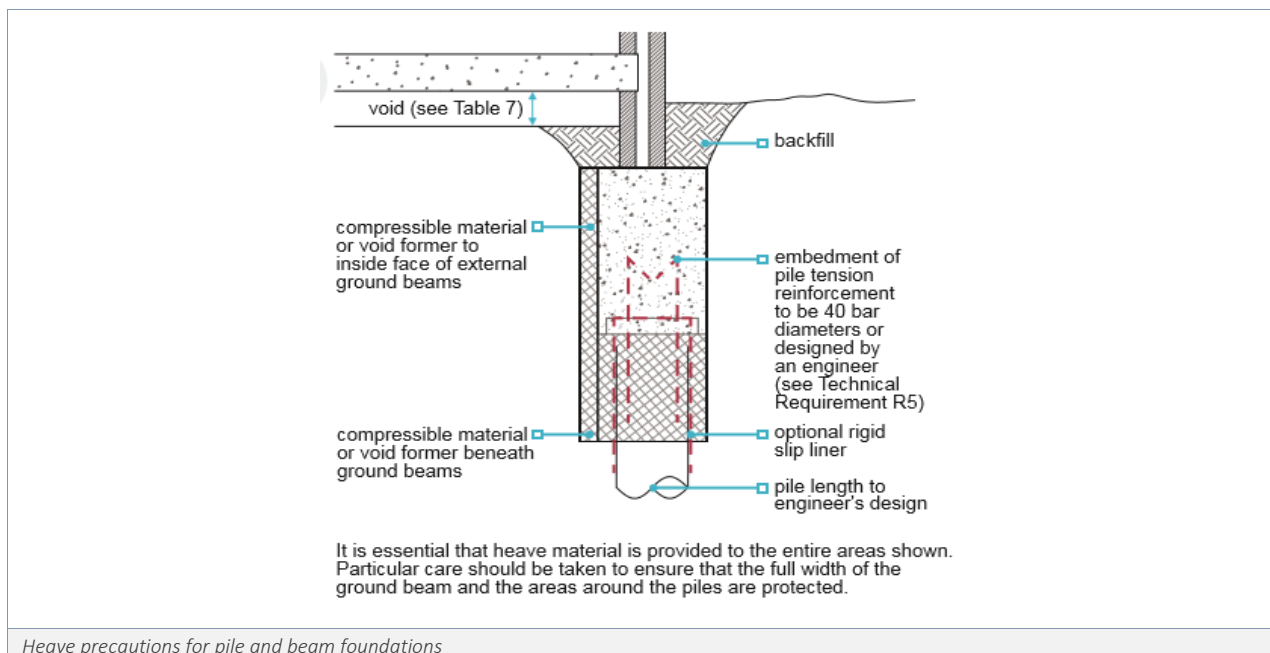
6.5 Building Near Trees

A number of mature trees are present in the southern part of the site. Foundation excavations will encounter cohesive strata in the vicinity of existing, proposed or recently removed trees, foundations should be adjusted in full accordance with current guidance.

All foundations should be deepened below roots of greater than 5mm diameter during excavations for footings. The clay is of a low volume change potential.

A survey of all trees and hedges on the site and within 30m of the site boundary should be undertaken to identify tree species, locations and heights. This information will be required in order to assess the effects of trees on the cohesive strata and inform a foundation schedule.

Where heave precautions are deemed necessary, the pile installation design will need to accommodate the following precautions in the design.



6.6 Floor Slabs

Floor slab design should take into consideration the presence of deep Made Ground to 6.5m bgl. A suspended floor slab is considered to be suitable for the proposed development that is compatible with the proposed piled foundations.

Heave precautions will need to be installed when within the influence of trees. The Clay at the site are of low volume change potential, therefore the void beneath ground beams and suspended in-situ ground floors should be 50mm and 200mm beneath a suspended precast floor.

6.7 Construction

The hand pits and boreholes undertaken indicate that instability of excavations is not anticipated provided they are not exposed to adverse weather conditions for any substantial period of time. Instability of the Made Ground is a possibility and should be considered in the groundworks method statements.

Tracked high specification plant is recommended to maintain the build programme. Breaking equipment may also be required locally to penetrate any local obstructions.

Groundwater has been encountered at depths of between 7.0m and 10.0m bgl and is therefore unlikely to be encountered in foundation excavations.

6.8 Concrete Classification

Made Ground

Water soluble sulphate testing was undertaken on six samples of the Made Ground. The range of soluble sulphate (SO_4) recorded is 2.8mg/l to 26.0mg/l and associated pH values ranged between 6.40 and 8.08 indicating slightly acidic to slightly alkaline conditions.

In a dataset where there are between five and nine results, the average of the highest two water soluble sulphate results and the average of the lowest two pH values should be taken as characteristic values. For the natural soils, the characteristic water soluble sulphate concentration is 25.85mg/l and the pH value is 6.5.

Natural Strata

Water soluble sulphate testing was also undertaken on four samples of the natural strata. The range of soluble sulphate (SO_4) recorded is 10.2mg/l to 33.5mg/l and associated pH values ranged between 6.59 and 8.79 indicating slightly acid/neutral and slightly alkaline conditions.

In a dataset where there are less than five samples, the highest measured water soluble sulphate concentration should be taken as the characteristic value together with the lowest of the pH results. The characteristic water soluble value is 33.5mg/kg and the pH value is 6.59.

Natural granular soils are present beneath the site therefore the groundwater is considered to mobile.

The results of laboratory pH and sulphate content indicate that ACEC Class AC-1 and sulphate class DS-1 conditions prevail in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005. The specific concrete mixes (the Design Concrete Class) to be used on site will be determined by the site-specific concrete requirements in terms of the durability and structural performance. These are assessed in terms of the Structural Performance Level (SPL) and any need for Additional Protective Measures (APM) detailed in Part D of BRE Special Digest 1 with further guidance in Pt E and F.

6.9 Pavement Design

Based on the ground conditions encountered, Made Ground will be present at formation level of any new car parking areas or access roads.

Untreated Made Ground should be assumed to have a CBR value of less than 2.5%, unless proven otherwise. Highways Agency document HD25 'Interim Advice Note 73/06 Revision 1' (2009) states that where a subgrade has a CBR value lower than 2.5%, it is considered unsuitable support for a pavement foundation since it would tend to deform under construction traffic and must be improved.

The soils are considered to be frost susceptible due to the fines content and highway construction should be a minimum thickness of 450mm to mitigate the risk.



6.10 Sustainable Urban Drainage System (SuDS)

The use of SuDS drainage is not considered to be feasible as deep Made Ground is present beneath the proposed development area.

7.0 LAND QUALITY

7.1 Geo-Environmental Testing Results - Soils

Samples of Made Ground have been tested for a range of relevant Contaminants of Concern. In accordance with LCRM, a Generic Quantitative Risk Assessment (GQRA) has been undertaken to determine the significance of the concentrations as derived through Geo-Environmental analysis.

The GQRA process comprises the comparison of the actual concentrations measured on site with Generic Assessment Criteria (GACs) for the protection of human health.

The GACs used for the assessment of soil concentrations have been derived using the CLEA model. The GACs used and their ranking of importance are listed below:

- *Soil Guideline Values (SGVs) which demonstrate minimal risk.*
- *LQM/CIEH S4ULs which use the same toxicological data as the SGVs but different exposure criteria.*
- *C4SLs which demonstrate low risk.*

In deriving the GACs for use on Brownfield sites, we have assumed a 1% Soil Organic Matter unless the results indicate otherwise.

The proposed end-use for the site is a commercial warehouse development with a small car park to the east. We have therefore undertaken the GQRA on the basis that the proposed development site falls under the commercial land-use scenario as defined in SR3 (EA, 2009b).

The strata or sources of contamination targeted by the laboratory testing scheduled is summarised in the table below:

Strata	Number of Samples Tested	Locations
<i>Cohesive Made Ground (Population 1)</i>	2	<i>BH5, BH7</i>
<i>Granular Made Ground (Population 2)</i>	5	<i>BH4, BH6, HP1 and HP3</i>

A summary of the Geo-Environmental Testing results is presented below and the GQRA Screening Values are presented in *Appendix 8*:

Contaminant	Range (mg/kg)	Metals		
		Screening Value (mg/kg)	Exceedances	Locations
<i>Arsenic</i>	<i>4.9 - 11.2</i>	<i>640</i>	<i>0</i>	<i>-</i>
<i>Cadmium</i>	<i><0.1</i>	<i>230</i>	<i>0</i>	<i>-</i>
<i>Chromium</i>	<i>42.8 - 56.8</i>	<i>8600</i>	<i>0</i>	<i>-</i>
<i>Hexavalent Chromium</i>	<i><0.3</i>	<i>49</i>	<i>0</i>	<i>-</i>
<i>Copper</i>	<i>14 - 28</i>	<i>68000</i>	<i>0</i>	<i>-</i>
<i>Lead</i>	<i>11 - 46</i>	<i>2300</i>	<i>0</i>	<i>-</i>
<i>Mercury</i>	<i><0.1 - 0.1</i>	<i>26</i>	<i>0</i>	<i>-</i>
<i>Nickel</i>	<i>14.3 - 35.1</i>	<i>1800</i>	<i>0</i>	<i>-</i>
<i>Selenium</i>	<i><1 - 2</i>	<i>2300</i>	<i>0</i>	<i>-</i>
<i>Zinc</i>	<i>45 - 84</i>	<i>730000</i>	<i>0</i>	<i>-</i>

Polycyclic Aromatic Hydrocarbons (PAHs)				
Contaminant	Range (mg/kg)	Screening Value (mg/kg)	Exceedances	Locations
<i>Naphthalene</i>	<0.04	190	0	-
<i>Acenaphthylene</i>	<0.03	83000	0	-
<i>Acenaphthene</i>	<0.05	84000	0	-
<i>Fluorene</i>	<0.04	63000	0	-
<i>Phenanthrene</i>	<0.03 – 0.67	22000	0	-
<i>Anthracene</i>	<0.04 – 0.15	520000	0	-
<i>Fluoranthene</i>	<0.03 – 1.41	23000	0	-
<i>Pyrene</i>	<0.03 – 1.16	54000	0	-
<i>Benzo(a)anthracene</i>	<0.06 – 0.65	170	0	-
<i>Chrysene</i>	<0.02 – 0.68	350	0	-
<i>Benzo(b)fluoranthene</i>	<0.05 – 0.66	44	0	-
<i>Benzo(k)fluoranthene</i>	<0.02 – 0.26	1200	0	-
<i>Benzo(a)pyrene</i>	<0.04 – 0.46	35	0	-
<i>Indeno(123cd) pyrene</i>	<0.04 – 0.41	500	0	-
<i>Dibenzo(ah)anthracene</i>	<0.04 – 0.05	3.5	0	-
<i>Benzo(ghi)perylene</i>	<0.04 – 0.37	3900	0	-
Others				
Moisture Content 0.46 – 14%				
pH value 7.1 – 8.8				
Organic Matter 0.1 – 5.4%				
Asbestos Screen				
Position	Depth (m bgl)	Asbestos Type	Quantification (mass%)	
<i>BH4</i>	1.5	<i>Not detected</i>	-	
<i>BH5</i>	2.0	<i>Not detected</i>	-	
<i>BH6</i>	1.5	<i>Not detected</i>	-	
<i>BH6</i>	2.2	<i>Not detected</i>	-	
<i>BH7</i>	1.5	<i>Not detected</i>	-	
<i>HP1</i>	0.5	<i>Not detected</i>	-	
<i>HP3</i>	0.5	<i>Not detected</i>	-	

7.2 Generic Quantitative Risk Assessment - Soils

Made Ground was encountered beneath the proposed development area to a maximum depth of 6.5m bgl and generally consisted of reworked topsoil overlying dark brown sandy gravelly clay with minor constituents of brick. In BH4, sandstone cobbles overlaid dark brown clayey slightly gravelly sand with minor constituents of sandstone and brick. The material gathered from the bund at the south end of the site (HP1, HP2, HP3) was the same material as the made ground encountered in the boreholes. No elevated levels of contamination were found in these samples.

No visual or olfactory evidence of contamination was noted in the soils that were recovered.

Metals

No elevated concentrations of metals were recorded in the Made Ground soils that have been tested based on the site having a commercial end use.

Speciated Polycyclic Aromatic Hydrocarbons (PAHs)

No elevated speciated PAHs were recorded in the samples that were tested in relation to a commercial end use.

Asbestos

No asbestos was detected in the seven samples of Made Ground that were screened.

7.3 Permanent Ground Gases

Two gas monitoring visits have been carried out to date on 28th July and the 18th August 2022. Carbon dioxide (CO₂) was detected within the standpipes at a maximum concentration of 6.3% v/v and Methane (CH₄) concentrations were recorded within the standpipes at a maximum concentration of 46.4% v/v with associated depleted oxygen (O₂) levels of 0.0% v/v.

No positive gas flows were recorded within any of the boreholes during the visit.

The atmospheric pressure recorded was between 1002mb and 1007mb and monitoring was undertaken during periods of steady barometric pressure.

Groundwater was encountered in BH07 at depth of 4.79m bgl during the second monitoring visit. No groundwater was recorded within the remaining standpipe.

Characterisation of the Gas Screening Value (GSV)

Based upon the results recorded, in accordance with CIRIA Report C665, the risk to the site from ground gases has been assessed by converting the results to gas screening values (GSVs), calculated by multiplying the typical maximum gas concentrations with the recorded maximum positive flow rates.

For this assessment, the maximum recorded concentration of carbon dioxide of 6.3%v/v and methane of 46.4%v/v have been used to calculate the GSVs together with a positive flow rate of 0.1 l/hr (the limit of detection of the gas analyser).

$$\text{Carbon Dioxide GSV} = 0.063 (6.3\%) \times 0.1 = 0.0063 \text{ l/hr}$$

$$\text{Methane GSV} = 0.464 (46.4\%) \times 0.1 = 0.0464 \text{ l/hr}$$

In order to assess the ground gas regime beneath the site and the need to incorporate ground gas precautions, guidance was taken from CIRIA C665 'Assessing risks posed by hazardous ground gases to buildings'. Based on the site being developed for a commercial end use, the Wilson and Card method has been used to carry out the assessment.

When considering the results in accordance with CIRIA C665 (Section A Development and Table 8.5 – Modified Wilson and Card Classification) it can be seen that the GSV value for carbon dioxide and methane is below the assessment GSV of 0.07 l/hr and falls within Characteristic Situation 1. However, due to the high concentrations of methane and carbon dioxide that have been recorded during the initial monitoring visits, the site has been increased to CS2 and gas protection measures will be required. Depending on the

final results, the classification could potentially be increased to CS3. Anecdotal evidence suggests a large landfill is located to the east of the site.

Characteristic Situation 2

A full ground gas risk assessment will be carried out on completion of the monitoring.

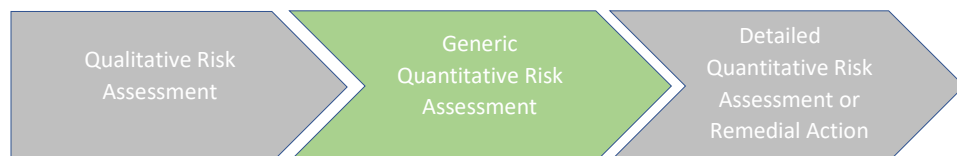
Radon

The site is not located in an area where basic radon precautions are required within the proposed development.

7.4 Pollution Linkage Assessment

A CSM has been compiled based on the findings of the Ground Investigation and testing to inform the following pollution linkage assessment. Using Source-Pathway-Receptor assessment criteria that is applicable in the UK, the risk assessment has been devised to determine if a plausible pollution linkage exists between the identified contaminants and receptors. An Illustrative Revised CSM is presented on Groundtech Consulting Plan *GRO-22216-P04* and the risk classification has been estimated in accordance with the CIRIA C552 assessment criteria outlined in *Appendix 9*.

Human Health Pollution Linkage Assessment



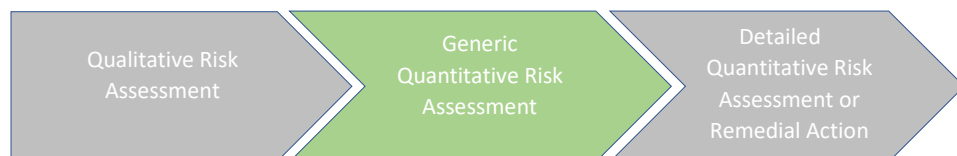
- The table below represents the second stage in the land quality risk assessment process - **the Generic Quantitative Risk Assessment**.
- In order for a development site to be deemed 'suitable for use' the level of risk needs to be reduced to an acceptable level - low to negligible risk. The purpose of each stage of risk assessment is to establish if there is a requirement for additional stages of assessment in order to have sufficient confidence to support a risk characterisation or remedial action.

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	Rationale and Action
PL1	Contaminated Soils	Ingestion of soil and dust. Dermal contact with soil.	Unlikely	Medium	Low	<i>Pollution Linkage 1 refers to proposed site users coming into contact with contaminated soils on the site.</i> <i>Made Ground was encountered to a maximum depth of 6.5m bgl and no visual or olfactory evidence of contamination was noted within the soils that were recovered.</i> <i>Geo-environmental testing indicates that there are no elevated Contaminants of Concern present within the Made Ground soils beneath the site. In addition, no asbestos was detected in the samples that were screened.</i> <i>The proposed development is to extend the current commercial building therefore the site will be entirely covered with hard surfacing breaking the pathway to potentially contaminated soils.</i> <i>Therefore, a viable pollution linkage is not considered to exist.</i>

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	Rationale and Action
PL2	Contaminated Soils	Inhalation of vapour.	Unlikely	Medium to Severe	Low	Pollution Linkage 2 refers to volatile vapours migrating into confined spaces within the proposed development. No sources of volatiles or hydrocarbons have been identified onsite. A plausible pollution linkage is not considered to exist.
PL3	Contaminated Soils	Inhalation of soil dust by adjacent site users.	Unlikely	Medium	Low	This pollution linkage relates to contamination on the subject site affecting adjacent site users. No mobile sources of mobile contamination have been identified and the wider site has similar end uses. Therefore, no pollution linkage has been identified.
PL4	Contaminated Soils	Attacking potable water supply pipe.	Unlikely	Medium	Low	Pollution Linkage 4 refers to the possible contaminants permeating potable water pipes and consumption by the future site end users of the tainted water supply. Deep Made Ground has been encountered to a maximum depth of 6.5m bgl however, it is likely that existing water supply pipes will be used to feed the proposed extension. In addition, no source of organic contamination has been recorded. If new water pipes are to be included, it is recommended that a local water company risk assessment is carried out to ensure that the correct water supply pipes are installed.

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	Rationale and Action
PL5	Ground Gas	Migration and accumulation of ground gas in internal spaces.	Likely	Medium to Severe	High	Deep Made Ground has been encountered to a maximum depth of 6.5m bgl. Gas monitoring to date has recorded high concentrations of carbon dioxide and methane. The site is currently classified as being in CS2 and gas protection measures are required. The level of precautions will be confirmed on completion of the monitoring period. As a minimum, any gas protection measures installed in the existing building should be followed through into the extension. The site is not within an area requiring radon precautions within foundations.

Controlled Waters Pollution Linkage Assessment



- The table below represents the second stage in the land quality risk assessment process – **Generic Quantitative Risk Assessment**.
- In order for a development site to be deemed 'suitable for use' the level of risk needs to be reduced to an acceptable level - low to negligible risk. The purpose of each stage of risk assessment is to establish if there is a requirement for additional stages of assessment in order to have sufficient confidence to support a risk characterisation or remedial action.

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential source	Pollution linkage	Likelihood	Severity	Level of risk	Rationale
PL6	Contaminated Soils	Impaction of groundwater from soil contamination (diffuse and point). Impaction of groundwater from groundwater plume.	Unlikely	Medium	Low	Deep Made Ground has been encountered beneath the site to a maximum depth of 6.5m bgl. However, no sources of mobile contamination were identified as part of the Ground Investigation. The site is indicated to be underlain by superficial Hummocky (Moundy) Glacial Deposits (Secondary A Aquifer) and the solid geology is the Pennine Lower Coal Measures Formation (Secondary A Aquifer). The proposed development will be largely covered by the extension and a new drainage system installed. This will considerably reduce infiltration and leaching of potential contaminants. Based on the results of testing and observations made during the Ground Investigation, a pollution linkage is not considered to exist.

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential source	Pollution linkage	Likelihood	Severity	Level of risk	Rationale
PL7	Contaminated Soils	Migration of soil and groundwater contamination impacting surface waters.	Unlikely	Medium	Low	Pollution Linkage 7 refers to the impaction of the watercourse c.193m to the east of the site from contaminated soils and groundwater No mobile contamination was encountered as part of the Ground Investigation. A viable pollution linkage is not considered to exist.

7.5 Outline Remedial Strategy

Soils and Controlled Waters

Based on the results of the investigation, no specific remedial measures are required with respect to contaminated soils or groundwater.

Ground Gas

Based on the initial gas monitoring dataset, the site is likely to be classified as CS2 at a minimum and gas protection measures will be required within the proposed extension. Any gas protection measures installed in the existing building should be followed through into the extension.

The site is in area not requiring radon precautions.

A full ground gas risk assessment will be carried out on completion of the gas monitoring.

Watching Brief and Regulatory Approval

A watching brief should be maintained during future groundworks and the demolition of the existing buildings, if any previously unseen contamination is encountered, work should cease in that area and advice sought from Groundtech Consulting.

Approval from the regulators should be obtained prior to the development commencing to avoid any delays at the construction stage.

7.6 Asbestos in Soils

No asbestos has been detected in the Made Ground soils that have been screened.

7.7 Health and Safety - Construction and Ground Workers

During the reclamation and construction phases of the site development it will be necessary to protect the health and safety of site personnel. The risk to construction and ground workers is assessed in the table below:

PL Ref	Potential Source	Pollution Linkage	Likelihood	Severity	Level of Risk
PL8	Made Ground	Ingestion, direct contact, inhalation of dusts.	Unlikely	Medium	Low

No elevated Contaminants of Concern have been recorded in the samples tested and no asbestos was detected. The risk to ground workers should be communicated through a site induction and information boards. It is recommended that ground workers wear gloves when handling Made Ground soils and hand-washing facilities should be made available.

General guidance on these matters is given in the Health and Safety Executive (HSE) document "Protection of Workers and the General Public during the Redevelopment of Contaminated Land". In summary, the following measures are suggested to provide a minimum level of protection:

- All ground workers should be issued with the relevant protective clothing, footwear and gloves. These protective items should not be removed from the site and personnel should be instructed as to why and how they are to be used.

- *Hand-washing and boot-washing facilities should be provided.*
- *Care should be taken to minimise the potential for off-site migration of contamination by the provision of dust suppression control and wheel cleaning equipment during the construction works.*
- *Good practices relating to personal hygiene should be adopted on the site.*
- *The contractor shall satisfy the Health and Safety Executive with regard to any other matters concerning the health, safety and welfare of persons on the site.*

7.8 Waste Classification by Assessment

We have reviewed the testing results and inputted them into the HazWasteOnline model which allows users to code and classify waste as defined in the EWC (European Waste Catalogue 2002) based on EC Regulation 1272/2008 on the Classification, labelling and packaging of substances and mixtures (CLP) and latest Environment Agency guidance (WM3 "Guidance on the classification and assessment of waste (1st edition 2015)-Technical Guidance").

This is a useful tool as waste producers have the legal responsibility to classify any waste they produce.

Seven samples of Made Ground soils were tested to assess whether they contained any contaminants in the hazardous range when screened against assessment criteria within WM3. The results are in the Waste Classification Report presented in *Appendix 10*.

Based on the assessment tool, the Made Ground soils at the site have been classified as *Non-Hazardous* for waste disposal purposes.

Total testing was not undertaken on the natural soils and are assumed to be *Non-Hazardous*.

7.9 Waste Acceptance Criteria (WAC) Results

The Landfill Directive (Directive 1999/31/EC on the landfilling of waste) led to the establishment of a methodology for classifying wastes. Wastes can only be accepted at a landfill if they meet the relevant Waste Acceptance Criteria (WAC) for that type of landfill. There are three different WAC, these are for:

- *Inert waste*
- *Non-Hazardous waste*
- *Hazardous waste*

Wastes should first be classified based on their total concentrations as detailed in the previous section. WAC testing is then required if the end disposal route is a landfill.

Solid and eluate WAC analysis was undertaken on two samples, the findings of which are presented in the table below.

Reference	Depth (m)	Strata Type	Classification by Assessment	WAC Analysis	Landfill Disposal
BH6	1.50	Made Ground	Non-Hazardous	Inert	Inert
HP3	0.50	Made Ground	Non-Hazardous	Inert	Inert

The WAC testing has revealed that if the end disposal route of the Made Ground is landfill, the material would be accepted at an Inert Landfill.

The possibility of automatic inert classification of the natural soils should be explored in accordance with Section 4.3 of the EA guidance document. The Council Decision includes a list of wastes in Section 2.1.1 of the document that are assumed to be inert and therefore acceptable at a landfill for inert waste without testing, this is the case if:

- *They are single stream waste of a single waste type (although different waste types from the list may be accepted together if they are from a single source)*
and
- *There is no suspicion of material or substances such as metals, asbestos, plastics, chemicals, etc to an extent which increases the risk associated with the waste sufficiently to justify contamination and they do not contain other their disposal in other classes of landfill.*

If any organic contaminated material is encountered during the construction phase, it is possible that this may be classified as hazardous, and testing should be undertaken at that time.

Materials should be segregated and where necessary, sufficient time is allowed to further classify the material properly, including discussion with landfill sites and waste transfer stations to find the best disposal route. It is recommended that where possible, the soils could be recycled at a suitable local waste treatment plant or transfer station rather than a landfill disposal route.

The reuse of soils on the site this should be done in accordance with the CL:AIRE “Development Industry Code of Practice for the Definition of Waste” (CL:AIRE CoP). Any re-use scheme should be designed to minimise disposal costs.

After a cut and fill balance plan/volume calculation has been carried out, a U1 and T5 exemption could be registered. This will allow the use of the following soils without a waste permit or under Dow CoP MMP:

- *1,000 tonnes (c.600m³) of non-hazardous soil.*
- *5,000 tonnes (c.3,000m³) of natural sand and gravels.*
- *50,000 tonnes (c.25,000m³) of bituminous material to be used in roadways.*
- *5,000 tonnes (c.3,000m³) of crushed concrete / stone.*

8.0 FINAL APPRAISAL

8.1 Land Quality

It is proposed to extend the Holchem laboratories. Made Ground was encountered to a maximum depth of 6.5m bgl however, no visual or olfactory evidence of contamination was noted within the soils that were recovered.

Geo-environmental testing indicates that there are no elevated Contaminants of Concern present within the Made Ground soils beneath the site. The site is to be predominantly covered with hardsurfacing breaking the pathway to site end users and the risk to human health is considered to be *Low*.

No source of mobile contamination has been identified on the site, therefore the risk to controlled waters is *Low*.

Gas monitoring to date has recorded high concentrations of carbon dioxide and methane. The site is currently classified as being in CS2 and gas protection measures will be required. This will be confirmed or otherwise on completion of the monitoring. As a minimum, any gas protection measures installed in the existing building should be followed through into the extension.

The site is not within an area requiring Radon precautions within foundations.

The Made Ground soils have been classified as *Non-Hazardous* for waste disposal purposes and would be accepted at an Inert Landfill.

8.2 Ground Engineering

It is proposed to extend the current commercial property building. Shallow foundations are not considered to be suitable for the proposed development due to the depth of Made Ground across the site. Based on the ground conditions encountered and the sensitive nature of the laboratory, CFA piles are considered to be the best option.

The results of laboratory pH and sulphate content indicate that ACEC Class AC-1 and sulphate class DS-1 conditions prevail in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005.

Based on the ground conditions encountered, Made Ground will be present at formation level of any new car parking areas or access roads. Untreated Made Ground should be assumed to have a CBR value of less than 2.5%, unless proven otherwise.

The use of SuDS drainage is not considered to be feasible as deep Made Ground is present beneath the proposed development area.

8.3 Required Further Work

The following further work is considered necessary to progress the site to construction phase:

Completion of gas monitoring programme and issue the gas risk assessment.

Design of remedial specification.

Detailed foundation design.

Confirmation of the recommendations made within this report with the regulators.

9.0 RELEVANT INDUSTRY REFERENCES

- British Standards Institution. *Investigation of Potentially Contaminated sites - code of practice*. BS 10175:2017.
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- CIRIA 552 "*Contaminated Land Risk Assessment – A guide to good practice*" 2001.
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Environment Agency. R&D Publication 20. Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources. 1999.

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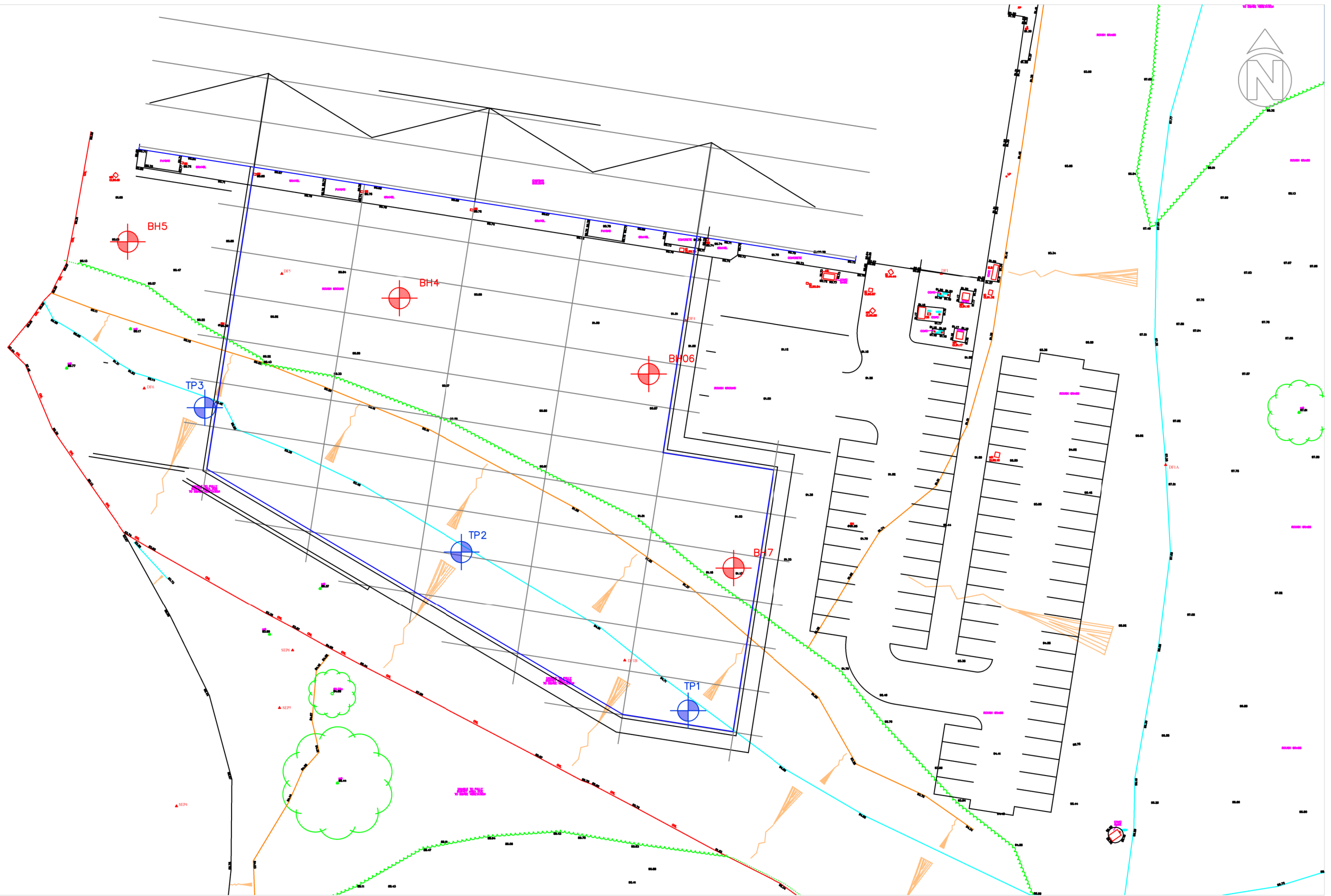
Specification for Highways Works – Series 600 Earthworks November 2016.



APPENDIX 1 - Plans



GROUNDTECH CONSULTING	CLIENT	DATE				Status		Notes SITE LOCATION
	HOLCHEM LABORATORIES LTD	SEPTEMBER 2022				Preliminary		
	PROJECT TITLE	SCALE				Draft		
	HOLCHEM, PILSWORTH IND ESTATE	NTS				Issued		
	PLAN TITLE	PLAN NUMBER				For Comment		
	PROJECT LOCATION PLAN	GRO-22216-P01	Rev.	Details	Date	Approved		



- A. Contaminated soils / Made ground.
- B. Ground gas.

- P1. Ingestion of soil and dust.
- P2. Inhalation of vapour.
- P3. Inhalation of soil dust by adjacent site users.
- P4. Attacking of potable water supply pipe.
- P5. Migration and accumulation of ground gas in internal places.
- P6. Impaction of groundwater from soil contamination.
- P7. Migration of soil and groundwater contamination impacting surface waters.

- W. Watercourse 193m away.
- X. Groundwater in the Secondary A Aquifers.
- Y. Site end users
- Z. Adjacent site users.

