



Generic Quantitative Risk Assessment

Rochdale Road, Manchester

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Comments

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Contents

Executive Summary

1. Introduction	5
1.1 Objectives	5
1.2 Proposed Development	5
1.3 Planning Context.....	6
2. Procedures	7
3. Preliminary Conceptual Model	8
3.1 Site History	8
3.2 Anticipated Geology	8
3.3 Controlled Waters	9
3.4 Ground Gas Regime	9
3.5 Vapour Regime	9
3.6 Unexploded Ordinance	9
3.7 Potentially Significant Pollution Linkages	10
4. Site Activities and Results.....	12
4.1 Deviations	13
4.2 Ground Conditions	15
4.2.1 Visual and Olfactory Evidence of Contamination.....	15
4.3 Underground Structures and Obstructions	16
4.4 Controlled Waters	17
4.5 Vapours.....	20
5. Geotechnical Testing	21
5.1 In-Situ Testing	21
5.1.1 Standard Penetration Testing	21
5.1.2 Hand Shear Vane Testing.....	21
5.2 Laboratory Testing	21
5.3 Natural Moisture Content and Plasticity Index	22
5.4 pH Value and Water Soluble Sulphate (SD1 Suite).....	22
5.5 Particle Size Distribution (PSD)	22
5.6 Dry Density / Moisture Content Relationship	23
5.7 Undrained Triaxial Testing	24
5.8 One Dimensional Consolidation.....	25
5.9 Unconfined Compressive Strength	25
5.10 Point Load Testing	25
5.11 Excavations, Trench Shoring & Dewatering	27
6. Human Health Risk – Soil	28

6.1	Generic Assessment Criteria – Soil	28
6.2	Quantitative Risk Assessment – Soil	29
7.	Human Health Risk - Vapours	35
7.1	Generic Assessment Criteria - Vapours.....	35
7.2	Quantitative Risk Assessment – Vapours.....	35
8.	Human Health Risk – Ground Gas	37
8.1	Generic Assessment Criteria – Ground Gas	37
8.2	Quantitative Risk Assessment – Ground Gas	37
9.	Controlled Waters	40
9.1	Generic Assessment Criteria – Controlled Waters	40
9.2	Quantitative Risk Assessment – Controlled Waters	40
10.	Preliminary Waste Classification Assessment.....	43
10.1	Introduction	43
10.2	Hazardous Property Assessment	43
10.3	Waste Acceptance Criteria	44
10.4	Preliminary Waste Classification Assessment Summary	44
11.	Geotechnical Assessment.....	46
11.1	Proposed Development	46
11.2	Characteristic Values and Design Bearing Resistance	46
11.2.1	Shrinkability / Volume Change Potential.....	46
11.2.2	Design Class for Concrete	47
11.2.3	Piled Foundations	47
11.2.4	Earthworks / Pavement Design.....	49
11.2.5	Floor Slabs	51
11.2.6	Groundwater / Stability of Excavations	51
11.2.7	Soakaway Drainage	51
12.	Conclusions and Risk Evaluation.....	52
12.1	Environmental	52
12.2	Geotechnical	52
13.	Recommendations	58

Tables

Table 1:	Previous Reports.....	8
Table 2:	Anticipated Ground Conditions	9
Table 3:	Exploratory hole purposes	12
Table 4:	Ground Conditions	15
Table 5:	Summary of visual and or olfactory evidence of contamination	16

Table 6:	Summary of ACMs encountered	16
Table 7:	Underground structures and obstructions	16
Table 8:	Groundwater Strikes	17
Table 9:	Groundwater Levels	19
Table 10:	Standard penetration test results	21
Table 11:	Standard penetration test results	21
Table 12:	Volume change potential	22
Table 13:	Summary of SD1 suite analysis	22
Table 14:	Summary of PSD Analysis	23
Table 15:	Dry Density / Moisture Content Relationship Results	24
Table 16:	Triaxial test results	24
Table 17:	Summary of 1D consolidation testing	25
Table 18:	Summary of UCS testing	25
Table 19:	Summary of point load testing	25
Table 20:	Stability of excavations and groundwater flows	27
Table 21:	Soil Laboratory Result Exceedances	29
Table 22:	Asbestos in Soils	33
Table 23:	Significantly elevated concentrations of volatile groundwater contaminants – off-site borehole	35
Table 24:	Ground Gas Monitoring Summary	38
Table 25:	Significantly elevated concentrations of volatile groundwater contaminants – off-site borehole	40
Table 26:	Elevated Groundwater Concentrations-BH107	42
Table 27:	Summary of Samples Reported as Containing Hazardous Properties	43
Table 28:	Characteristic values for geotechnical design	46
Table 29:	Estimated Pile Capacities (Sandstone)	48
Table 30:	Estimated Pile Capacities (Boulder Clay)	48
Table 31:	Earthworks materials classification	50
Table 32:	Final Conceptual Model	55

Appendices

Appendix A	Site Plans
Appendix B	Factual Report
Appendix C	Laboratory Certificates
Appendix D	Risk Rating Matrix
Appendix F	Waste Classification Process
Appendix G	Limitations and Constraints

Executive Summary

Objectives	
McGoff Construction Limited (Client) instructed Waterman Infrastructure & Environment Limited (Waterman) to prepare a Generic Quantitative Risk Assessment (GQRA) for ground contamination for the proposed residential redevelopment of land at Rochdale Road, Manchester (hereafter named "Site").	
Site Setting	
History	A review of the historical mapping suggests the Site was occupied by terraced housing in 1848. These were demolished in 1892 and replaced with what is considered to be part of the Rochdale Road Gas works facility located offsite to the north. Mapping suggests that train/tram tracks crossed the Site leading to high level platforms to allow coal to be tipped into hoppers below before entering the off-site retort facility for refining. It should be noted that the gasometers, used to store the town gas finished product, are located offsite to the west together with the former tar tanks and other ancillary infrastructure suggesting potentially significant historical contamination off-site. Historical maps suggest the Site was levelled and then backfilled to create the industrial building with rail lines indicating use as locomotive or goods shed outside of the Gas Works. By circa 1948 a weighbridge was added to the site and by 1962 much of the rail infrastructure appears to have been cleared to be replaced by two depots on the southern boundary. By 1989, the Site has reached its present-day configuration comprising two warehouse buildings.
Ground Conditions	A significant thickness of Made Ground was recorded at the Site up to depths of 7.80m below ground level (bgl). Glacial Till (Boulder Clay) was recorded underlying Made Ground between 13.0 and 19.2m in thickness. Bedrock comprising Chester Sandstone Formation was recorded between 15m and 26m m bgl. Significantly elevated concentrations of PAHs, TPH, metals, cyanide and VOCs were recorded across the Site. Suspected Asbestos tiles were recorded at two locations and asbestos fibres were also recorded in the Made Ground at 5No. locations.
Controlled Waters	Groundwater collected at the interface of the base of the Made Ground / surface of the Glacial Till (Boulder Clay) was recorded at the Site. The water was found to be impacted with visual and olfactory evidence of contamination during the ground investigation, confirmed with laboratory testing recording elevated concentrations of TPH, phenol and naphthalene. The elevated concentrations of contaminants were found to reduce to the north of the Site and the potential for off-site migration is considered to be Low. The risk to controlled waters is considered to be Low.
Ground Gas Regime	2No. rounds of ground gas monitoring have been undertaken to date which designates the Site as Characteristic Situation 1, requiring no special protection measures. This is a preliminary assessment only and will be updated on completion of the ground gas monitoring period.
Vapour Regime	The vapour risk from contamination within the groundwater is considered to be Low. The vapour risk from contamination contained within the site soils is considered to be unacceptable and remedial measures will be necessary.

Environmental Conclusions

Significantly elevated concentrations of contaminants have been recorded within the Made Ground at the Site, considered to be typical of the former uses of the Site as a former mechanics garage and gas works.

Diesel contamination recorded at depth associated with the groundwater trapped in the Made Ground at the Site is considered to pose an unacceptable vapour risk and remediation will be required. The most viable solution is considered to be the inclusion of a suitable vapour membrane within the proposed buildings and structures.

An engineered cover system will also be necessary within all areas of garden and soft landscaping to prevent contact with the underlying site soils.

Geotechnical Conclusions

Foundations

Due to the depth of Made Ground recorded across the site and the increased loadings the apartment blocks are expected to exert, it is considered that piled foundations will be required.

It is recommended that the advice of a specialist piling contractor should be obtained to confirm the suitability of piling and the most appropriate pile type. However, based on the site investigation information, end bearing piles would key into the sandstone bedrock between approximately 21m and 26m bgl.

It is expected that the proposed three storey buildings will also require piled foundations due to the depth of Made Ground recorded across the site. It is anticipated that underlying Boulder Clay will have sufficient bearing capacity to support the smaller structures utilising skin friction piles.

Preliminary pile capacity calculations have been undertaken and are summarised in Section 11.2.3. The pile capacities presented should be used as guidance only and shall not be used as an indicator of the final capacity and design parameters of piled solutions at the Site.

Buried Concrete

The Design Sulphate (DS) and Aggressive Chemical Environment for Concrete (ACEC) classifications are considered to be:

Concrete in contact with granular Made Ground: DS1 AC1;

Concrete in contact with cohesive Made Ground: DS1 AC1;

Concrete in contact with Boulder Clay: DS3 AC3;

Concrete in contact with Sand (Glacial Till): DS1 AC1.

Earthworks

The results of compaction and PSD testing undertaken on samples of Made Ground and the underlying natural soils indicate that:

Granular Made Ground could be recompacted to achieve >95% of MDD and <5% air voids;

Boulder Clay could be recompacted to achieve >95% of MDD and <5% air voids;

Underlying Sand (Glacial Till) could be recompacted to achieve >95% of MDD and <5% air voids.

The majority of the cohesive material underlying the site is classified as Class 2A (wet cohesive material), while the majority of the overlying granular Made Ground is classified as Class 6E (selected granular material).

Where made ground is to be reused as an engineered fill, it would be sensible to select granular fills only and subject them to a confirmatory testing regime where they were required to achieve a compaction specification as a structural fill.

Construction plant should be provided with an adequate working platform in line with the requirements of BRE report, "BR 470: Working Platforms for Tracked Plant". Again, further advice should be sought from the temporary works designer.

Pavements

The shallow subgrade is likely to exhibit very low CBR values (i.e. generally less than 2.5%). The near surface subgrade is not considered likely to support construction traffic without deteriorating rapidly.

During construction, the in-situ CBR value must be checked against the Design CBR value, to confirm design requirements are being met.

Floor Slabs

It is recommended that suspended floor slabs be adopted due to the anticipated low CBR value of the shallow subgrade and the depth and variability of the Made Ground recorded across the site.

The design of floor slabs should only be finalised when gas monitoring has been completed and assessed, as the recommendations of the gas monitoring report will influence the final choice of floor slab design. The above advice is provided for guidance only at this stage.

Excavations

Based on observations made during fieldwork, shallow excavations (<1.2m) are unlikely to remain stable in the short term; as such trench support is likely to be required. Should previously unrecorded shallow groundwater be encountered, sump pumping should be sufficient to deal with any water ingress.

Consideration should be given to the re-use of arisings from foundation trenches / drainage runs etc. Where contamination has been encountered, it may be possible to reuse foundation arisings subject to risk assessment; however, certainty of use and volume should be confirmed in accordance with the requirements of CL:AIRE guidance.

In line with BS6031, all excavations should be examined daily by a competent person to ensure that they remain safe. Where the sides cannot be sloped back to a safe angle, as approved by a competent and experienced person, their continued stability should not be taken for granted. Vertical or steep faces should be provided with support unless instructed otherwise by a competent person.

Soakaway Drainage

Given the widespread deep Made Ground recorded across the site, soakaway drainage is not considered suitable for use at the site and an alternative drainage scheme will be required.

Recommendations

The following actions are recommended to address the potentially unacceptable risks that remain:

An unacceptable risk is considered to exist at the Site with regard to volatile contaminants. It is recommended that a suitable vapour membrane is included in the buildings and structures at the Site to mitigate against this risk;

Significantly elevated concentrations of contaminants are recorded in the Made Ground, which requires suitable measures to manage the risk to the end-users. A suitably engineered capping layer will be required in all garden and soft landscaping areas;

The ground investigation recorded significant in ground obstructions together with buried known and unknown voids across the majority of the Site. Further investigation of these features will be necessary for building design;

The presence of the hydrocarbon impacted groundwater indicates a potential remains for further soil contamination not recorded during this ground investigation. A Watching Brief should be completed by a Environmental Engineer during Enabling and Earthworks;

This report should be updated on completion of the ground gas monitoring period and the conclusions reviewed accordingly;

A Remediation Strategy should be prepared for the Site to outline the procedures required to manage risks to the end-users from the Made Ground soils;

A Materials Management Plan should be produced by contractors to ensure that materials that may be excavated during their works (including pile arisings) may be suitable for re-use on the Site. The re-use of materials should be identified and designated under the CL:AIRE Definition of Waste: Code of Practice (DoWCoP), i.e. the earthworks phase of the development should be planned and managed such that re-use of suitable site-won arisings is maximised and waste is minimised;

An Asbestos Risk Management and Discovery Plan should be prepared by contractors to include methods and measures for managing asbestos in soils during the demolition and earthworks;

An Environmental Management Plan (EMP) should be prepared including measures for managing waste, control run-off during earthworks, suppressing dust and asbestos fibres etc;

The conclusions of this report should be subject to review and approval by Manchester City Council;

Barrier pipes will provide sufficient protection for potable water supply pipes in all brownfield conditions. The requirement for water barrier pipes should be confirmed with the local water provider;

Buried concrete should be designed in accordance with the recommendations provided in this report;

Topsoil, Subsoil and any Engineered Fill imported for use at the Site should be certified as suitable for use.

Samples of imported soils should be taken and scheduled for laboratory testing to verify certification. All supplier and verification chemical results should be collated by a contractor for inclusion in a Completion Report;

Construction and Maintenance workers should undertake risk assessments and prepare method statements before commencing work and should be provided with and make use of appropriate Personal Protective Equipment (PPE). Appropriate hygiene facilities should also be provided on Site and it should be ensured that all future construction personnel have been provided with asbestos awareness training;

Construction workers should avoid entering excavations. If entry cannot be avoided, a risk assessment should be undertaken with PPE and RPE used where appropriate, and in line with the Confined Space Entry Regulations 1997.

1. Introduction

1.1 Objectives

McGoff Construction Limited (Client) instructed Waterman Infrastructure & Environment Limited (Waterman) to prepare a Generic Quantitative Risk Assessment (GQRA) for ground contamination for the proposed residential redevelopment of land at Rochdale Road, Manchester (hereafter named “Site”).

This assessment follows on from the Preliminary Risk Assessment (PRA) prepared by a E3P in 2018.

The main objectives of the report are to:

- Provide an exploratory investigation as defined by BS10175;
- Assist in discharging planning conditions relating to the investigation and remediation of contaminated land;
- Derive representative geotechnical parameters in accordance with Eurocode 7 and characterize the ground for the purposes of geotechnical design;
- Provide an assessment of suitable foundation types for the proposed development;
- Investigate pavement design and provide CBR values at selected locations at formation level; and,
- Provide an assessment of hazardous gas risk in accordance with CIRIA Report C665 / BS8485 and preliminary recommendations relating to protective measures required in foundations (if any).

This assessment has been undertaken in general accordance with the Land Contamination: Risk Management Document (Environment Agency, 2021) and forms a decision record in relation to the assessment of the Site. The report also provides a refined conceptual based on the findings of the ground investigation, an evaluation of potential risks and recommendations relating to any necessary remediation.

The assessment was undertaken in accordance with the scope agreed between Waterman and McGoff Construction Limited, as documented in Waterman’s fee letter (Ref. WIE19453-100-F-220803-RT-Fee Proposal, dated 4th August 2022), and with Waterman’s standard Terms of Appointment. The benefit of this report is made to McGoff Construction Limited.

This is a third issue report, prepared following further Client comments.

1.2 Proposed Development

The Proposed Development is defined as:

‘The Erection of a part 11, part 13 storey building to form residential apartments (Use Class C3a) together with the erection of two blocks of 3 storey duplexes (Use Class C3a) to form 237 residential homes in total with associated commercial floor (Use Class E) (132 sqm), basement car parking, landscaping and public realm, and associated engineering and infrastructure works following demolition of existing buildings and structures’.

The consented development Drawings are presented in Appendix A.

1.3 Planning Context

The Rochdale Road Site was granted planning consent by Manchester City Council in December 2018 (Ref. 12-922-R1), with a number of planning conditions. Planning conditions 7 and 8 relate to ground contamination, as follows:

'Prior to the commencement of the development the following information should be submitted for approval in writing by the City Council, as Local Planning Authority:

- Intrusive investigation assessment;*
- Updated final risk assessment; and,*
- Remediation Strategy.*

'a) In the event of the Preliminary Risk Assessment identifying risks which in the written opinion of the Local Planning Authority require further investigation, the development shall not commence until a scheme for the investigation of the site and the identification of remediation measures (the Site Investigation Proposal) has been submitted to and approved in writing by the City Council as local planning authority.

The measures for investigating the site identified in the Site Investigation Proposal shall be carried out, before the development commences and a report prepared outlining what measures, if any, are required to remediate the land (the Site Investigation Report and/or Remediation Strategy) which shall be submitted to and approved in writing by the City Council as local planning authority.

b) When the development commences, the development shall be carried out in accordance with the previously agreed Remediation Strategy and a Completion/Verification Report shall be submitted to and approved in writing by the City Council as local planning authority prior to the first occupation of the residential element of the scheme.

In the event that ground contamination, groundwater contamination and/or ground gas, not previously identified, are found to be present on the site at any time before the development is occupied, then development shall cease and/or the development shall not be occupied until, a report outlining what measures, if any, are required to remediate the land (the Revised Remediation Strategy) is submitted to and approved in writing by the City Council as local planning authority and the development shall be carried out in accordance with the Revised Remediation Strategy, which shall take precedence over any Remediation Strategy or earlier Revised Remediation Strategy'.

This Geo-Environmental Assessment has been prepared in pursuit of discharge of planning condition 7 part a. A Site Investigation Proposal was prepared and submitted to Manchester City Council in September 2022.

2. Procedures

This GQRA report has been undertaken in general accordance with the Land contamination: risk management guidance (LCRM – Environment Agency, 2021). The report includes the following:

- Review and confirmation of the overall site objectives;
- Outline Conceptual Model for the Site;
- Results of Intrusive Ground Investigation;
- Confirmation of Generic Assessment Criteria used to assess risks;
- Assessment of results against Generic Assessment Criteria;
- Formulation of a new Conceptual Model for the Site;
- Identification of potentially unacceptable risks;
- Present a record of findings and recommendations for further action.

This report forms a decision record for the contaminant linkages identified, the generic assessment criteria used to assess risks, the unacceptable risks identified and the proposed next steps in relation to the site. The report also provides an explanation of the refinement of the outline conceptual model following the ground investigation, the selection of criteria and assumptions, an assessment of uncertainties, degree of confidence and limitations, the evaluation of potential risks and the basis for the decision on what happens next.

3. Preliminary Conceptual Model

A Phase 1 Geo-Environmental Site Assessment (Preliminary Risk Assessment) was carried out by a Third Party (E3P Limited) to support the planning application. The following summary presents the key features of the Site, which will be targeted as part of the ground investigation.

For a detailed review of the Site's environmental setting the previous reports identified in Table 1 should be reviewed.

Table 1: Previous Reports

Report Title	Author	Date	Report Reference
Phase 1 Geo-Environmental Site Assessment	E3P	12/2018	12-922-R1
Site Investigation Proposal	Waterman	September 2022	WIE19453-100-TN-1.2.1-GI Scope

3.1 Site History

A review of the historical mapping suggests the Site was occupied by terraced housing in 1848. These were demolished in 1892 and replaced with what is considered to be part of the Rochdale Road Gas works facility located offsite to the north. Mapping suggests that train/tram tracks crossed the Site leading to high level platforms to allow coal to be tipped into hoppers below before entering the off-site retort facility for refining. It should be noted that the gasometers, used to store the town gas finished product, are located offsite to the west together with the former tar tanks and other ancillary infrastructure suggesting potentially significant historical contamination off-site. Aerial imagery and maps suggest the Site is on the same level as Rochdale Road to the east with the Gas Works facility to the west at a considerably lower elevation.

Historical maps suggest the Site was levelled and then backfilled to create the industrial building with rail lines indicating use as locomotive or goods shed outside of the Gas Works. By circa 1948 a weighbridge was added to the site and by 1962 much of the rail infrastructure appears to have been cleared to be replaced by two depots on the southern boundary. By 1989, the Site has reached its present-day configuration comprising two warehouse buildings.

3.2 Anticipated Geology

The following summary (Table 2) of anticipated ground conditions is presented in the PRA. A significant thickness of Made Ground is anticipated due to the change in topographic level from Rochdale Road to the south and the adjacent land at the north (approx. 5m). Significant void space is also anticipated beneath the Site from the existing tunnels running immediately underneath the Site.

Table 2: Anticipated Ground Conditions

Stratum	Area Covered	Depth to Top of Stratum	Typical Description
Made Ground	-	-	A thickness of Made Ground is expected due to the former industrial nature of the site and the changes in levels at the Site boundaries.
Superficial Deposits (Glacial Till)	Whole site	Not known	Glacial Till anticipated to be sands clays and gravels.
Sandstone (Chester Formation)	Whole site	14.30m - 14.90mbgl	Fine and Medium gravel of grey and red-brown weathered sandstone in a sandy clay matrix.

3.3 Controlled Waters

The River Irk is located 193m to the north-west of the Site.

The Glacial Till (Boulder Clay) underlying the Site is classified as Unproductive. The solid geology is designated as a Principal Aquifer.

It is considered the pathways to the River Irk are likely to be limited based on the low permeability Clay deposits. The thickness of the Glacial Till requires determination.

3.4 Ground Gas Regime

The PRA states there are no active landfill sites or waste treatment sites within 250m of the Site.

The PRA concludes that a risk exists at the Site from ground gas associated with the presence of historic Made Ground and possible hydrocarbon contamination.

It should be noted that the north of the Site comprises a thin layer of Made Ground above the rooves of the existing tunnels indicating the thickness of Made Ground will be variable based on voids/tunnels and backfilled ground.

3.5 Vapour Regime

The potential exists for vapours to be present at the Site as a result of the following uses of the Site:

- Vehicle maintenance garages at the south of the Site. Internally within the garages, a mechanics inspection pit was recorded together with a paint spray booth; and,
- Former use of the Site as a Coal Stocking and adjacent to the main gas works Site.

3.6 Unexploded Ordinance

The PERA states the Site is designated as a Medium risk from Unexploded Ordnance (UXO). A detailed UXO Desk study has been commissioned and the findings indicate the Site has been re-classified as a Low risk. The report recommends that UXO safety awareness training should be given at all levels of site personnel and selected individuals on the project staff with relevant responsibilities. A competent person as part of the project safety induction course should provide the awareness training. It should be reinforced with specific safety briefings and toolbox talks to individuals involved in conducting intrusive earthworks.

3.7 Potentially Significant Pollution Linkages

The preliminary conceptual model presented in the Phase 1 PRA is replicated below:

Source	Pathway	Receptor	Risk	Justification / Mitigation
Human Health				
Heavy metals / Semi Volatile Organic Compounds (SVOC) associated within Made Ground and historical uses on and adjacent to the site such as gas works, railway land and depots.	Dermal contact Ingestion and consumption of home grown produce	Construction worker Residential end-users		The presence of variable Made Ground associated with historic activities/previous developments is anticipated to underlie the site. Made Ground may be a potential source of heavy metals and semi-volatile Polycyclic Aromatic Hydrocarbons (PAH) which may pose a short-term risk to construction workers who may come into contact with impacted soils during earthworks. All construction works must be undertaken using the appropriate Personal Protective Equipment (PPE) to remove this potential risk. Given the proposed development is likely to comprise a high-rise development with limited areas of landscaping future residential users are unlikely to come into contact with impacted soils within any garden and landscaped areas. However, if areas of landscaping are included as part of the proposed development and if impacted soils are identified then localised remediation or an appropriate cover system, designed in accordance with BRE465 (Cover Systems for Land Regeneration), will remove the exposure pathway and therefore risk to future residential site users.
Volatile hydrocarbon compounds associated with former gas works/railway land/garages/former fuel filling station etc	Volatilisation / Accumulation, Vapour Inhalation	Construction Workers, Residential End Users		Anticipated Made Ground on site is a potential source of hydrocarbon compounds. The historical commercial/industrial land uses both on site and in the surrounding area, including the gas works plant, fuel filling station, railway tracks, goods shed and garages, as well as the current land uses are potential sources of hydrocarbons, SVOCs, VOCs and chlorinated hydrocarbons associated with the use and storage of fuels and chemicals. Hydrocarbon compounds, SVOCs, VOCs and chlorinated hydrocarbons may pose a risk to construction workers if they come into contact with impacted soil during further earthworks, however appropriate PPE/ Respiratory Protective Equipment (RPE) will ensure they are at no unacceptable risk. Future residential end users may come into contact with impacted soil in landscaped areas, if proposed, and via indoor inhalation of vapours.
Asbestos Containing Materials (ACM) within Made Ground/Existing Buildings	Fibre / Dust Inhalation	Construction Workers Residential End Users Third Party Property		No ACM was identified during the external walkover survey; however, the presence of ACM underlying Made Ground and within the fabric of the existing buildings cannot be discounted. ACM poses a risk through fibre and dust inhalation and if present may pose a risk to construction workers during any future earthworks / demolition and to adjacent third-party property should dust be generated during those works. These risks can be mitigated through the development of a detailed enabling works strategy following guidance and protocol specified within the Control of Asbestos Regulations (2012) and industry best practice as detailed in CIRIA733 (Asbestos in Soil and Made Ground: A guide to understanding risk). A pre-demolition asbestos survey will likely be required in all existing on-site buildings.

Source	Pathway	Receptor	Risk	Justification / Mitigation
Hazardous Ground Gases				
Methane and Carbon Dioxide associated with possible on-site fill material	Inhalation Accumulation	Construction Workers Residential End Users		The presence of historic Made Ground and possible hydrocarbon contamination may be a source of hazardous ground gas (such as carbon dioxide & methane) which may pose a risk to construction workers and residential end users. Carbon dioxide and methane have associated asphyxiation and explosive risks, respectively. Should a ground gas risk be identified to end users, the risks can be mitigated through the adoption of suitable control measures within the building construction using guidance presented within CIRIA 665 (Assessing Risk Posed by Hazardous Ground Gases to Buildings) and BS8485 (Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments).
Controlled Waters				
Hydrocarbon compounds associated with former/current site uses	Vertical / Lateral Migration	Principal Aquifer River Irk		The presence of mobile hydrocarbon compounds within the groundwater associated with the former gas works, railway tracks, fuel filling station and garages and also associated with historic spillages from vehicles currently on the site cannot be discounted, however there is a limited potential for contamination to controlled waters. The Principal Aquifer within the underlying bedrock geology is considered a potential receptor, however, given the absence of any potable groundwater abstractions within close proximity to the site and the likely presence of substantial thicknesses of impermeable clays beneath the site the overall sensitivity of this receptor is reduced. Given the significant distance of the site from the River Irk; the Site is considered to pose a low risk to this watercourse.
Buildings and Infrastructure				
pH & Sulphate	Corrosion of Concrete	Foundations / Concrete		Presence of pH and sulphate within any Made Ground deposits may result in corrosion of buried concrete within the proposed development. Assessment must be undertaken to confirm the levels of pH and sulphate within Made Ground deposits and thus determine the concrete classification0.

4. Site Activities and Results

A ground investigation was completed at the Site between 26th October and 19th November 2022. The ground investigation scope of works comprised:

- 7No. cable percussive boreholes to depths of between 10m bgl and rockhead (between 15.0m and 26.0m bgl);
- 4No. rotary cored follow-on boreholes to gain a suitable 10m rock core;
- 5No. Window sample probeholes to a maximum depth of 3.4m bgl;
- 19No. trial pits to a maximum depth of 4.20m bgl; and,
- 6No. hand pits to a maximum depth of 1.2m bgl.

Due to access restrictions and encountering below ground voids, the location and viability of the trial pitting was reviewed midway through the ground investigation and an additional day of trial pitting was added to the scope of ground investigation:

- 4No. trial pits (TP120 to TP123) to depths of between 0.50m bgl and 2.80m bgl.

The ground investigation was undertaken in accordance with the Ground Investigation Specification which should be referred to for a detailed review of the ground investigation methodology. Pertinent details have been included in Section 4 as required only to avoid repetition between documents.

The purposes of exploratory hole locations and potential contamination sources are targeted are included in Table 3.

Table 3: Exploratory hole purposes

Layer / Target feature	Exploratory Holes	Ground water Wells	Gas Wells	Comments
Former Gas Woks & ancillary buildings	BH101 to BH106, WS101 to WS105, TP101 to TP116	BH101, BH102, BH105	WS101 to WS105	Boreholes to reach natural ground at depth. Investigate potential perched groundwater WS & TP to investigate Made Ground
Former Joinery Workshop and coal stocking areas	TP114, TP115, WS105, TP111, BH	BH101, BH102, BH105	-	Located at the west of the Site
Former railway lines	WS102, TP112, TP116, BH101, BH103, BH104, WS103, HDP101, HDP102	BH101, BH102, BH105	WS103	Located to the east of the Site during the off -site gas works operation
Mechanics inspection Pit within garage area – recent usage	TP102		-	Large inspection pit associated with recent use of the garages
Former Spray booth – recent usage	WS105		-	Small internal room used for spray painting, in recent use of buildings.
Former Spray booth – recent usage	HDP104		-	Signs of use of area for spray painting of vehicles

Layer / Target feature	Exploratory Holes	Ground water Wells	Gas Wells	Comments
Depot buildings – recent usage	TP103, TP102, WS106, TP101, TP103, HDP101 to 104	WS106	-	Coverage within current building footprints to investigate contamination from current/recent depot uses
Coverage of Made Ground within existing buildings over tunnels	HDP101 to HDP104	-	-	Voids and tunnels located directly beneath area so WS or TP not viable due to risk of collapse
Basement Excavation Area No safe drilling for WS/BH or TP, long reach trial pitting from firm ground	TP108, TP109 TP111, TP112, TP110	-	-	Potential soils destined for excavation and offsite disposal for a basement. WAC testing and general soils characterisation
Large open void areas above tunnels No safe drilling for WS/BH or TP, long reach trial pitting from firm ground	TP113	TP113	WS104	Soils destined to be excavated to allow retaining wall to be shored and then and re-used
Ground Gas – Made Ground	WS101 to WS105 BH101, BH103	-	WS101 to WS105. BH101, BH103	Targeting the Made Ground to assess potential ground gas.
Geotechnical parameters from adjacent land	BH106, BH107 & TP104	N/A	N/A	Not to be sampled for contamination as not part of the Site. To provide geotechnical information in absence of safe ground for drilling on site.
Geotechnical parameters & rock strength	BH101, BH102, BH105 & BH106	BH101, BH102, BH103 & BH104	N/A	Boreholes to be extended by rotary follow on to gain rock cores of the sandstone.
Investigation of existing foundations	TP105, TP106, TP103,	N/A	N/A	Investigation of existing and retained foundations.
Off-site Garage to the SW	TP107, WS102, BH102	BH102	-	Off-site garage and PFS (assumed), possible migration of contamination.

4.1 Deviations

The ground conditions at the Site were found to be challenging due to known and unknown voids within the ground together with extensive obstructions detailed as follows:

Unstable ground

The trial pits were generally unstable due to the loose Made Ground which caused early termination of the following trial pits:

- TP104 terminated at 0.4mbgl due to cables, concrete foundations also found 0.4mbgl;
- TP107 terminated at 3.5mbgl due to collapse;
- TP112 terminated at 2.6mbgl due to collapse;
- TP115 terminated at 3.0mbgl due to collapse;
- TP119 terminated at 3.0mbgl due to collapse;
- TP120 terminated at 2.8mbgl due to collapse.

Suspected Asbestos Containing Materials (ACMs)

Suspected ACMs were recorded at a number of locations which resulted in the trial pits terminating:

- TP111 terminated at 1.4mbgl due to encountering asbestos tiles;
- TP113 terminated at 2.1mbgl due to encountering asbestos tiles.

Below Ground Obstructions

The below ground obstructions encountered were extensive as a result of former buildings at the Site together with known and unknown voids:

- TP110 brick arch encountered at 0.5m bgl;
- TP118 terminated at 1.0mbgl due to unstable ground, void and historic wall encountered;
- TP121 terminated at 1.6mbgl due to encountering concrete;
- TP122 terminated at 0.6mbgl due to encountering steel beams;
- BH104 terminated at 6.0mbgl due to encountering an obstruction;
- BH107 terminated at 10.0mbgl due to SPT refusal;
- WS101 terminated at 3.4mbgl due to SPT refusal;
- WS102 terminated at 3.0mbgl due to SPT refusal;
- WS103 terminated at 2.0mbgl due to SPT refusal;
- WS104 terminated at 0.8mbgl due to SPT refusal.

The deviations did not have a material impact on the ground investigation's ability to meet its required objectives.

Buried Voids

- Trial pit TP118 was abandoned due to large void area recorded from 1.0m bgl;
- Trial pit TP123 was not started due to large, buried void area evident from the surface;
- TP122 terminated at 0.4mbgl due to encountering plastic sheet covering void.

Re-location off-Site

Due to the presence of on-site voids associated with the tunnel features beneath the Site, BH106 and BH107 was re-located to the north, off-Site. Window sample probehole WS104 was moved south to avoid the potential voids areas.

4.2 Ground Conditions

Ground conditions encountered during the ground investigation are summarised in Table 4.

Table 4: Ground Conditions

Strata	Typical Thickness (m)	Description
Tarmac	0.07m	WS102
Concrete	0.1m - 0.2m	-
Made Ground (Granular)	0.90m – 7.8m	Brown, dark brown to Black slightly clayey to clayey gravelly medium to coarse Sand. Gravel is angular to subangular fine to coarse of mixed lithologies including brick, ash, clinker, glass, plastic, tarmac, wood and concrete.
Made Ground (Cohesive) BH102	1.1m	Firm dark brown sandy gravelly clay. Sand is fine to coarse. Gravel is angular to subangular fine to coarse of mixed lithologies including brick.
Glacial Till	13.0m - 19.2m	Firm to Stiff brown sandy gravelly CLAY to Firm brown very sandy gravelly friable CLAY with bands of Sand. Sand is fine to coarse. Gravel is angular to subangular fine to subrounded of mixed lithologies.
Sand	1.3m – 2.8m	Interbedded sand bands within the Glacial Till: Orange, brown fine to coarse Sand to Orange brown slightly clayey gravelly medium to coarse Sand. Gravel is angular to subangular fine to medium of sandstone.
Sandstone	From 15.00m - 26.0m unproven	Red brown SANDSTONE residually weathered. Recovered as sandy angular to subangular medium to coarse gravel of sandstone Extremely weak to weak medium to coarse red brown Sandstone

Hardstanding and building footprints cover 100% of the Site area.

A number of geological cross sections are presented in Appendix A.

Soil samples were taken in accordance with the methodology set out in the Ground Investigation Specification and scheduled for the previously identified contaminants of concern given the Site's historical and current uses. The soil laboratory results are included in Appendix C.

4.2.1 Visual and Olfactory Evidence of Contamination

Visual and olfactory evidence of contamination was recorded at a number of locations across the Site. Table 5 presents the contamination recorded and the associated PID readings.

Table 5: Summary of visual and or olfactory evidence of contamination

Exploratory Hole I.D.	Depth (m bgl)	Observation	PID Reading (ppm)
BH107	1-7m bgl	No observations	51, 32.7, 13.5, 7.6, 2.9, 2.5
BH105	5.0 - 7.00m bgl	Strong hydrocarbon odour from 5.0m bgl	9.80, 5.2, 22.4
BH104	5.8m bgl	Strong hydrocarbon odour	11.8, 40.7, 1.4, 3.6, 21.6
BH103	6.5m bgl	Strong hydrocarbon odour	3.1, 180, 6.4, 3.2, 16.9
BH102	5.8m bgl	Strong hydrocarbon odour	21.4, 17.7, 15.5, 8.7
TP116	1.0 – 3.0	No observations	18.1, 7.2, 3.4
WS102	0.3	No observations	4.6
WS104	0.8	No observations	3.8
TP113 & TP121	GL to base	Blue green clayey sandy gravels – gas works waste	0.7ppm & 9ppm

Potential Asbestos Containing Materials (ACMs)

Potential ACMs were recorded at a number of locations as presented in Table 6. The trial pits were terminated on discovery of the ACMs.

Table 6: Summary of ACMs encountered

Exploratory Hole I.D.	Depth (m bgl)	Observation
TP111	1.3m bgl	High cobble content of asbestos tiles
TP113	2.1m bgl	Asbestos tiles encountered at 2.1m bgl.

The two trial pit locations are positioned centrally in the Site and adjacent to each other suggesting the asbestos tiles are potentially confined to a localised area only.

4.3 Underground Structures and Obstructions

A number of obstructions were recorded during the works, as detailed below. In addition, a number of the trial pits terminated at an early depth due to stability of the side walls.

Table 7: Underground structures and obstructions

Exploratory Hole	Obstruction Depth (m bgl)	Description
WS101	3.4	Hole terminated – SPT refusal
WS102	3.30	Hole terminated – SPT refusal
WS103	2.0	Hole terminated – SPT refusal
WS104	0.80	Hole terminated – SPT refusal
WS105	2.0	Hole terminated – SPT refusal
BH104	6.00	Hole terminated on obstruction
TP104	0.40	Concrete foundation and buried cables

Exploratory Hole	Obstruction Depth (m bgl)	Description
TP109	2.00	Brick arch encountered at 2.00m bgl
TP110	0.50	Brick arch encountered at 0.50m bgl
TP111	1.40	Hole Terminated at 2.00m bgl due to asbestos tiles recorded
TP112	2.60	Trial pit terminated due to side collapse
TP113	2.10	Trial pit terminated at 2.1m bgl due to asbestos tiles encountered
TP114	3.00	Trial pit terminated due to side collapse
TP115	3.00	Trial pit terminated due to side collapse
TP116	3.00	Trial pit terminated due to side collapse
TP118	1.00	Trial pit terminated due void and historic brick wall encountered. Unstable ground
TP119	3.00	Trial pit terminated due to side collapse
TP120	2.80	Trial pit terminated due to side collapse
TP121	1.60	Trial pit terminated due to concrete at 1.6m bgl
TP122	0.60	Trial pit terminated due to steel beams – suspected tunnel roof
TP123	0.4	Trial pit terminated due to plastic covering void

4.4 Controlled Waters

Groundwater Level

Limited groundwater was recorded during the ground investigation. Table 8 presents the groundwater strikes recorded.

Table 8: Groundwater Strikes

Project Stage	Location ID	Depth Groundwater Struck (m bgl)	Elevation Groundwater Struck (m AOD)	Comments
Intrusive Investigation	BH102	5.80m bgl	45.50	Strong hydrocarbon odour
	BH103	6.5m bgl	44.98	Perched groundwater – strong hydrocarbon odour
	BH104	5.8m bgl	45.61	Perched ground – strong hydrocarbon odour

Where the Glacial Till has been excavated at the Site, groundwater is encountered within the Made Ground contained above the Glacial Till surface. The groundwater level is dictated by the depth to the surface of the Glacial Till. The groundwater is likely to be perched and discontinuous across the Site, as evidenced by dry boreholes recorded at BH101 and BH104. Groundwater levels recorded during the post

works monitoring indicates the groundwater will migrate locally to the north-east from BH105 towards BH102.

6No. groundwater level monitoring rounds will be completed as part of the post fieldwork monitoring. The groundwater level monitoring results and relative ground levels to date are presented in Table 9.

It should be noted that borehole BH107 and BH105 are located off-site to the north. The topographic level of the adjacent site is approximately 5m lower than the subject Site

Table 9: Groundwater Levels

Exploratory Hole	Ground Level (mAOD)	Groundwater Level (mAOD)					
		Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
On-site Up Hydraulic Gradient							
BH101 - MG	51.90	DRY	DRY				
BH101-piezo	51.90	DRY	DRY				
BH102-MG	51.30	45.65	45.77				
BH102 - piezo	51.30	DRY	DRY				
BH103 - MG	51.48	45.92	45.92				
BH104 - MG	51.41	DRY	DRY				
BH105 - MG	51.30	45.98	46.16				
On-site Down Hydraulic Gradient							
BH106	45.782	44.442	44.50				
BH107	46.28	45.18	45.19				

Groundwater Samples

Groundwater sampling was carried out during one monitoring visit. The presence of hydrocarbon free product on the groundwater was investigated using a free phase dip-meter, which did not show evidence of a hydrocarbon sheen on the surface.

Groundwater samples were obtained from the monitoring wells following purging of three well volumes using submersible low flow pump. On-site testing of groundwater for temperature, pH, conductivity, and dissolved oxygen was undertaken. The collected water samples were then sealed into bottles with pre-measured fixatives where necessary, as supplied by the specialist laboratory, and transported in cool boxes to the testing laboratory.

4.5 Vapours

The Site's vapour regime will be assessed through multiple lines of evidence using soil headspace analysis, volatile soil and groundwater laboratory analysis. A qualitative review of the ground investigation data is included below.

Soil Headspace Analysis

All soil samples were subject to headspace screen for volatile contaminants. There is no general guideline for an elevated result, however, anything above 10ppm was scheduled for a VOC and sVOC suite to determine the nature of the elevated readings. Table 5 presents the elevated readings recorded across the Site. The headspace results generally correlated with visual and olfactory observations of contamination.

Perched Hydrocarbon Impacted Groundwater

Boreholes BH102, BH103 and BH104 struck groundwater between depths of between 5.80m and 7.80m bgl. On inflow of groundwater, hydrocarbon odours were noted. Observations of contamination were not recorded in the shallower arisings above the hydrocarbon odours, indicating the contamination is likely to be associated with groundwater caught above the Glacial Till.

Gas Works Waste

Two adjacent trial pits (TP113 & TP121), recorded visual and olfactory evidence of gas works waste. The two trial pits were located in areas of former tunnels, and observations of walls within the trial pits were noted. It is considered that the former tunnel areas were potentially backfilled with gas works waste. The same blue odorous material was not recorded in other locations at the Site.

No visual/olfactory observations

A number of areas on the Site recorded elevated PID readings, with no obvious signs of contamination noted during the fieldwork. These locations were scheduled for a VOC and an sVOC suite to determine the potential hazard.

5. Geotechnical Testing

5.1 In-Situ Testing

5.1.1 Standard Penetration Testing

Standard Penetration Tests (SPTs) were undertaken at regular intervals within the boreholes to provide 'N' values for empirical assessment of strength and density parameters. Detailed results of the SPTs and blow counts are included on the borehole logs included in Appendix B and a summary is presented in Table 10 below.

Table 10: Standard penetration test results

Stratum / Geological Origin	Range of SPT 'N' Values	Number of Tests	Average SPT 'N' Value	Derived Values Range of ϕ' or c_u
Made Ground (Granular)	0 – 50	36	24.6	34 ^o
Made Ground (Cohesive)	9	1	9	75 kPa
Boulder Clay (Glacial Till)	0 – 50	37	30.2	188 kPa
Sand (Glacial Till)	50	3	50	>41 ^o
Sandstone (Chester Formation)	50	2	50	-

5.1.2 Hand Shear Vane Testing

One hand shear vane test was undertaken in the underlying natural cohesive soils. Details of the results of the testing are included on the borehole logs included in Appendix B and a summary is presented in Table 11 below:

Table 11: Standard penetration test results

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Shear strength (kPa)
Boulder Clay (Glacial Till)	TP107 at 3.20m	150

5.2 Laboratory Testing

Representative soil samples were scheduled for:

- Natural moisture content and plasticity index;
- pH value and water soluble sulphate (Full BRE SD1 Suite);
- Particle Size Distribution (PSD) tests (wet sieve and pipette);
- Dry density / moisture content relationship (2.5kg compaction) testing;
- Triaxial undrained shear strength testing;
- One-dimensional consolidation testing;
- Unconfined compressive strength (rock) testing; and
- Point load (rock) strength testing.

The results are summarised below and presented in Appendix B.

5.3 Natural Moisture Content and Plasticity Index

Samples of natural cohesive material were taken for moisture content and plasticity index determinations. The test results are included in Appendix B and are summarised in Table 12 below. The modified plasticity index can be used as an indicator of volume change potential of the soil and is calculated as the plasticity index of the soil multiplied by the fraction of particles less than 425µm.

Table 12: Volume change potential

Stratum / Geological Origin	Range of Plasticity Indices % (Modified)	Volume Change Potential
Boulder Clay (Superficial Glacial Till)	12.88 to 23.28	Low to Medium

One sample (BH105 at 21.00m bgl in sand) was recorded as non-plastic.

5.4 pH Value and Water Soluble Sulphate (SD1 Suite)

The Aggressive Chemical Environment for Concrete classifications for the soil types identified at the site have been determined in accordance with BRE Special Digest 1:2005 (SD1). SD1 requires that sites are first identified as being in one of four categories based on natural ground / 'Brownfield' conditions and pyrite content. The site has been categorised as: Brownfield - Non-pyrite.

The results of laboratory testing are included in Appendix B and summarised in Table 13 below:

Table 13: Summary of SD1 suite analysis

Stratum / Geological Origin	Characteristic Water Soluble Sulphate Value (mg/l SO ₄)	Characteristic pH Value
Made Ground (Granular)	437	8.7
Made Ground (Cohesive)	166	8.5
Boulder Clay (Glacial Till)	1,725	8.6
Sand (Glacial Till)	185	9.2

As the characteristic value of sulphate is less than 3,000mg/l and the characteristic pH is greater than 5.5, the concentrations of magnesium, nitrate and chloride are not considered significant in determining the design sulphate class.

5.5 Particle Size Distribution (PSD)

Sixteen particle size distribution (PSD) were undertaken on selected bulk soil samples of Made Ground and the underlying natural soils from across the site. The results of the laboratory testing are included in Appendix B and summarised in Table 14 below:

Table 14: Summary of PSD Analysis

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Grading			
		Very Coarse	Gravel	Sand	Fines <0.063mm
Made Ground (Granular)	BH101 at 2.00m	0%	62%	25%	13%
	BH102 at 0.50m	0%	50%	38%	12%
	BH102 at 2.00m	0%	55%	29%	16%
	BH105 at 2.00m	15%	64%	16%	5%
	TP101 at 1.00m	25%	52%	11%	12%
	TP112 at 1.00m	18%	53%	20%	9%
Made Ground (Cohesive)	BH102 at 7.50m	15%	73%	10%	2%
	TP108 at 2.00m	0%	7%	19%	40% Silt 34% Clay
Boulder Clay (Glacial Till)	BH101 at 8.00m	0%	4%	19%	42% Silt 35% Clay
	BH101 at 13.00m	0%	7%	18%	40% Silt 35% Clay
	BH105 at 9.00m	0%	4%	19%	41% Silt 36% Clay
	BH105 at 15.00m	0%	8%	40%	30% Silt 22% Clay
	BH107 at 3.00m	0%	4%	25%	39% Silt 32% Clay
	BH107 at 5.00m	0%	4%	40%	32% Silt 24% Clay
Sand (Glacial Till)	BH101 at 21.50m	8%	10%	43%	23% Silt 16% Clay
	BH105 at 19.50m	0%	19%	60%	21%

5.6 Dry Density / Moisture Content Relationship

Dry Density / Moisture Content Relationship testing was undertaken on a total of three samples of Made Ground to assess the feasibility of re-compaction of shallow fills at the site. The results of the compaction tests are presented within Appendix B and summarised within Table 15 below.

Table 15: Dry Density / Moisture Content Relationship Results

Stratum / Geological Origin	Exploratory Hole Reference and Depth	MDD (Mg/m ³)	Initial Moisture Content %	OMC %	> 95% of MDD?	<5% air voids?
Made Ground (Granular)	TP101 at 1.00m	1.47	27%	21%	Y	Y
	TP112 at 1.00m	1.65	22%	18%	Y	Y
Made Ground (Cohesive)	TP108 at 2.00m	1.73	21%	18%	Y	Y

The compaction data has been assessed by comparing the results against criteria commonly used in earthworks to achieve an adequate density for engineered fills. The criteria summarised in the above table indicate whether the samples could achieve in excess of 95% of maximum dry density (a requirement often included in highways specifications) and whether they could be compacted to less than 5% air voids ratio (a requirement applied where raft foundations are to be adopted).

5.7 Undrained Triaxial Testing

Shear strength of the natural superficial strata was determined by quick undrained triaxial tests (multi-stage) on single 100mm diameter specimens at a series of confining pressures. The results of the tests are presented in Appendix B, and are summarised in Table 16 below:

Table 16: Triaxial test results

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Apparent Cohesion Values – Quick Triaxial Tests (kN/m ²)	Comments
Boulder Clay (Glacial Till)	BH101 at 6.50m	130	High Strength
	BH101 at 12.50m	105	High Strength
	BH101 at 15.00m	146	High Strength
	BH101 at 18.50m	72	Medium Strength
	BH102 at 9.00m	76	High Strength
	BH105 at 9.00m	128	High Strength
	BH105 at 15.00m	129	High Strength
	BH107 at 2.00m	64	Medium Strength
	BH107 at 4.00m	52	Medium Strength

The results for the Boulder Clay (Glacial Till) ranged between 52 kN/m² and 146 kN/m², indicating clays of medium to high strength, which are consistent with the descriptions presented within the exploratory hole logs.

5.8 One Dimensional Consolidation

One dimensional consolidation tests were undertaken on 100mm diameter specimens of natural soils at a series of confining pressures. The results of the tests are presented within Appendix C and summarised within Table 17 below.

Table 17: Summary of 1D consolidation testing

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Range of mv values (m ² /MN)				Comments
		Overburden	x2	x4	x8	
Boulder Clay (Glacial Till)	BH101 at 4.00m	0.242	0.122	0.077	0.050	Low to Medium Compressibility
	BH101 at 9.50m	0.213	0.081	0.051	0.032	Very Low to medium Compressibility

5.9 Unconfined Compressive Strength

Unconfined compressive strength tests were undertaken on 80mm diameter samples of the underlying bedrock that were at least 150mm in length. The results of the tests are presented within Appendix C and summarised within Table 18 below.

Table 18: Summary of UCS testing

Stratum / Geological Origin	Exploratory Hole Reference and Depth	UCS (MPa)	Failure Mode
Chester Formation (Sandstone)	BH101 at 28.80m	10.4	Brittle
	BH101 at 25.60m	9.4	Brittle
	BH102 at 28.10m	7.7	Brittle
	BH102 at 34.15m	9.4	Brittle
	BH106 at 23.20m	9.7	Brittle
	BH106 at 27.00m	11.2	Brittle

5.10 Point Load Testing

Point load strength tests were undertaken on samples of the underlying bedrock. The results of the tests are presented within Appendix C and summarised within Table 19 below.

Table 19: Summary of point load testing

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Orientation	Corrected Strength (I _{S50} , MPa)
Chester Formation (Sandstone)	BH101 at 28.80m	Perpendicular	0.26
		Parallel	0.14
	BH101 at 33.20m	Perpendicular	0.27
		Parallel	0.08

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Orientation	Corrected Strength (I ₅₅₀ , MPa)
	BH101 at 32.71m	Perpendicular	0.17
		Parallel	0.06
	BH101 at 35.60m	Perpendicular	0.22
		Parallel	0.07
	BH101 at 26.38m	Perpendicular	0.23
		Parallel	0.06
	BH101 at 27.52m	Perpendicular	0.15
		Parallel	0.06
	BH101 at 29.85m	Perpendicular	0.16
		Parallel	0.06
	BH101 at 32.20m	Perpendicular	0.22
		Parallel	0.07
	BH101 at 34.78m	Perpendicular	0.25
		Parallel	0.06
	BH102 at 28.10m	Perpendicular	0.27
		Parallel	0.08
	BH102 at 34.15m	Perpendicular	0.30
		Parallel	0.05
	BH102 at 26.42m	Perpendicular	0.28
		Parallel	0.09
	BH102 at 28.66m	Perpendicular	0.17
		Parallel	0.05
	BH102 at 30.40m	Perpendicular	0.32
		Parallel	0.06
	BH102 at 32.40m	Perpendicular	0.24
		Parallel	0.13
	BH102 at 35.03m	Perpendicular	0.14
		Parallel	0.04
	BH106 at 23.20m	Perpendicular	0.32
		Parallel	0.08
	BH106 at 27.00m	Perpendicular	0.29
		Parallel	0.06
	BH106 at 21.21m	Perpendicular	0.09
		Parallel	0.02
	BH106 at 23.30m	Perpendicular	0.16
		Parallel	0.06
	BH106 at 26.14m	Perpendicular	0.22
		Parallel	0.07

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Orientation	Corrected Strength (I ₅₅₀ , MPa)
	BH106 at 28.57m	Perpendicular	0.13
		Parallel	0.06
	BH106 at 29.37m	Perpendicular	0.09
		Parallel	0.02

5.11 Excavations, Trench Shoring & Dewatering

All trenches should be excavated in accordance with CIRIA Report 97 'Trenching Practice'. Comments relating to the stability of excavations (i.e. trial pits) and groundwater seepages are included in the logs in Appendix B and a summary of the stability is provided in Table 20 below.

Table 20: Stability of excavations and groundwater flows

Stratum / Geological Origin	Stability / Seepages	Comments
Made Ground	Unstable	Excavations in soft/loose strata likely to require shoring to maintain stability. No shallow groundwater encountered during investigation. If encountered simple sump pumping should be sufficient to control groundwater ingress.
Boulder Clay (Glacial Till)	Stable	Shallow excavations (<1.2m) are likely to be stable in the short term. No groundwater encountered during investigation. If encountered simple sump pumping should be sufficient to control groundwater ingress.

6. Human Health Risk – Soil

6.1 Generic Assessment Criteria – Soil

The proposed Development comprises a residential development comprising apartment blocks and soft landscaping areas. A Generic Assessment Criteria (GAC) for a residential without homegrown produce has been used to screen the laboratory data. Where exceedances of the GAC occur, further assessment may be undertaken to assess whether the Site and its redevelopment would still indicate a risk.

A Soil Organic Matter (SOM) content of the site soils is highly variable. In the first instance a SOM of 1% has been used as a preliminary screen given the organic matter concentrations recorded in the soil samples.

The proposed development has a basement car park, located centrally at the Site. The basement excavation is likely to extend to approximately 4.5m bgl. In addition, the site levels at the east are likely to be reduced by 1m. However, at this stage, this material is proposed for re-use within the scheme to backfill the voids and tunnels encountered.

The assessment of Poly-cyclic Aromatic Hydrocarbons (PAH) has been undertaken using benzo(a)pyrene as a surrogate marker for all carcinogenic PAHs. This approach was set out by the Health Protection Agency (Once Public Health England, now UK Health Security Agency and Office for Health Improvement and Disparities) and adopted in the 2013 C4SL guidance. The surrogate marker approach assumes the cancer risk of PAHs in a complex mixture is proportional to the concentration of a surrogate marker benzo(a)pyrene, and therefore accounts for the insufficiencies present in the toxicity database for the less well studied PAH contaminants.

The use of benzo(a)pyrene as a surrogate marker is only valid where the PAH soil profile is sufficiently like the coal tars mixtures used as the toxicological benchmarks in tests by Culp et al (1998). Screening of the PAH concentrations using the LQM 2015 profiling tool identifies **all** samples as being consistent with the coal tars making the application of the surrogate marker approach as valid.

Off-site Residents/Users

An open car park bounds the Site to the north, with a car park / vehicle washing company to the east and residential properties to the south and west. The risk to receptors in the surrounding area will be assessed through analysis of soil, groundwater, and vapour levels, and their potential for migrating off-site.

Construction Workers

A qualitative assessment will be completed.

6.2 Quantitative Risk Assessment – Soil

Future Site Users

The initial assessment of the soil laboratory results against the residential without homegrown produce GAC identifies the following contaminant exceedances.

Table 21: Soil Laboratory Result Exceedances

Contaminant	Threshold Value (mg/kg)	Exploratory Holes (Depth (mbgl))	Concentration (mg/kg)
Arsenic	40	TP113 at 1.0m	79.90
		TP108 at 4.0m	395
		TP114 at 1.0m	360
Lead	310	TP113 at 1.0m	3,919
		TP115 at 2.0m	721
		TP102 at 2.0m	474
Mercury	1.20	TP113 at 1.0m	13.40
Cyanide (free)	26	TP113 at 1.0m	240.70
TPH Aromatic EC10-EC12	250	BH103 at 6.50m	347.90
		BH102 at 5.80m	352
TPH Aromatic EC16-EC21	1,900	BH102 at 5.80m	6,172
		BH103 at 6.50m	2,358
		BH103 at 6.50m	3,047
TPH Aromatic EC21-EC35		TP113 at 1.0m	2,952
		BH102 at 5.80m	7,296
Benzene	0.38	BH103 at 6.50m	4.58
		TP109 at 2.0m	46.64
		BH103 at 5.0m	26.03
		BH103 at 6.50m	323.10
Naphthalene	2.30	TP113 at 1.0m	2.74
		BH104 at 1.0m	19.67
		BH104 at 5.0m	18.27
		BH102 at 8.50m	8.50
		BH102 at 5.80m	188.91
Naphthalene	2.30	HDP102 at 0.6m	4.141
		TP109 at 2.0m	61.43
Beno(a)anthracene	11	BH103 at 5.0m	15
		BH103 at 6.50m	28

Contaminant	Threshold Value (mg/kg)	Exploratory Holes (Depth (mbgl))	Concentration (mg/kg)
Chrysene	30	BH104 at 1.0m	12.64
		BH102 at 5.80m	116.61
		BH102 at 5.80m	135.54
		BH105 at 7.0m	929
Benzo(b)fluoranthene	3.90	TP109 at 2.0m	67.94
		BH103 at 5.0m	14.44
		BH103 at 6.50m	30.59
		TP113 at 1.0m	4.48
		TP115 at 2.0m	5.35
		BH104 at 1.0m	11
		BH102 at 3.80m	5.69
		BH102 at 5.80m	115.59
Benzo(a)pyrene	3.20	BH105 at 7.0m	6.543
		TP109 at 2.0m	66.84
		BH103 at 5.0m	12.09
		BH103 at 6.50m	24.59
		TP115 at 2.0m	4.43
		BH104 at 1.0m	10.09
		BH102 at 3.80m	5.39
		BH102 at 5.80m	113.39
Dibenzo(ah)anthracene	0.31	HDP102 at 0.6m	6.347
		BH101 at 0.5m	1.55
		TP109 at 2.0m	10.97
		BH103 at 5.0m	2.40
		BH103 at 6.50m	4.63
		TP113 at 1.0m	0.55
		TP115 at 2.0m	0.76
		TP102 at 2.0m	0.44
		BH104 at 1.0m	1.70
		BH104 at 5.0m	0.41
		BH102 at 3.80m	0.78
		BH102 at 5.80m	16.70
		HDP102 at 0.6m	0.96

Contaminant	Threshold Value (mg/kg)	Exploratory Holes (Depth (mbgl))	Concentration (mg/kg)
4-Methylphenol & 2,4-Trimethylphenol*	3.90	BH103 at 6.50m	31.33
			63.33
1,2,4-Trimethylbenzene & 1,3,5-Trimethylbenzene*	0.41	BH103 at 6.50m	41.28
			8.76
		BH102 at 5.80m	4.24
			0.63

*Where no published GACs are available the lowest similar chemical species was used as an indicator of risk.

In addition to those in the table Carbazole and Dibenzofuran, which are typically found alongside diesel contamination, have no published GACs, however, concentrations were elevated in BH103 and BH102.

There are considered to be a number of different areas of contamination recorded at the Site, as identified in Section 4.6.

Diesel Contamination at Depth

Visual and olfactory evidence of contamination was recorded in BH102, BH103, BH104 and BH105 associated with the inflow of groundwater caught at the base of the Made Ground and surface of the Glacial Till. The laboratory data confirms that the shallower soils are not impacted with hydrocarbon contamination, however, the soils in contact with the groundwater, recorded elevated PID readings and elevated contamination concentrations.

The significantly elevated contaminants comprise TPH, benzene, PAHs including naphthalene, trimethylbenzenes and phenols. The TPH interpretations report the contamination comprises 'coal tar PAHs, degraded diesel and possible naturally occurring compounds'. This interpretation is consistent with the former uses of the Site as a mechanics garage and as part of a former gas works.

The number of exploratory hole locations at the Site was extensive and no obvious soil source of TPH (diesel contamination) was recorded. No underground or overground fuel storage tanks were noted at the Site at the time of the ground investigation. Due to the absence of a soil source, it is considered likely that the contamination at depth has resulted from poor site housekeeping practices and damaged drainage, although a soil source cannot be ruled out with certainty.

Benzene, naphthalene, trimethylbenzenes and phenol are volatile contaminants and present a risk through the vapour inhalation pathways. The location of the contamination together with the depth at which the contamination is recorded indicates removal of hotspots would likely be unfeasible. The presence of these contaminants is considered to pose an unacceptable risk to the proposed end-user and remediation measures will be required. It is recommended that suitable vapour membranes are incorporated into the foundation design of the proposed buildings and structures.

Gas Works Waste

Significantly elevated concentrations of cyanide, TPH, PAHs, arsenic, lead and mercury were recorded at trial pit TP113 and also similar observations were recorded at TP121. In addition, significantly elevated concentrations of naphthalene were recorded at the adjacent trial pit, TP109. This area of the Site is considered to be a hotspot of gas works waste. Exploratory holes were excavated to the east, south and

west of this location and visual observations of gas works waste were not recorded, which is confirmed with the laboratory testing.

Trial pits TP113 and TP121 were positioned in the location of a former tunnel, which was found to be backfilled, as concluded from the buried structures noted in the trial pits. This is considered to be an isolated location on the Site and should be treated as such.

Metals and PAHs

Concentrations of low volatility metals and PAHs were recorded at a number of locations across the Site. The proposed end-use of the Site will comprise building footprints, hardstanding or soft landscaping areas. A potential risk from direct contact will exist at the Site and a suitable engineered cover system will be necessary in all areas of soft landscaping, and garden areas, to suitably manage the risk from low volatility contaminants.

Naphthalene

Significantly elevated concentrations of naphthalene were recorded across the Site in the hotspot areas indicated above, together with hand dug pit HDP102.

Asbestos Fibres

Made Ground soils were subject to an asbestos screen to determine the presence of asbestos fibres. Asbestos fibres were recorded in a number of locations as detailed in the Table 22 below. Visual signs of asbestos were recorded in 2 No. trial pits (TP111 and TP113), which were abandoned due to the presence of a significant quantity of asbestos tiles.

Table 22: Asbestos in Soils

Exploratory Hole Location and depth (m bgl)	Asbestos Type	Asbestos Form	Concentration (%)
TP111 at 1.40m	Fibre Bundles	Chrysotile, Amosite & Crocidolite	0.11%
BH103 at 6.50m	Fibre Bundles	Chrysotile	0.0014%
TP114 at 1.0m	Fibre Bundles	Chrysotile	0.012%
TP113 at 1.0m	ACM Debris	Amosite & Chrysotile	1.45%
WS104 at 1.0m	unknown	Chrysotile	Trace Asbestos

Future Site Users – Conclusion

Significantly elevated concentrations of contaminants have been recorded within the Made Ground at the Site, considered to be typical of the former uses of the Site as a former mechanics garage and gas works.

Diesel contamination recorded at depth within the site soils (associated with the groundwater trapped in the Made Ground at the Site) is considered to pose an unacceptable vapour risk and remediation will be required. Although the groundwater is not considered a vapour risk. The most viable solution is considered to be the inclusion of a suitable vapour membrane within the proposed buildings and structures.

A large basement excavation is proposed centrally within the Site together with a reduced level dig at the east to allow the Site to align with external ground levels. Due to the nature of the Site, with an amount of below ground voids and tunnels, this material is proposed for re-use at the Site. The incorporation of vapour membranes and a suitably engineered cover system will break the pathways between the contamination and the proposed end-users.

Off-site Human Health Receptors - Conclusion

Proposed Development construction will include extensive earthworks, which have the potential to liberate dust, asbestos fibres, or contaminants from the soil matrix and enable their lateral migration off-site. To mitigate this risk dust mitigation measures will be required throughout the development construction, notably during earthworks to minimise the creation and migration of dust, contaminants, or asbestos fibres. Details on how contaminants and dust will be managed during enabling works will be set out in a Construction Environmental Management Plan (CEMP).

To allow the works to progress an Asbestos Risk Management Plan (ARMP) shall be prepared which will comply with the Control of Asbestos at Work Regulations (2012) for use during the earthworks and construction works. The requirement for air monitoring or similar shall be considered by the ARMP. In addition, in order to manage potential fibre release, dust suppression techniques may be required when excavating the site soils.

The gas works waste recorded at trial pits TP113 and TP121 is potentially odorous material may be exposed during enabling works. Whilst the odour is unlikely to pose a significant risk to surrounding receptors it may pose a nuisance, which will require management to minimise odours as far as is

reasonably practicable. The mitigation measures and working methodologies are included within an Odour Management Plan produced separately to this report.

Construction Workers – Conclusion

Contaminants present in the Made Ground and natural deposits pose a risk to construction workers where robust health and safety measures are not employed. All construction works should be undertaken under a risk assessment which accounts for the ground conditions identified during previous remedial work and subsequent ground investigations. In addition, all works should be completed in accordance with the Control of Asbestos Regulations 2012 (CAR 2012) and an Asbestos Plan of Work completed and kept up to date as a live document throughout the works.

7. Human Health Risk - Vapours

7.1 Generic Assessment Criteria - Vapours

The risk from vapours to future Site users will be assessed qualitatively through using soil headspace analysis and the VOC laboratory testing of soil and groundwater. A quantitative assessment will also be taken through comparison of the groundwater sample results against the Society of Brownfield Risk Assessment (SoBRA) derived vapour GAC (VAP_{GW}).

The SoBRA VAP_{GW} builds in several precautionary assumptions into its model, including;

- No biodegradation is occurring between the source term, and the receptor;
- The groundwater is at 0.65mbgl;
- The geology on-site is a sandy stratum; and
- The omission of capillary fringe between the saturated and unsaturated zones.

Given the differences in the proposed Development and ground conditions on-site relative to the SoBRA model, the geological and hydrogeological conditions comparison of the groundwater results against the SoBRA VAP_{GW} will be conservative.

7.2 Quantitative Risk Assessment – Vapours

As detailed through this report a review of the lines of evidence has been used to assess whether a significant vapour regime is present as follows:

- The PID results have been summarised and compared against the visual and olfactory evidence of contamination in the site soils has been presented in Section 4.6.
- A review of the soil laboratory certificates has been provided in Section 6.2 indicating the elevated concentrations of volatile contaminants.
- Comparison of the groundwater laboratory results against the SoBRA VAP_{GW} is presented below.

Groundwater Vapour Assessment

Groundwater was recorded in three of the boreholes installed at the Site, together with one, off-site borehole (BH107). The groundwater was sampled and scheduled for both VOC and sVOC analysis to characterise the groundwater. The results have been compared to the SoBRA VAP_{GW} assessment criteria. The three on-site boreholes did not record significantly elevated concentrations of contaminants on comparison to the SoBRA VAP_{GW} assessment criteria.

The off-site borehole, BH107, was also subject to sampling and analysis. Comparison of the laboratory data to the SoBRA VAP_{GW} assessment criteria recorded elevated concentrations of contaminants, as detailed in the table 23 below.

Table 23: Significantly elevated concentrations of volatile groundwater contaminants – off-site borehole

Contaminant	Exploratory Hole Location	Concentration (µg/m ³)	SoBRA VAP _{GW}
TPH Aliphatic C8 – C10	BH107	91	57
TPH Aliphatic C10 – C12	BH107	39	37

The concentrations of TPH are greater off-site than on the subject site, therefore it is considered migration to the north is not significant from the subject Site. The off-site borehole is outside of the scope of this ground investigation.

Based on the groundwater concentrations the risk from the on-site groundwater is considered to be low.

The lines of evidence indicate a vapour risk from the groundwater at the Site is considered to be Low.

Vapour Regime Conclusion

The PID readings indicated elevated volatile contaminants may be present at the Site at a number of locations. Representative soil samples were subject to laboratory testing to further characterise the site soils. The elevated PID readings are likely to be attributed to the presence of naphthalene and benzene, recorded at number of locations as discussed in the previous section.

A vapour risk is considered to exist at the site within regard to the Site soils, please refer to Section 6.2 for full details.

8. Human Health Risk – Ground Gas

8.1 Generic Assessment Criteria – Ground Gas

The ground gas risk will be assessed utilising the TOC soil sample results and the ground gas monitoring results.

The TOC concentrations will be assessed in accordance with the requirements of CLAIRE Research Bulletin, November 2012, A Pragmatic Approach to Ground Gas Risk Assessment as an additional line of evidence to support the ground gas monitoring data.

The ground gas monitoring results will be assessed through calculation of the Site's Gas Screening Value (GSV) in accordance with the CIRIA C665. At all stages in the assessment only ground gas monitoring results representative of the Site's ground gas regime will be used.

8.2 Quantitative Risk Assessment – Ground Gas

As identified in the CL:AIRE 2012 RB17 guidance document and CIRIA C665 ground gases only pose a risk to developments when the following can be satisfied, which is in line with source – pathway – receptor model followed by LCRM.

- An accumulation of a large volume of gas in the ground in or near the buildings (source).
- A pathway that allows gas to migrate through and/or out of the ground into a building or other structure sufficiently quickly to allow it to build up inside the building (pathway).
- A confined space within the building or structure where gas can build up to unacceptable levels (receptor).

For a risk from ground gases a source – pathway – receptor linkage needs to be present. This requires sufficient gas to pose a hazard and one or more pathways by which it may cause significant harm to people. For sustained gas migration to occur gas must be replenished at the source to negate the effects of attenuating factors such as oxidation of the methane/carbon dioxide to oxygen in the aerobic zone or low permeability soils decreasing the migration potential. Therefore, sustained high levels of gas generation are required for ground gas to migrate via advective or diffusive flow and cause high ground gas concentrations at the surface/within built structures. The volume of ground gas is therefore the principal factor which should be considered rather than the ground gas concentration and not the gas concentration present in the ground (or monitoring well) which is commonly mistaken as posing a risk to future Site users.

Potential Sources of Ground Gas

The desk study indicates that the two key sources of ground gas at the Site are Made Ground and potential hydrocarbon contamination. The boreholes at the site were suitably installed to monitor both the Made Ground and hydrocarbon contamination recorded.

The ground investigation recorded varying depths of Made Ground up to a depth of 7.80m bgl. There is a significant topographic level change between the site surface and Site located to the north of approximately 5-6m, with the northern site boundary comprising of former tunnels and retaining features. The installed monitoring wells at the Site target the Made Ground.

TOC Analysis

Total Organic Carbon (TOC) analysis was undertaken on Made Ground samples. Whilst forensic description of the Made Ground was not undertaken the relative homogeneity of the Made Ground, and absence of bulk material typically associated with landfills (wood, branches, textiles, cloth, vegetable matter etc) indicates the TOC fraction recorded is representative of the material.

TOC results from the Made Ground ranged between 0.61% and 23.17%

2No. ground gas monitoring rounds have been completed to date, with 6No rounds currently programmed and the ground gas monitoring period remains ongoing.

In accordance with best practice the results from the ground gas monitoring were reviewed post completion of each monitoring round and where factors which may result in unrepresentative monitoring results were recorded these monitoring wells have been excluded from further consideration.

A full record of the ground gas monitoring results is included in Appendix B.

Ground Gas Monitoring Results Summary

A summary of the ground gas monitoring results representative of the Site's ground gas regime is included in Table 24: [Ground Gas Monitoring Summary](#)

Table 24: Ground Gas Monitoring Summary

Monitoring Well	Steady Concentration Range (%)	Steady Concentration Range (%)	Steady Range (l/hr)
	Methane	Carbon Dioxide	Flow Rate
BH101 – Made Ground	<0.1	2.4	0.0
BH102 – Made Ground	<0.1	<0.1	0.0
BH103 – Made Ground	<0.1	<0.1	0.0
BH104 – Made Ground	<0.1	<0.1	0.0
BH105 – Made Ground	<0.1	0.4	0.0
BH106 – Made Ground	<0.1	1.0	0.0
BH107 – Made Ground	<0.1	0.6	0.0
WS101 – Made Ground	<0.1	0.5	0.0
WS102 – Made Ground	<0.1	N/A	0.0
WS103 – Made Ground	<0.1	0.5	0.0
WS105 – Made Ground	<0.1	0.2	0.0

The depth of the Made Ground across the Site was recorded between 0.7m bgl and 7.80m bgl. The range of response zones across the Made Ground has allowed the Made Ground layers to be monitored.

Based on the ground gas monitoring completed to date the Qhg (borehole hazardous gas flow rate) has been determined for each borehole monitored. Assessment of the results records a maximum Qhg of

0.0027l/hr (CO₂). Based solely on the Q_{hg} the ground gas regime would be classified as Characteristic Situation 1 (CS1) – Very low risk in which ground gas protection measures.

The guidance in CIRIA C665 (2007) requires a potential increase to a Characteristic Situation 2 (CS2) classification (low risk) where methane >1.0% and carbon dioxide is >5.0% with the overall ground gas conceptual to be considered to determine the appropriate ground gas classification.

As identified in BS8485: 2015+A12019 and 2018 EPG, Using Ternary Plots for Interpretation of Ground Gas Monitoring Results guidance an exceedance of 5% carbon dioxide does not necessitate an increase from CS1 to CS2.

At this stage based on a preliminary assessment the ground gas regime at the Site is designated as Characteristic Situation 1. However, this is based on 2No. rounds only and should be considered preliminary until the ground gas monitoring period can be completed.

9. Controlled Waters

9.1 Generic Assessment Criteria – Controlled Waters

The controlled waters receptors at the Site are the underlying Chester Formation Sandstone designated as a Principal Aquifer and the Risk Irk, located 193m to the north of the Site.

The ground investigation has recorded a thickness of between 13.0m and 19.2m of Glacial Till between the Made Ground and the underlying Sandstone Principal Aquifer. The Glacial Till is a low permeability layer that will prevent the vertical migration of contamination from the Made Ground to the underlying Principal Aquifer. The Principal Aquifer is discounted as a key receptor at the Site due to the significant thickness of Glacial Till.

The River Irk is located 193m to the north of the Site. The River Irk is considered the primary controlled waters receptor. The groundwater samples will be assessed against the Environment Agency (EA) derived Environmental Quality Standards (EQS) in the first instance.

The base EQS values for bioavailable contaminants have been applied given the absence of relevant surface water samples. This approach retains conservatism.

The EQS for benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene is based on the toxicity of benzo(a)pyrene, with the EQS for these PAH identifying the use of benzo(a)pyrene as a marker for these PAH. This approach will be followed with the assessment of benzo(a)pyrene as a marker of the risk posed by benzo(k)fluoranthene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene.

The threshold criteria are applicable at the surface water receptor, and do not account for contaminant attenuation along the migration pathway. Exceedances of the threshold criteria does not necessarily indicate a risk exists and means further qualitative/quantitative assessment of the results are required.

9.2 Quantitative Risk Assessment – Controlled Waters

Groundwater samples were collected on one occasion from the installed boreholes at the Site. The groundwater was collected from water collected within the Made Ground sitting above the Glacial Till surface.

An additional borehole was installed off-site at the northern boundary. The groundwater results for this borehole are also included in this assessment. The table below presents the elevated concentrations recorded when compared to EQS Values.

Table 25: Significantly elevated concentrations of volatile groundwater contaminants – off-site borehole

Contaminant	Threshold Value (µg/l)	No. of Samples above EQS	Max. Concentration (µg/l)
Nickel	4	2 (BH103 & BH105)	9,8
2,4-Dimethylphenol	7.7	1 (BH105)	95
Naphthalene	2	1 (BH105)	62
2-Methylnaphthalene	2	1 (BH105)	25
TPH Aromatic EC10-EC12	N/A	1 (BH105)	245

Contaminant	Threshold Value (µg/l)	No. of Samples above EQS	Max. Concentration (µg/l)
TPH Aromatic EC12-EC16	N/A	2 (BH103 & BH105)	110, 580
TPH Aromatic EC16-EC21	N/A	2 (BH103 & BH105)	340, 410
TPH Aromatic EC21-EC35	N/A	2 (BH103 & BH105)	480

The groundwater samples were scheduled for a sVOC suite, and a VOC suite and the majority of determinants were recorded at the laboratory detection limit.

There is no published EQS for TPH, however the elevated concentrations are included in the table above.

Significantly elevated concentrations of naphthalene 2-Methylnaphthalene and 2-4,Dimethyphenol have been recorded in the groundwater at one location, BH105. Concentrations of similar contaminants were recorded in the site soils and are consistent with the mobility of naphthalene in soils and would be considered typical gas works contaminants.

Borehole BH106 was dry during the sampling visit, indicating limited migration is occurring to the north. However, the groundwater levels recorded at the Site indicate the movement of water within the Made Ground is to the east towards BH102. Concentrations of naphthalene, 2-methylnaphthalene and 2,4-dimethylnaphthalene were not elevated in BH102.

Elevated concentrations of TPH were recorded in the groundwater at BH103 and BH105, which is consistent with the observations of hydrocarbons within the groundwater recorded during the drilling. Concentrations of TPH were greater at BH105, reducing towards BH103. However, TPH was not recorded to be elevated in BH102.

The trend in groundwater concentrations indicates that the TPH is elevated within the groundwater at BH105 and BH103, however concentrations are not elevated at BH102 indicating off-site migration is likely to be limited.

The elevated concentrations of contaminants are contained within water collected within the Made Ground, perched above the surface of the Glacial Till. The extent of the water is discontinuous, as boreholes BH106, BH104 and BH101 were recorded to be dry during the two monitoring rounds. The migration of the water is inferred from west to east, with concentrations reducing. BH102 did not record elevated concentrations. Based on the limited volume of groundwater, its discontinuous nature together with the distance of 193m to the River Irk indicates the risk to the River Irk is therefore considered to be Low.

Glacial till was recorded at a depth 0.9m bgl at WS101 at the east of the Site, indicating that historic excavation of the Glacial Till has occurred within the Site, resulting in the significant thickness of Glacial Till. The potential migration of contamination to the east is considered to be limited as the low permeability clay will prevent the movement of the trapped groundwater.

Borehole BH106 & BH107

Due to the presence of an existing open tunnel network and potential underground voids, advancing boreholes towards the northern boundary was deemed unsafe from a Health and Safety perspective. To provide geotechnical properties of the ground two boreholes were advanced off-site to the north (BH106 and BH107). BH106 was dry during the recent monitoring rounds and a groundwater sample collected

from BH107. It was considered that should contamination be recorded at the Site, BH107 would act as a Sentinel borehole to determine whether contamination is migrating off-site.

The following significantly elevated concentrations of contaminants were recorded in borehole BH107.

Table 26: Elevated Groundwater Concentrations-BH107

Contaminant	Threshold Value (µg/l)	No. of Samples above EQS	Max. Concentration (µg/l)
Nickel	4	1 (BH107)	5
Naphthalene	2	1 (BH107)	59
2-Methylnaphthalene	2	1 (BH107)	6
TPH Aromatic EC10-EC12	N/A	1 (BH107)	133
TPH Aromatic EC12-EC16	N/A	1 (BH107)	540
TPH Aromatic EC16-EC21	N/A	1 (BH107)	730
TPH Aromatic EC21-EC35	N/A	1 (BH107)	120
TPH Aliphatic EC6-EC8	N/A	1 (BH107)	22
TPH Aliphatic EC6-EC8	N/A	1 (BH107)	730
TPH Aliphatic EC6-EC8	N/A	1 (BH107)	180

Similar contaminants were recorded to be elevated in BH107, which would be expected for a former gas works site.

It was concluded that the groundwater migrating to the north, and based on groundwater elevations, would be towards BH107. However, BH102 did not record elevated concentrations of contaminants, indicating that the concentrations recorded in borehole BH107 are likely to have a source on the adjacent site rather than sourced from this Rochdale Road site.

10. Preliminary Waste Classification Assessment

The proposed development includes a basement car park to the centre of the Site, likely to be excavated to a depth of 4.5m bgl, as indicated on Drawing WIE19453-100-ZZ-XX-DR-V-80-005-P01. In addition, the site levels to the east of the Site will be reduced to match that of the levels on the adjacent highway, Clive Street. At this stage it is understood that there is a requirement for this material to be re-used at the Site to fill the voids and tunnels at the Site.

However, should surplus materials be generated at the Site the following section provides a guide to the likely waste classification. All samples collected during the site investigation have been subject to a Preliminary Waste Classification Assessment. The process of waste classification is set out in Appendix F.

10.1 Introduction

A Preliminary Waste Classification Assessment has been undertaken on discreet soil samples recovered from exploratory holes undertaken as part of the contaminated land assessment for the Site. The samples collected from each location are discreet and have not been sampled in strict accordance with UK Environment Agencies guidance WM3 “Guidance on the classification and assessment of waste” (1st Edition v1.2.GB 2021) (hereafter “WM3”). The assessment should be regarded as indicative only. Further assessment will be required once it is known how the waste will arise, and what off-site recovery or disposal options are available.

Our assessment includes firstly considering whether or not the waste displays hazardous properties and secondly, should landfill disposal be a potential offsite option for the wastes, the findings of additional waste acceptance criteria (WAC) testing. WAC testing remains in the laboratory and will be reported at a later date.

The hazardous property assessment has been undertaken using HazWasteOnline™.

HazWasteOnline™ is a web-based tool for classifying hazardous waste. The tool follows the latest Environment Agencies guidance and European regulations.

10.2 Hazardous Property Assessment

The dry soils chemical analysis results from the Site Investigation have been entered into HazWasteOnline™. Results from the HazWasteOnline™ assessment are included in Appendix F.

7No. of the 22No. dry soil samples screened have been reported as containing hazardous properties by HazWasteOnline™. The samples were taken from the Made Ground.

Details of the samples identified as containing hazardous properties are provided in the table below.

Table 27: Summary of Samples Reported as Containing Hazardous Properties

Sample Reference	Strata	Hazardous Properties
TP111 at 1.4m bgl	Made Ground	HP7: Carcinogenic – Asbestos 0.116%.
TP114 at 1.0m bgl	Made Ground	HP7: Carcinogenic - TPH C6 to C40 (unknown oil). HP11: Mutagenic - TPH C6 to C40 (unknown oil).
TP113 at 1.0m bgl	Made Ground	HP6: Acute toxicity – hydrogen cyanide

Sample Reference	Strata	Hazardous Properties
		HP7: Carcinogenic – lead & asbestos compounds HP12: Release of an acute toxic gas – hydrogen cyanide HP14: Ecotoxic – Copper (I) oxide; lead compounds; zinc oxide.
TP115 at 2.0m bgl	Made Ground	HP14: Ecotoxic – Zinc oxide;
BH104 at 5.0m bgl	Made Ground	HP7: Carcinogenic - TPH C6 to C40 (unknown oil). HP11: Mutagenic - TPH C6 to C40 (unknown oil).
BH102 at 3.80m bgl	Made Ground	HP7: Carcinogenic - TPH C6 to C40 (unknown oil). HP11: Mutagenic - TPH C6 to C40 (unknown oil).
BH102 at 5.8m bgl	Made Ground	HP7: Carcinogenic - TPH C6 to C40 (unknown oil). HP11: Mutagenic - TPH C6 to C40 (unknown oil).

All samples of Made Ground were screened for the presence of asbestos. 5No. samples were identified containing asbestos fibres / fragments. Table 22 presents the asbestos results.

Asbestos quantification analysis indicates concentrations of between <0.001% and 1.45%.

Visible fragments of potentially asbestos containing materials were identified during field work at two locations, TP111 and TP113 describes as asbestos tile. The asbestos quantifications in these locations are reflective of this.

Waste soils with identifiable pieces of asbestos containing materials are classified as a mixed waste. The soil / made ground matrix in this case is classified as Hazardous (Waste Catalogue code 17 05 03* - *Soils and stones containing hazardous substances*).

10.3 Waste Acceptance Criteria

In addition to the HazWasteOnline™ assessment, Waste Acceptance Criteria (WAC) analysis is currently being undertaken on the following samples to indicate if any soils may be suitable for disposal to a hazardous waste landfill without further treatment.

The soil samples have been chosen on the basis of firstly hazardous and within the proposed excavation footprints:

- BH102 at 3.80m bgl (Made Ground);
- TP113 at 1.0m bgl (Made Ground).

This section will be updated in due course on receipt of the laboratory data.

10.4 Preliminary Waste Classification Assessment Summary

The Preliminary Waste Classification Assessment has indicated that the relevant Waste Catalogue code for the disposal of the materials are as follows:

Soils identified as containing no hazardous properties use: 17 05 04: Soils and stones other than those mentioned in 17 05 03.

Soils identified as containing hazardous properties use 17 05 03*: Soils and stones containing hazardous substances. (THIS INCLUDES SOILS CONTAINING 0.1% W/W OF LOOSE FIBRES/ ASBESTOS NOT VISIBLE TO THE NAKED EYE)

Soils containing visible asbestos (excluding insulation material) and contain hazardous properties use 17 06 05* Construction material containing asbestos and 17 05 03* Soils and stones containing hazardous substances.

“Mixed wastes” should be separated where technically and economically feasible. Where this is not feasible the waste is regarded as a mixed waste and classified accordingly. Separation may include mechanical screening or hand picking of materials, subject to relevant waste management regulatory controls and health and safety requirements.

11. Geotechnical Assessment

11.1 Proposed Development

This assessment has been prepared on the understanding that the Proposed Development is defined as:

'The Erection of a part 11, part 13 storey building to form residential apartments (Use Class C3a) together with the erection of two blocks of 3 storey duplexes (Use Class C3a) to form 237 residential homes in total with associated commercial floor (Use Class E) (132 sqm), basement car parking, landscaping and public realm, and associated engineering and infrastructure works following demolition of existing buildings and structures'.

If development proposals change, it may be necessary to revise the conclusions and recommendations made in this report and Waterman IE should be contacted to provide further advice.

11.2 Characteristic Values and Design Bearing Resistance

Based upon the site investigation data and a review of the derived values summarised in Section 5, characteristic values can be assigned to each strata. EC7 defines the characteristic value of a soil or rock as a cautious estimate of the value affecting the occurrence of the limit state. The characteristic values to be used in design are highlighted in Table 28 and considered to be:

Table 28: Characteristic values for geotechnical design

Stratum / Geological Origin	Strength / Density Descriptor	Undrained Strength (c_u - kPa)	Angle of Shearing Resistance (ϕ' – deg)
Made Ground (Granular)	Very loose to very dense	-	34°
Made Ground (Cohesive)	Firm / Medium Strength	75	-
Boulder Clay (Glacial Till)	Generally firm to stiff / medium to high strength	100	-
Sand (Glacial Till)	Very dense	-	>41°
Chester Formation (sandstone)	Extremely weak to weak	-	-

Given the depth to Made Ground recorded across the site, shallow foundations are not considered to be suitable for use across the site. Piled foundations are considered to be the most appropriate foundation solution at the site.

11.2.1 Shrinkability / Volume Change Potential

The cohesive Boulder Clay has been shown to have a low to medium volume change potential. Foundations placed on shrinkable soils should be deepened where necessary to accommodate the effects of trees and hedgerows. Where foundations are beyond the influence of existing and proposed planting (i.e. 1.5 times the mature tree height), a minimum foundation depth of 0.9m bgl should be adopted.

Foundations within the zone of influence of existing or proposed trees should be deepened as necessary in accordance with recommendations provided in NHBC Chapter 4 – Building Near Trees. If trees are

present within influencing distance of proposed foundations, a tree survey should be undertaken to identify appropriate founding depths.

11.2.2 Design Class for Concrete

Based on the characteristic values derived from SD1 testing, the Design Sulphate (DS) and Aggressive Chemical Environment for Concrete (ACEC) classifications are considered to be:

- Concrete in contact with granular Made Ground: DS1 AC1;
- Concrete in contact with cohesive Made Ground: DS1 AC1;
- Concrete in contact with Boulder Clay: DS3 AC3;
- Concrete in contact with Sand (Glacial Till): DS1 AC1.

11.2.3 Piled Foundations

Due to the depth of Made Ground recorded across the site and the increased loadings the apartment blocks are expected to exert, it is considered that piled foundations will be required.

~~It is recommended that the advice of a specialist piling contractor should be obtained to confirm the suitability of piling and the most appropriate pile type. However,~~ based on the site investigation information, end bearing piles would key into the sandstone bedrock between approximately 21m and 26m bgl.

The final design of the piles will be the responsibility of the piling contractor. Dependant on whether all existing foundations are removed during demolition, an allowance for probing of pile positions and/or drilling of obstructions may be required.

The influence of the overlying Made Ground should be ignored in the pile capacity calculations; however, the Boulder Clay could provide additional skin friction capacity. During detailed pile design the choice of factors of safety should ensure that appropriate safe working loads and settlement tolerances are met.

Preliminary Pile Resistance calculations were undertaken to provide estimations as to the capacities achievable in a variety of pile constructions and diameters, taking into account the skin friction of the overlying Boulder Clay. These calculations were undertaken based on the findings of intrusive investigation and laboratory testing undertaken across the site. The following assumptions have been made:

- Continuous Flight Auger (CFA) piles are to be utilised;
- Piles are to be socketed 1m into competent sandstone bedrock;
- Groundwater has been assumed to be 5.8m bgl;
- Piles are constructed of concrete with a compressive strength of 40 MPa;
- 10mm wall thickness and open base for low displacement driven piles;
- Bentonite is not used in the construction of bored piles.

The following shall only be used as guidance and shall not be used as an indicator of the final capacity and design parameters of piled solutions at the Site.

Table 29: Estimated Pile Capacities (Sandstone)

Pile Length (m)	Estimated Pile Load by diameter (kN)		
	d=300mm	d=450mm	d=600mm
High Displacement Driven Piles			
22.50	2,113	4,077	6,611
Low Displacement Driven Piles			
22.50	1,104	1,696	2,280
Bored Piles			
22.50	1,990	3,854	6,297

It is expected that the proposed three storey buildings will also require piled foundations due to the depth of Made Ground recorded across the site. It is anticipated that underlying Boulder Clay will have sufficient bearing capacity to support the smaller structures utilising skin friction piles. The estimated pile capacities are summarised below.

Table 30: Estimated Pile Capacities (Boulder Clay)

Pile Length (m)	Estimated Pile Load by diameter (kN)		
	d=300mm	d=450mm	d=600mm
High Displacement Driven Piles			
10.00	314	487	673
11.00	362	560	769
12.00	410	632	865
13.00	458	704	961
14.00	504	776	1,057
15.00	552	848	1,154
Low Displacement Driven Piles			
10.00	294	441	588
11.00	342	513	684
12.00	390	585	780
13.00	438	657	876
14.00	484	729	972
15.00	532	801	1,069
Bored Piles			
10.00	285	445	616
11.00	320	497	686
12.00	355	550	756
13.00	390	603	826
14.00	425	655	896
15.00	461	708	967

An acceptable percentage of piles should be load tested to at least twice working load. All piles should be integrity tested.

A number of underground obstructions were noted during the investigation; these should be removed prior to construction and the pile design take account of their removal.

On significantly contaminated sites, the Environment Agency may object to the use of piles on the basis that they can introduce pathways for contaminant migration. Such objections can usually be overcome if piles are designed in accordance with the EA's advice "Piling and Penetrative Ground Improvement Methods on Land Affected by contamination: Guidance on Pollution Prevention. NC/99/73.

Consideration should be given to the re-use of pile arisings if bored piles are used. It may be possible to re-use pile arisings subject to risk assessment; however, certainty of use and volume should be confirmed in accordance with the requirements of CLAIRE guidance.

The effects of noise and vibration (e.g. from piling plant) on neighbouring structures / properties should be addressed as part of the contractors method statement.

11.2.4 Earthworks / Pavement Design

The results of compaction and PSD testing undertaken on samples of Made Ground and the underlying natural soils indicate that:

- Granular Made Ground could be recompacted to achieve >95% of MDD and <5% air voids;
- Boulder Clay could be recompacted to achieve >95% of MDD and <5% air voids;
- Underlying Sand (Glacial Till) could be recompacted to achieve >95% of MDD and <5% air voids.

The majority of the cohesive material underlying the site is classified as Class 2A (wet cohesive material), while the majority of the overlying granular Made Ground is classified as Class 6E (selected granular material), as summarised below.

Table 31: Earthworks materials classification

Stratum / Geological Origin	Exploratory Hole Reference and Depth	Classification (SHW Vol 1; Series 600 – Earthworks)
Made Ground (Granular)	BH101 at 2.00m	6E / 6R
	BH102 at 0.50m	6F1
	BH102 at 2.00m	2C
	BH105 at 2.00m	6E / 6R
	TP101 at 1.00m	6E / 6R
	TP112 at 1.00m	6E / 6R
Made Ground (Cohesive)	BH102 at 7.50m	6E / 6R
	TP108 at 2.00m	2A / 2B
Boulder Clay (Glacial Till)	BH101 at 8.00m	2A / 2B
	BH101 at 13.00m	2A / 2B
	BH105 at 9.00m	2A / 2B
	BH105 at 15.00m	2A / 2B
	BH107 at 3.00m	2A / 2B
	BH107 at 5.00m	2A / 2B
Sand (Glacial Till)	BH101 at 21.50m	2A / 2B
	BH105 at 19.50m	2A / 2B

Where made ground is to be reused as an engineered fill, it would be sensible to select granular fills only and subject them to a confirmatory testing regime where they were required to achieve a compaction specification as a structural fill.

Construction plant should be provided with an adequate working platform in line with the requirements of BRE report, "BR 470: Working Platforms for Tracked Plant". Again, further advice should be sought from the temporary works designer. However, the following factors should be considered.

The shallow subgrade is likely to exhibit very low CBR values (i.e. generally less than 2.5%). The near surface subgrade is not considered likely to support construction traffic without deteriorating rapidly. Low strength subgrades could be improved using one of the following options:

- The material at the surface could be removed and replaced with suitable material. The thickness removed may typically be between 0.5 and 1.0m and the new Design CBR should be assumed to be equivalent to 2.5%;
- A lime / cement stabilisation process could be utilised to increase the CBR value of the near surface subgrade, enabling proposed pavement areas, temporary access roads and working platforms to be designed based on an improved CBR value (design value in excess of say 2.5%). A specialist contractor should be asked to confirm suitability and the most appropriate method and technique;
- The incorporation of a geogrids/geosynthetic material may be assist in reducing capping layer thicknesses. However, it should be noted that excavating back through areas treated with geogrid, e.g. to install drainage or foundations, would result in damage to the geogrids which would then require repairing; and

- A land drainage system may be considered, together with a system of monitoring the improvement achieved.

During construction, the in-situ CBR value must be checked against the Design CBR value, to confirm design requirements are being met.

11.2.5 Floor Slabs

it is recommended that suspended floor slabs be adopted due to the anticipated low CBR value of the shallow subgrade and the depth and variability of the Made Ground recorded across the site.

The design of floor slabs should only be finalised when gas monitoring has been completed and assessed, as the recommendations of the gas monitoring report will influence the final choice of floor slab design. The above advice is provided for guidance only at this stage.

11.2.6 Groundwater / Stability of Excavations

Comments relating to the stability of excavations (i.e. trial pits) and groundwater seepages are included in the logs in Appendix B. No shallow groundwater has been recorded across the site, with localised deeper groundwater recorded at depths of between 5.8m and 6.5m bgl.

Based on observations made during fieldwork, shallow excavations (<1.2m) are unlikely to remain stable in the short term; as such trench support is likely to be required. Should previously unrecorded shallow groundwater be encountered, sump pumping should be sufficient to deal with any water ingress.

Consideration should be given to the re-use of arisings from foundation trenches / drainage runs etc. Where contamination has been encountered, it may be possible to reuse foundation arisings subject to risk assessment; however, certainty of use and volume should be confirmed in accordance with the requirements of CL:AIRE guidance.

In line with BS6031, all excavations should be examined daily by a competent person to ensure that they remain safe. Where the sides cannot be sloped back to a safe angle, as approved by a competent and experienced person, their continued stability should not be taken for granted. Vertical or steep faces should be provided with support unless instructed otherwise by a competent person.

11.2.7 Soakaway Drainage

Given the widespread deep Made Ground recorded across the site, soakaway drainage is not considered suitable for use at the site and an alternative drainage scheme will be required.

12. Conclusions and Risk Evaluation

12.1 Environmental

A ground investigation has been completed at the Site comprising a combination of boreholes, window sample probe holes and trial pits. The ground investigation was designed to provide sufficient information in support of the redevelopment proposals at the Site.

Following the implementation of the ground investigation, the contaminant linkages identified during the Preliminary Environmental Risk Assessment have been re-evaluated and reclassified in relation to the additional information obtained. The results of the reassessment are summarised in Table 12.

Overall, the risk rating for the Site is assessed as **Medium**, whereby without implementation of the recommendations in Section 13 complete contaminant linkages are present.

Where the recommendations are implemented, the contaminant linkages will be broken, and the Site's overall risk rating will be reduced to **Low**. In addition, the Site is unlikely to be capable of being classified as Contaminated Land under the Environmental Protection Act 1990, thus meeting the requirements of paragraphs 183 to 188 of the National Planning Policy Framework

12.2 Geotechnical

Foundations

Due to the depth of Made Ground recorded across the site and the increased loadings the apartment blocks are expected to exert, it is considered that piled foundations will be required.

It is recommended that the advice of a specialist piling contractor should be obtained to confirm the suitability of piling and the most appropriate pile type. However, based on the site investigation information, end bearing piles would key into the sandstone bedrock between approximately 21m and 26m bgl.

It is expected that the proposed three storey buildings will also require piled foundations due to the depth of Made Ground recorded across the site. It is anticipated that underlying Boulder Clay will have sufficient bearing capacity to support the smaller structures utilising skin friction piles.

Preliminary pile capacity calculations have been undertaken and are summarised in Section 11.2.3. The pile capacities presented should be used as guidance only and shall not be used as an indicator of the final capacity and design parameters of piled solutions at the Site.

Buried Concrete

The Design Sulphate (DS) and Aggressive Chemical Environment for Concrete (ACEC) classifications are considered to be:

- Concrete in contact with granular Made Ground: DS1 AC1;
- Concrete in contact with cohesive Made Ground: DS1 AC1;
- Concrete in contact with Boulder Clay: DS3 AC3;
- Concrete in contact with Sand (Glacial Till): DS1 AC1.

Earthworks

The results of compaction and PSD testing undertaken on samples of Made Ground and the underlying natural soils indicate that:

- Granular Made Ground could be recompacted to achieve >95% of MDD and <5% air voids;
- Boulder Clay could be recompacted to achieve >95% of MDD and <5% air voids;
- Underlying Sand (Glacial Till) could be recompacted to achieve >95% of MDD and <5% air voids.

The majority of the cohesive material underlying the site is classified as Class 2A (wet cohesive material), while the majority of the overlying granular Made Ground is classified as Class 6E (selected granular material).

Where made ground is to be reused as an engineered fill, it would be sensible to select granular fills only and subject them to a confirmatory testing regime where they were required to achieve a compaction specification as a structural fill.

Construction plant should be provided with an adequate working platform in line with the requirements of BRE report, "BR 470: Working Platforms for Tracked Plant". Again, further advice should be sought from the temporary works designer.

Pavements

The shallow subgrade is likely to exhibit very low CBR values (i.e. generally less than 2.5%). The near surface subgrade is not considered likely to support construction traffic without deteriorating rapidly.

During construction, the in-situ CBR value must be checked against the Design CBR value, to confirm design requirements are being met.

Floor Slabs

It is recommended that suspended floor slabs be adopted due to the anticipated low CBR value of the shallow subgrade and the depth and variability of the Made Ground recorded across the site.

The design of floor slabs should only be finalised when gas monitoring has been completed and assessed, as the recommendations of the gas monitoring report will influence the final choice of floor slab design. The above advice is provided for guidance only at this stage.

Excavations

Based on observations made during fieldwork, shallow excavations (<1.2m) are unlikely to remain stable in the short term; as such trench support is likely to be required. Should previously unrecorded shallow groundwater be encountered, sump pumping should be sufficient to deal with any water ingress.

Consideration should be given to the re-use of arisings from foundation trenches / drainage runs etc. Where contamination has been encountered, it may be possible to reuse foundation arisings subject to risk assessment; however, certainty of use and volume should be confirmed in accordance with the requirements of CL:AIRE guidance.

In line with BS6031, all excavations should be examined daily by a competent person to ensure that they remain safe. Where the sides cannot be sloped back to a safe angle, as approved by a competent and experienced person, their continued stability should not be taken for granted. Vertical or steep faces should be provided with support unless instructed otherwise by a competent person.

Soakaway Drainage

Given the widespread deep Made Ground recorded across the site, soakaway drainage is not considered suitable for use at the site and an alternative drainage scheme will be required.

Table 32: Final Conceptual Model

Source	Pathway	Receptor	Risk	Justification	Residual Risk
Human Health					
Arsenic, lead, TPH asbestos and PAHs	Dermal contact Direct Contact with soils Inhalation of dusts	Construction worker Residential end-users	Medium	A significant thickness of Made Ground was recorded at the Site. The laboratory testing has recorded significantly elevated concentrations of arsenic, lead, TPH and PAHs across the Made Ground. These contaminants pose a risk through direct contact with the underlying Made Ground and pose an unacceptable risk to the proposed end-users. Remediation will be necessary to mitigate the potential risk to the proposed end-uses. Large sections of the site comprise building footprints or hardstanding which will prevent contact with the underlying soils. In garden areas and areas of soft landscaping a suitable engineered cover system will be necessary to prevent contact with the underlying Made Ground.	Low
Cyanide(free), Benzene, naphthalene, mercury, 1,2,4-trimethylbenzene, 1,2,5-trimethylbenzene, 4-methylphenol, 2,4-trimethylphenol	Volatilisation / Accumulation, Vapour Inhalation	Construction Workers, Residential End Users	Medium	Significantly elevated concentrations of volatile contaminants have been recorded within the Made Ground at depths ranging between 1.0m and 6.50m. Remediation will be necessary at the Site to manage the risk to the proposed end-users. It is recommended that suitable vapour membranes are incorporated into the buildings and structures at the Site. The identified hydrocarbon compounds, may pose a risk to construction workers if they come into contact with impacted soil during further earthworks, however appropriate PPE/ Respiratory Protective Equipment (RPE) will ensure they are at no unacceptable risk.	Low
Asbestos Containing Materials (ACM) within Made Ground	Fibre / Dust Inhalation	Construction Workers Residential End Users Third Party Property		Buried suspected Asbestos tiles were recorded at two locations during the ground investigation. Asbestos fibres were recorded at 5No. locations following laboratory testing. A engineered cover system will be necessary to manage the risk to the proposed end-users from asbestos fibres within the site soils. ACM poses a risk through fibre and dust inhalation and if present may pose a risk to construction workers during any future earthworks / demolition and to adjacent third-party property should dust be generated during those works. These risks can be mitigated through the development of a detailed enabling works strategy following guidance and protocol specified within the Control of Asbestos Regulations (2012) and industry best practice as detailed in	

Source	Pathway	Receptor	Risk	Justification	Residual Risk
CIRIA733 (Asbestos in Soil and Made Ground: A guide to understanding risk).					
Hazardous Ground Gases					
Methane and Carbon Dioxide associated Made Ground	Inhalation Accumulation	Construction Workers Residential End Users	Low	The ground gas monitoring completed to date indicates the Site is likely to be designated as Characteristic Situation 1. However, this is a preliminary assessment based on 2No rounds of monitoring and will require updating on completion of the ground gas monitoring period.	Low
Controlled Waters					

Controlled Waters

TPH, naphthalene, 2-methylnaphthalene & 2,4-dimethylphenol	Vertical / Lateral Migration	River Irk Principal Aquifer	The presence of hydrocarbon compounds within the groundwater is consistent with the former uses at the Site. The direction of movement of the groundwater within the Made Ground is to the east and north, with the concentration of the contaminants reducing towards the northern boundary. The limited nature of the groundwater and the inconsistent presence on site, together with the distance to the River Irk, indicates a Low risk. The Principal Aquifer within the underlying bedrock geology is considered a potential receptor, however, given the absence of any potable groundwater abstractions within close proximity to the site and the presence of substantial thicknesses of impermeable clays beneath the site the overall sensitivity of this receptor is reduced to Low.
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13. Recommendations

The following actions are recommended to address the potentially unacceptable risks that remain:

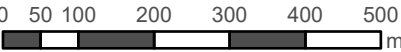
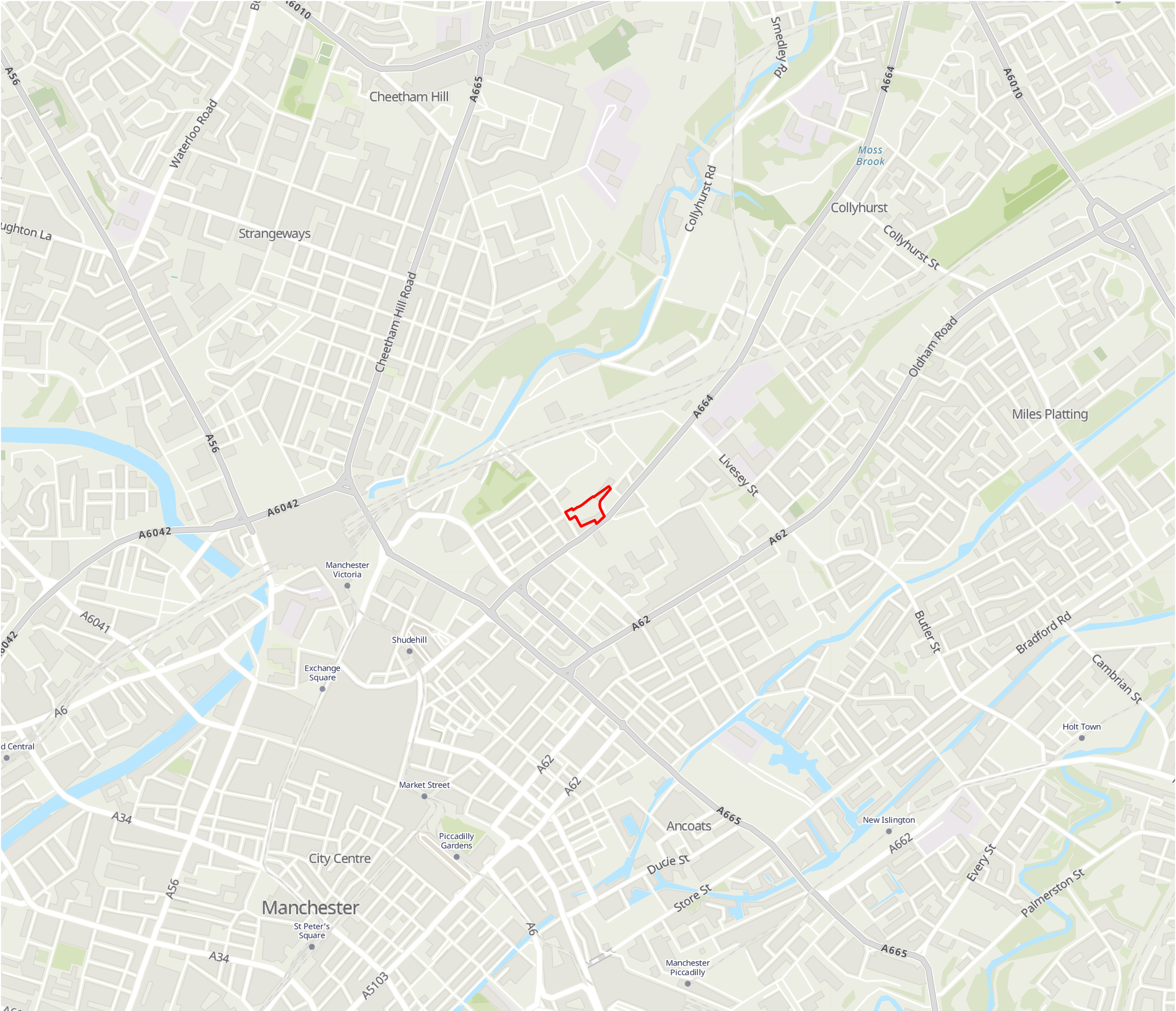
- An unacceptable risk is considered to exist at the Site with regard to volatile contaminants. It is recommended that a suitable vapour membrane is included in the buildings and structures at the Site to mitigate against this risk;
- Significantly elevated concentrations of contaminants are recorded in the Made Ground, which requires suitable measures to manage the risk to the end-users. A suitably engineered capping layer will be required in all garden and soft landscaping areas;
- The ground investigation recorded significant in ground obstructions and buried known and unknown voids across the majority of the Site. Further investigations of these features is recommended to inform further design;
- The presence of the hydrocarbon impacted groundwater indicates a potential remains for further soil contamination not recorded during this ground investigation. A Watching Brief should be completed by a Environmental Engineer during Enabling and Earthworks;
- The ground gas risk assessment should be updated following completion of the ground gas monitoring period and the conclusions of this report reviewed accordingly;
- A Remediation Strategy should be prepared for the Site to outline the procedures required to manage risks to the end-users from the Made Ground soils;
- A Materials Management Plan should be produced by contractors to ensure that materials that may be excavated during their works (including pile arisings) may be suitable for re-use on the Site. The re-use of materials should be identified and designated under the CL:AIRE Definition of Waste: Code of Practice (DoWCoP), i.e. the earthworks phase of the development should be planned and managed such that re-use of suitable site-won arisings is maximised and waste is minimised;
- An Asbestos Risk Management and Discovery Plan should be prepared by contractors to include methods and measures for managing asbestos in soils during the demolition and earthworks;
- An Environmental Management Plan (EMP) should be prepared including measures for managing waste, control run-off during earthworks, suppressing dust and asbestos fibres etc;
- The conclusions of this report should be subject to review and approval by Manchester City Council;
- Barrier pipes will provide sufficient protection for potable water supply pipes in all brownfield conditions. The requirement for water barrier pipes should be confirmed with the local water provider;
- Buried concrete should be designed in accordance with the recommendations provided in this report;
- Topsoil, Subsoil and any Engineered Fill imported for use at the Site should be certified as suitable for use. Samples of imported soils should be taken and scheduled for laboratory testing to verify certification. All supplier and verification chemical results should be collated by a contractor for inclusion in a Completion Report;
- Construction and Maintenance workers should undertake risk assessments and prepare method statements before commencing work and should be provided with and make use of appropriate Personal Protective Equipment (PPE). Appropriate hygiene facilities should also be provided on Site and it should be ensured that all future construction personnel have been provided with asbestos awareness training;
- Construction workers should avoid entering excavations. If entry cannot be avoided, a risk assessment should be undertaken with PPE and RPE used where appropriate, and in line with the Confined Space Entry Regulations 1997.

APPENDICES

Appendix A Site Plans

- Site Location Plan (Ref. WIE19453-100_GIS_GI_1A)
- Exploratory Hole Location Plan (Ref.19453-100-WIE-ZZ-XX-DR-V-80-001/P05)
- Geological Cross Sections (Ref 19453-100-WIE-ZZ-XX-DR-V-80-002/P01 & 003/P01)
- Soil Exceedances Plan (Ref. 19453-100-WIE-ZZ-XX-DR-V-80-004/P01)
- Soil Exceedances Plan with Proposed Building footprint (Ref. 19453-100-WIE-ZZ-XX-DR-V-80-005/P01)
- Groundwater Exceedances Plan (Ref. 19453-100-WIE-ZZ-XX-DR-V-80-006/P01)
- General Arrangement Drawing PLANIT I.E (Ref. 2624-PLA-XX-XX-DR-L-0002/S1/P06)
- Jon Matthew Architects Elevation AA (Ref. 136-JMA-MP-S-E-A-042200/C)

Site Location



Project Details WIE19453-100: Rochdale Road

Figure Title Figure 1: Site Location Plan

Figure Ref WIE19453-100_GIS_GI_1A

Date November 2022

File Location \\waterman-consulting.com\legacyfile\MR_WIEL\Projects\WIE19453\100\9_GIS\WIE

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GENERAL NOTES

-  SITE BOUNDARY
-  WS101 WINDOW SAMPLE LOCATIONS
-  BH101 15-20M CABLE PERCUSSIVE BOREHOLES WITH FOLLOW ON 10M ROTARY CORING
-  TP111 TRIAL PITS TO ESTABLISH EXISTING FOUNDATION ARRANGEMENTS
-  HDP101 HAND DUG PIT LOCATIONS (POSITIONED ON SITE, NOT SURVEYED)
-  EXPLORATORY HOLE LOCATIONS WITHIN BUILDING WERE POSITIONED ONSITE, NOT SURVEYED

P05	SO	22.11.22	AS BUILT ISSUE	DC	RT
P04	SO	17.10.22	AS BUILT ISSUE	DC	RT
P03	SO	20.09.22	UPDATED TOPO	DC	RT
P02	SO	15.09.22	GI LOCATIONS UPDATED	MC	RT
P01	SO	09.09.22	PRELIMINARY ISSUE	MC	RT
Status	Date	Description		By	Chk

Amendments

Project

ROCHDALE ROAD

Title

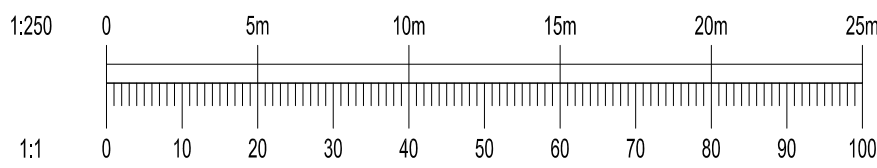
EXPLORATORY HOLE LOCATION PLAN

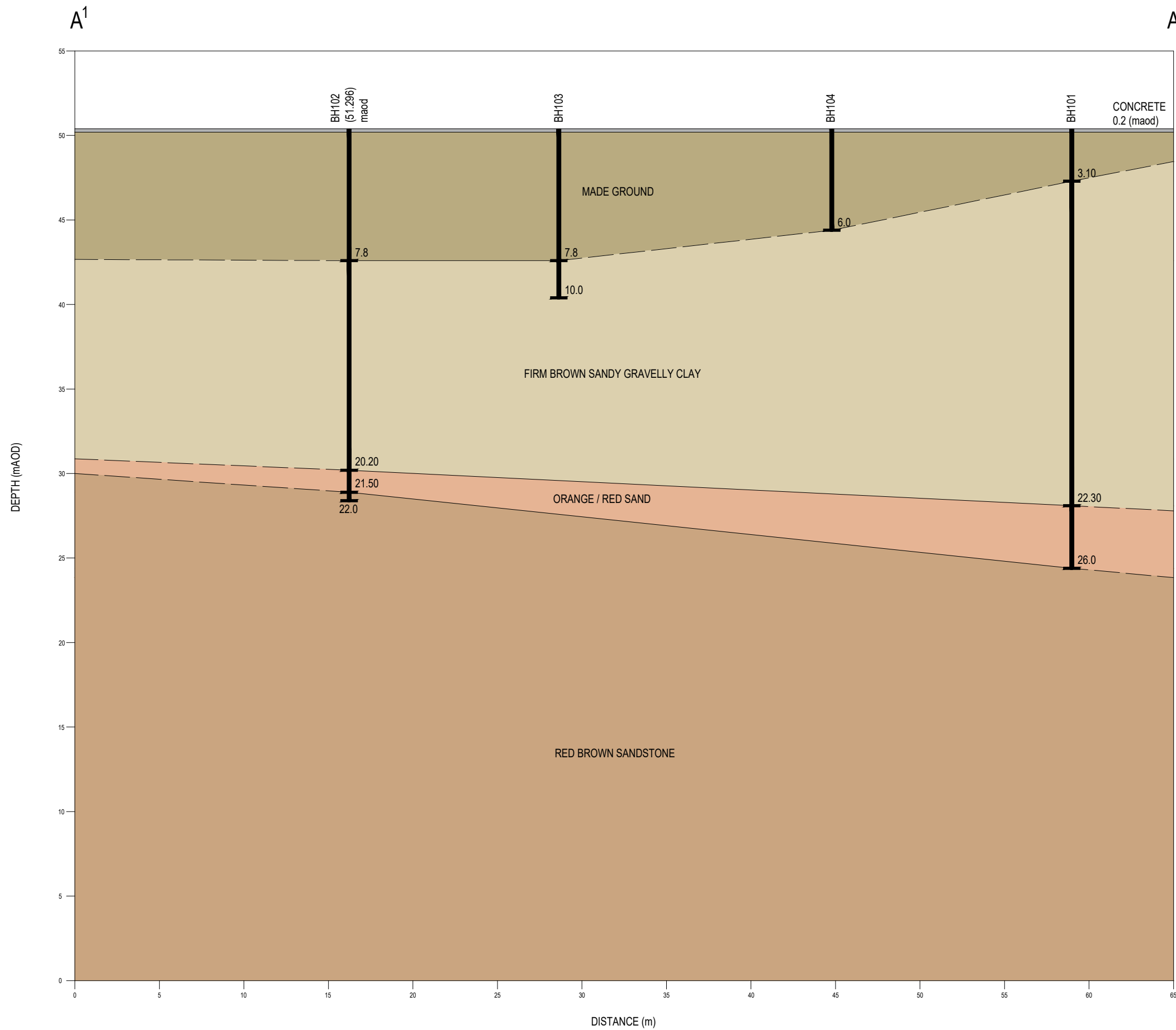
Client



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Status					
AS BUILT					
Designed By	RT	Director	RT	Waterman Ref	WIE19453-100
Drawn By	MC	Date	NOVEMBER 2022	Scales @ A1	1:250
Project - Originator - Volume - Level - Type - Role - Number					Revision
19453-100-WIE-ZZ-XX-DR-V-80-001					P05





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GENERAL NOTES

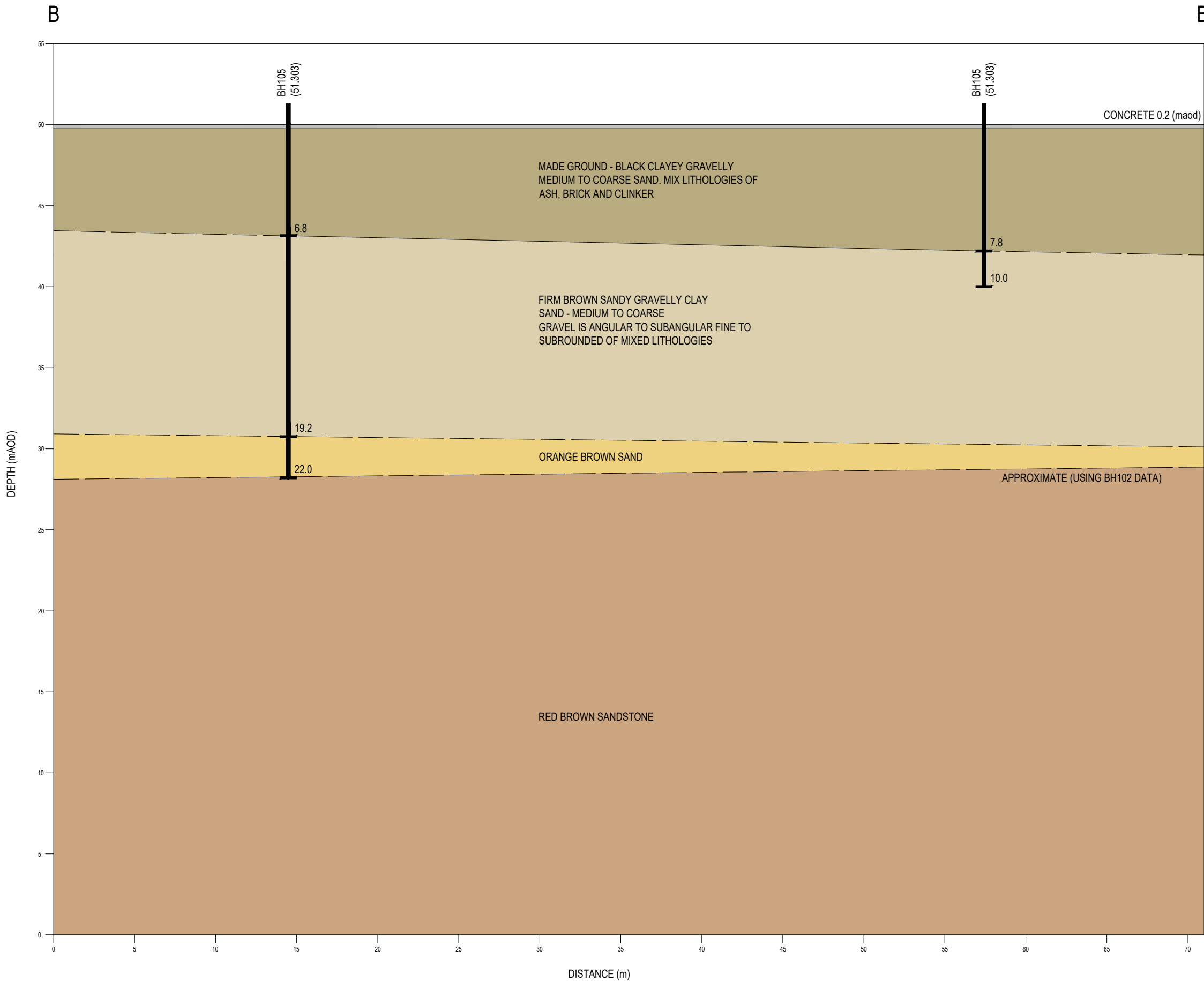
ROCHDALE ROAD



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PRELIMINARY

Designed By	RT	Director	19453- 100 WIE-ZZ-XX-DR-V-80-002	Waterman Ref
Drawn By	MC	Date	OCTOBER 2022	Scales @ A3 1:250
Project - Originator - Volume - Level - Type - Role - Number				Revision
19453-100-WIE-ZZ-XX-DR-V-80-002				P01



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GENERAL NOTES

P01	S0	21.10.22	PRELIMINARY ISSUE	MC	RT
Status	Date	Description		By	Chk

Amendments

Project

ROCHDALE ROAD

Title

CROSS SECTION B

Client



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PRELIMINARY

Designed By	RT	Director	19453-100-WIE-ZZ-XX-DR-V-80-002	Waterman Ref	19453-100-WIE-ZZ-XX-DR-V-80-002
Drawn By	MC	Date	OCTOBER 2022	Scales @ A3	1:250
Project - Originator - Volume - Level - Type - Role - Number					Revision
19453-100-WIE-ZZ-XX-DR-V-80-003					P01

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GENERAL NOTES

- SITE BOUNDARY
- ✱ WS101 WINDOW SAMPLE LOCATIONS
- ✱ BH101 15-20M CABLE PERCUSSIVE BOREHOLES WITH FOLLOW ON 10M ROTARY CORING
- ✱ TP111 TRIAL PITS TO ESTABLISH EXISTING FOUNDATION ARRANGEMENTS
- ✱ HDP101 HAND DUG PIT LOCATIONS (POSITIONED ON SITE, NOT SURVEYED)
- ▨ EXPLORATORY HOLE LOCATIONS WITHIN BUILDING WERE POSITIONED ONSITE, NOT SURVEYED
- SOIL EXCEEDANCES

TP113 @ 1.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Arsenic	40	79.9
Lead	310	3919
Mercury	1.2	13.4
Cyanide (free)	26	240.7
TPH Aromatic EC21-EC35	-	2952
Naphthalene	2.3	2.74
Benzo(b)fluoranthene	3.9	4.48
Dibenzo(ah)anthracene	0.31	0.55

TP109 @ 2.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Naphthalene	2.3	46.64
Benzo(a)anthracene	11	61.43
Benzo(b)fluoranthene	3.9	67.94
Benzo(a)pyrene	3.2	66.84
Dibenzo(ah)anthracene	0.31	10.97

HDP102 @ 0.6m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Naphthalene	2.3	4.141
Benzo(a)pyrene	3.2	6.347
Dibenzo(ah)anthracene	0.31	0.96

BH102 @ 3.8m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Benzo(b)fluoranthene	3.9	5.69
Benzo(a)pyrene	3.2	5.39
Dibenzo(ah)anthracene	0.31	0.78

BH102 @ 5.8m		
TPH Aromatic EC10-EC12	250	352
TPH Aromatic EC16-EC21	1900	6172
TPH Aromatic EC21-EC35	-	7296
Naphthalene	2.3	188.91
Benzo(a)anthracene	11	116.61
Chrysene	30	135.54
Benzo(b)fluoranthene	3.9	115.59
Benzo(a)pyrene	3.2	113.39
Dibenzo(ah)anthracene	0.31	16.7
1,2,4-Trimethylbenzene & 1,3,5-Trimethylbenzene*	0.41	4.24
1,2,4-Trimethylbenzene & 1,3,5-Trimethylbenzene*	0.41	0.63

BH102 @ 8.50m		
Naphthalene	2.3	8.5

BH103 @ 5.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Naphthalene	2.3	26.03
Benzo(a)anthracene	11	15
Benzo(b)fluoranthene	3.9	14.44
Benzo(a)pyrene	3.2	12.09
Dibenzo(ah)anthracene	0.31	2.4

BH103 @ 6.5m		
TPH Aromatic EC10-EC12	250	347.9
TPH Aromatic EC16-EC21	1900	2358
TPH Aromatic EC21-EC35	-	3047
Benzene	0.38	4.58
Naphthalene	2.3	323.1
Benzo(a)anthracene	11	28
Benzo(b)fluoranthene	3.9	30.59
Benzo(a)pyrene	3.2	24.59
Dibenzo(ah)anthracene	0.31	4.63
4-Methylphenol & 2,4-Trimethylphenol*	3.9	31.33
4-Methylphenol & 2,4-Trimethylphenol*	3.9	63.33
1,2,4-Trimethylbenzene & 1,3,5-Trimethylbenzene*	0.41	41.28
1,2,4-Trimethylbenzene & 1,3,5-Trimethylbenzene*	0.41	8.76

BH101 @ 0.5m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Dibenzo(ah)anthracene	0.31	1.55

TP108 @ 4.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Lead	310	395

TP114 @ 1.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Lead	310	360

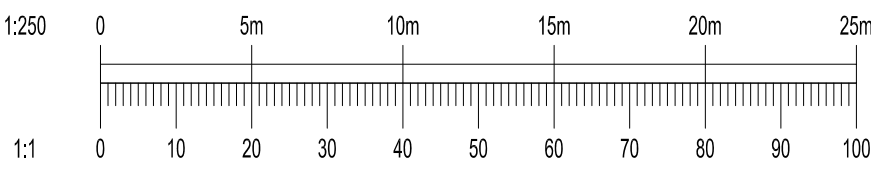
BH105 @ 7.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Chrysene	30	929
Benzo(b)fluoranthene	3.9	6.543

TP102 @ 2.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Lead	310	474
Dibenzo(ah)anthracene	0.31	0.44

TP115 @ 2.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Lead	310	721
Benzo(b)fluoranthene	3.9	5.35
Benzo(a)pyrene	3.2	4.43
Dibenzo(ah)anthracene	0.31	0.76

BH104 @ 1.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Naphthalene	2.3	19.67
Benzo(a)anthracene	11	12.64
Benzo(b)fluoranthene	3.9	11
Benzo(a)pyrene	3.2	10.09
Dibenzo(ah)anthracene	0.31	1.7

BH104 @ 5.0m		
Naphthalene	2.3	18.27
Dibenzo(ah)anthracene	0.31	0.41



P01	S0	22.11.22	AS BUILT ISSUE	DC	RT
Status	Date	Description	By	Chk	

Amendments					
Project					
ROCHDALE ROAD					
Title					
SOIL EXCEEDANCE PLAN					
Client					

					
6th Floor, Trinity Court, 16 John Dalton Street, Manchester, M2 6HY t 0161 839 8392 mail@watermangroup.com www.watermangroup.com					
Status					
AS BUILT					
Designed By	RT	Director	RT	Waterman Ref	WIE19453-100
Drawn By	DC	Date	NOVEMBER 2022	Scales @ A1	1:250
Project - Originator - Volume - Level - Type - Role - Number					Revision
19453-100-WIE-ZZ-XX-DR-V-80-004					P01

This drawing should not be scaled. Dimensions to be verified on site. Any discrepancies should be referred to the Engineer prior to work being put in hand.

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Pickfords Wharf, Clink Street, London SE1 5DG 1 020 7928 7888 1 03333 444 501

GENERAL NOTES

-  SITE BOUNDARY
-  WS101 WINDOW SAMPLE LOCATIONS
-  BH101 15-20M CABLE PERCUSSIVE BOREHOLES WITH FOLLOW ON 10M ROTARY CORING
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-  EXPLORATORY HOLE LOCATIONS WITHIN BUILDING WERE POSITIONED ONSITE, NOT SURVEYED
-  SOIL EXCEEDANCES
-  APPROXIMATE EXTENT OF PROPOSED BUILDING FOOTPRINT
-  APPROXIMATE EXTENT OF PROPOSED BASEMENT FOOTPRINT

TP113 @ 1.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
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Mercury	1.2	13.4
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Naphthalene	2.3	4.141
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BH103 @ 6.5m		
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TPH Aromatic EC21-EC35	-	3047
Benzene	0.38	4.58
Naphthalene	2.3	323.1
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1,2,4-Trimethylbenzene & 1,3,5-Trimethylbenzene*	0.41	41.28
1,2,4-Trimethylbenzene & 1,3,5-Trimethylbenzene*	0.41	8.76

BH101 @ 0.5m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Dbenzo(ah)anthracene	0.31	1.55

TP108 @ 4.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Lead	310	395

TP114 @ 1.0m		
Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
Lead	310	360

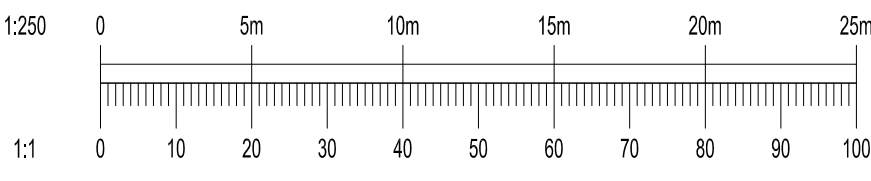
BH105 @ 7.0m		
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Contaminant	Threshold Value (mg/kg)	Concentration (mg/kg)
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Beno(a)anthracene	11	12.64
Benzo(b)fluoranthene	3.9	11
Benzo(a)pyrene	3.2	10.09
Dbenzo(ah)anthracene	0.31	1.7

BH104 @ 5.0m		
Naphthalene	2.3	18.27
Dbenzo(ah)anthracene	0.31	0.41



P01	S0	22.11.22	AS BUILT ISSUE	DC	RT
Status	Date	Description	By	Chk	

Amendments					
Project					
ROCHDALE ROAD					
Title					
SOIL EXCEEDANCES WITH PROPOSED BUILDING FOOTPRINT					
Client					

					
6th Floor, Trinity Court, 16 John Dalton Street, Manchester, M2 6HY t 0161 838 8392 mail@watermangroup.com www.watermangroup.com					
Status					
AS BUILT					
Designed By	RT	Director	RT	Waterman Ref	WIE19453-100
Drawn By	DC	Date	NOVEMBER 2022	Scales @ A1	1:250
Project - Originator - Volume - Level - Type - Role - Number					Revision
19453-100-WIE-ZZ-XX-DR-V-80-005					P01

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Pickfords Wharf, Clink Street, London SE1 5DG 1 020 7928 7888 1 03333 444 501

GENERAL NOTES

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-  HDP101 HAND DUG PIT LOCATIONS (POSITIONED ON SITE, NOT SURVEYED)
-  EXPLORATORY HOLE LOCATIONS WITHIN BUILDING WERE POSITIONED ONSITE, NOT SURVEYED
-  GROUNDWATER EXCEEDANCES

BH105		
Contaminant	Threshold Value (µg/l)	Max. Concentration (µg/l)
Nickel	4	8
2,4-Dimethylphenol	7.7	95
Naphthalene	2	62
2-Methylnaphthalene	2	25
TPH Aromatic EC10-EC12	N/A	245
TPH Aromatic EC12-EC16	N/A	580
TPH Aromatic EC16-EC21	N/A	410
TPH Aromatic EC21-EC35	N/A	480

BH103		
Contaminant	Threshold Value (µg/l)	Max. Concentration (µg/l)
Nickel	4	9
TPH Aromatic EC12-EC16	N/A	110
TPH Aromatic EC16-EC21	N/A	340
TPH Aromatic EC21-EC35	N/A	480

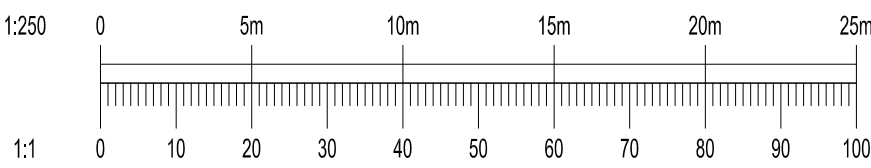
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Status	Date	Description	By	Chk

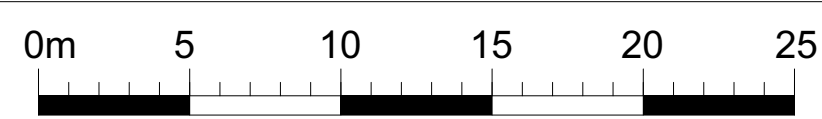
Amendments	
Project	ROCHDALE ROAD
Title	GROUNDWATER EXCEEDANCE PLAN
Client	



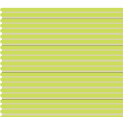
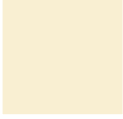
6th Floor Trinity Court 16 John Dalton Street Manchester M2 6HY
t 0161 839 8392
mail@watermangroup.com www.watermangroup.com

Status		AS BUILT	
Designed By	RT	Director	RT
Drawn By	DC	Date	NOVEMBER 2022
Project - Originator - Volume - Level - Type - Role - Number		Revision	
19453-100-WIE-ZZ-XX-DR-V-80-006		P01	

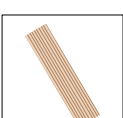
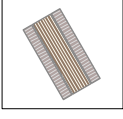
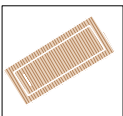
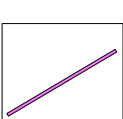
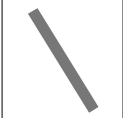
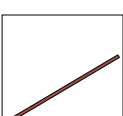
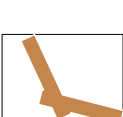
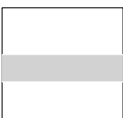
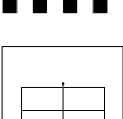
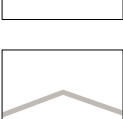
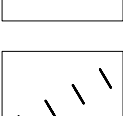
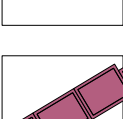




Key

- **Mulbury Planning Application Boundary**
- **Natural Stone Paving Mix 1**
To public realm & shared community space
Type: Portuguese granite
Colour: TBC
Finish: TBC
Supplier: Hardscape or similar approved
Note: allow for galvanised 3x150mm exccell edge
- **Clay Paving Mix 2**
To match adjacent MCR site (H3 material) pedestrian areas throughout the site.
Type: Clay Paving
Colour: Various to complement architectural material palette
Finish: TBC
Supplier: Hardscape or similar approved
Note: allow for galvanised 3x150mm exccell edge
- **Clay Paving Mix 3**
To private garden space
Type: Neland Clay Paving
Colour: TBC
Finish: TBC
Supplier: Hardscape or similar approved
Note: allow for galvanised 3x150mm exccell edge
- **Green gap concrete paving**
To Residential spaces
Type: Concrete
Colour: TBC
Finish: TBC
Supplier: Hardscape or similar approved
Note: allow for galvanised 3x150mm exccell edge
- **Granite Planks**
To Residential spaces
Type: Portuguese granite
Colour: TBC
Finish: TBC
Supplier: Hardscape or similar approved
- **Natural Stone Paving**
Type: Yorkstone
To match approved MCR site Gould street highway paving
Size, colour finish, to MCC standard detail
Note: allow for 125x255mm kerb edge

FURNITURE & STRUCTURES

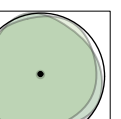
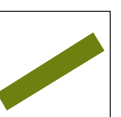
- **Seating Edge**
To Courtyards
Timber top corten frame
- **Picnic Table**
Timber top picnic table with powdercoated galvanised frame
- **Tiered Seating Feature**
Timber seating with integrated tree, details tbc
- **1.8m Rimini Galvanised Steel Fence**
details tbc
- **Retaining Structure**
Existing To Gould street & 87 Rochdale Road
- **1.1m Rimini Galvanised Steel Balustrade**
To private spaces, details tbc
- **Timber play feature**
To community shared spaces, details tbc
- **Proposed 1.1m wall with 500mm railing**
Brickwork finish to match building facade
- **1.5m Pillar Wall**
To courtyard edge
details tbc
- **Chess Board - Play**
To courtyard edge
- **Table tennis**
To courtyard edge
- **Planting Screen**
2.5m high Galvanised steel planting screen to courtyard
finish: tbc
- **Cycle Stands**
10no. Sheffield cycle stands to external spaces
- **Bin Store**
Controlled accessed 3 No. 1100L & 1no.240L bins to town house & duplex's

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- NOTES:
- Do not scale from this drawing.
 - Always work to noted dimensions.
 - All dimensions are in millimetres unless otherwise stated.
 - All setting out, levels and dimensions to be agreed on site.
 - The dimensions of all materials must be checked on site before being laid out.
 - This drawing must be read with the relevant specification clauses and detail drawings.
 - Order of construction and setting out to be agreed on site.

NOTE:
General Arrangement drawing to be read in conjunction with drawings:
2624-PLA-XX-XX-DR-L-1001
2624-PLA-XX-XX-DR-L-1002
2624-PLA-XX-XX-DR-L-2000
2624-PLA-XX-XX-DR-L-3000

SOFTWORKS

- **Trees**
A combination of single & multi-stem trees. Refer to drawing 2426-PLA-XX-XX-DR-L-2000 for specification.
- **Clipped Instant Hedge**
To private garden boundaries
Size: 800mmW x 1200mmH approx.
Refer to drawing 2426-PLA-XX-XX-DR-L-2000 for specification.
- **Ornamental Shrub and Herbaceous Planting**
Biodiversity rich planting.Refer to drawing 2426-PLA-XX-XX-DR-L-2000 for specification.
- **Marginal Ornamental Planting**
To swales / rain gardens Refer to drawing 2426-PLA-XX-XX-DR-L-2000 for specification.
- **Lawn**
Medallion turf
Supplier: Rolawn or similar approved
- **Planting Bed**
450mm high timber planter, planting to residential community choice

S1-P06	06-12-21	Bin storage and boundary update	AS	KR
S1-P05	11-11-21	Updated boundary	AS	KR
S1-P04	01-09-21	Planning Issue	AS	KR
S1-P03	02-08-21	Draft Planning	AS	KR
S1-P02	20-07-21	For information	AS	KR
S1-P01	27-05-21	For coordination	AS	KR

Revision	Date	Description	Drawn	Apprvd.
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T: 0151 363 1230
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Unit 6 Waterside, 44-48 Wharf Road, London, N1 7UX
T: 0207 253 5678
STANDISH
Standish Gatehouse, Stonehouse, Gloucestershire, GL10 3BZ
T: 0145 360 7080

Client **Portwood Development Ltd**

Project **87 Rochdale Road**

Drg Title **General Arrangement**

Created on	Created by	Approved by
02.08.21	AS	KR

Scale	Size	Workstage
1:250	A1	RIBA Stage 2

Drg No.	Suitability	Revision
2624-PLA-XX-XX-DR-L-0002	S1	P06