

LCRM: Intrusive Site Investigation

LAND OFF CHURCH LANE, MOSTON, GREATER MANCHESTER

Project Ref: GUK-0524-02

For: Built Developments Limited

CLIENT:
Built Developments Limited

PROJECT:
Residential Development

SITE REFERENCE:
**Land off Church Lane
Moston
Greater Manchester**

REPORT REFERENCE:
GUK-0524-02/Rp-002



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EXECUTIVE SUMMARY

This summary presents the salient points of the Report but should not be referred to in isolation of the body text. There will be other information contained within the Report which puts into context the findings of this summary. No reliance should therefore be placed on the summary until the Report has been read in full. The recommendations given are considered reasonable based on available information and the assessment of the Site as carried out by Groundsmiths (UK) Ltd at this time, although other interested parties may hold differing opinions.

1 ENVIRONMENTAL CONSTRAINTS

Radon: No radon precautions are indicated to be required in construction on the basis of available information.

General Soil Contamination: Elevated lead, PAH, and other contaminants of concern to above the residential with home-grown produce GAC has been measured within the made ground soils, although no particular elevated contaminant concentrations were identified within the underlying natural strata. These present a risk to Site end users.

Asbestos: Loose asbestos fibres were identified within some of the made ground soils. These present a risk to Site end users. Contamination could be derived from the former small garages that were once present, but may also be inherent to the made ground materials imported to Site.

Construction Workers: Other than for the made ground deposits, the on-Site ground conditions do not appear to present any particular risk to construction workers involved with the Site's redevelopment. However, all in-ground works should automatically be assessed and completed in accordance with current regulatory guidance.

Soil Remediation Requirements: Given the contaminated nature of the made ground, formal remediation to areas of proposed soft landscaping will be required to be protective of Site end users where these soils remain in areas of soft landscaping. A standalone LCRM Stage 3 Remedial Strategy detailing the installation and verification procedure to be followed will need to be issued to the Local Planning Authority. All remedial activities would need to be in accordance with the requirements of MCC guidance, including also where topsoil materials are to be imported.

Ground Gas and Remediation Requirements: Monitoring is ongoing, although a Characteristic Situation 2 determination in accordance with BS8485 is currently anticipated. The results of the monitoring and risk assessment will be issued under separate cover once complete, with any recommendation for mitigation being made at that time.

Controlled Waters Receptors: Risk from the off-site discharge of any leachable contaminants is considered to be very low. No further assessment is considered necessary.

Invasive Plant Species: Risk from invasive plant species has been identified. All further assessments and treatment will need to be completed prior to Site enabling and construction works taking place.

2 GEOTECHNICAL & GENERAL DEVELOPMENT CONSTRAINTS

Buried Concrete: Concrete to DS3/AC-2s is anticipated given the range of sulphate concentrations measured within the on-Site soils. This determination does not make any necessary allowance for the requirements of structural strength or durability so further consultation with the Designing Engineer should be made accordingly.

Anticipated Foundation Type: The foundations to be adopted will need to be based on the placement of dwellings in relation to the ground conditions encountered. On this basis, and with cognisance to the likely imposed loads and required settlement tolerances of the development, it is anticipated that dwellings located within the northern periphery of the Site (assuming natural undisturbed ground can be reached at normal founding depths) would likely be on traditional reinforced spread foundations, whilst for the remainder of the

Site (i.e. where the made ground thickens or is very deep) a piled foundation solution would need to be adopted. All further assessments should be completed as required, with compilation of a foundation schedule.

Anticipated Ground Floor Type: Suspended (e.g. beam and block) floors are anticipated at this time.

Heave Precautions: A worst case intermediate Volume Change Potential has been identified. All necessary precautions in construction will need to be provided where foundations lie within the influencing distance of existing, removed, or proposed planting and trees when in clay soils.

Retaining Structure: The need for retaining structures has not been identified.

Excavation: Preliminary excavation within the made ground to the infilled valley feature revealed side collapse and much general instability, with this being attributed to both the debris that is present within and the non-compacted nature of the soil. All excavations should be assumed to be unstable. Support should be provided as required.

Potable Water Supplies: Contamination within the made ground soils has been identified on a Site-wide basis. With the Site being determined as brownfield, and some organic contaminant concentrations being in excess of UKWIR threshold levels, it is considered that measures compliant with BS8588:2017 (e.g. Protecta-Line) will be required in development.

Slopes: Global slope stability problems are not expected, although due consideration will need to be given to the south-eastern boundary of the Site, the made ground, and how these interact with the proposed development.

General Ground Stability: The general instability of the underlying soils should be anticipated, particularly during prolonged periods of wet weather and/or where excavations are deep, or are left open for protracted periods of time. Where there is the possibility of weak/unstable ground being present or passing across any boundary, a geotechnical risk assessment of the integrity/stability should be undertaken prior to works being carried out. Designed and engineered temporary or permanent measures should be deployed to ensure their continued stability, as required.

Groundwater: No significant groundwater was encountered during the investigation. The large-scale dewatering of excavations is not anticipated, although all necessary equipment should be made available should differing groundwater conditions be encountered during construction.

Surface Water Drainage: Given that the Site is underlain by unstable and contaminated made ground, with stiff natural soils beneath that have negligible infiltration potential, it is anticipated that a piped drainage connection to an existing sewer will be needed. Further consultation with a specialist drainage consultant should be made. All drainage proposals will be subject to obtaining the necessary approvals from the Regulatory Authorities.

Pavement: Within the northern part, where the underlying natural strata is present at relatively shallow depth, it is anticipated for usual road construction methods to be deployed. At this time, however, it is recommended that a conservative design CBR value of 2.5% (perhaps less) should be assumed until Site-specific testing has been carried out. Where the made ground thickens and/or is deep and will remain beneath the pavement alignment, ground improvement will be required to facilitate construction as the soils are very poor, soft, and would be expected to settle in a differential manner under load. A high degree of excavation, sorting, reworking, and compaction is anticipated. Furthermore, it would be considered prudent to implement a polymeric geogrid (and potentially the introduction of asphalt reinforcement) within the makeup of the pavement to improve its load carrying capacity.

3 MINING LEGACY CONSTRAINTS

Risk from shallow coal mining is not expected on the basis of information obtained from the Coal Authority.

1 INTRODUCTION

1.1 Appointment

Groundsmiths (UK) Ltd ('Groundsmiths') were appointed by Built Developments Limited (the 'Client') to provide professional services in relation to the geotechnical and geo-environmental characterisation of land located off Church Lane, Moston, Greater Manchester (herein referred to as the 'Site').

Groundsmiths have prepared this report (the 'Report') for the sole use of the Client that commissioned it in accordance with the agreement under which our services are performed. No other warranty, expressed or implied, is made as to the professional advice included in this Report. Any unauthorised third parties using the information presented in this Report do so entirely at their own risk and are duly excluded from any warranty, duty of care or skill.

No part of this Report shall be reproduced or redistributed without the prior written consent of Groundsmiths. However, the Report may be issued by the Client or their Agent to the Local Planning Authority (the 'LPA') to support the discharge of any pre-commencement or other such pre-occupancy planning condition as may be imposed in relation to the Site's assessment under the Town and Country Planning Act 1990.

1.2 General Objectives

The aim of this Report is to present the findings of an intrusive ground investigation carried out to support the Client's intentions to redevelop of the Site. It follows on from previously submitted preliminary risk assessment ^[1] and therefore seeks to update the Conceptual Site Model (the 'CSM') on the basis of Site-specific data obtained with respect to the general properties of the underlying soils and their environmental status (considering the presence, extent, and nature of any contamination encountered and the potential impact this may have on sensitive receptors). Furthermore, the Report aims to identify where any additional Site-based works, risk assessment, and/or remediation is considered necessary to facilitate development within the framework of a generic residential with home-grown produce exposure scenario as defined by the Environment Agency ^[2].

1.3 Limitations of Study

This Report has been compiled subject to the limitations detailed in Section 9 and any other limitations stated specifically in the text.

Interpretation and recommendations given in this Report should not be assumed valid for adjacent areas of land, or for alternate land use. Should the proposed Site usage change, the recommendations and conclusions presented in this Report will need to be re-assessed in accordance with all current guidance.

All works presented herein have been completed in general accordance with the requirements of BS 10175:2011+A2:2017 ^[3], BS 5930:2015+A1:2020 ^[4] and Stage 1 of the Land Contamination Risk Management ('LCRM') guidance ^[5] (Note that CLR11 was withdrawn on the 8th October, 2020). Where further works are identified, these shall be completed within the framework of LCRM ^[6,7], any other current guidance, and/or specific regulatory requirements.

2 SUMMARY CONCEPTUAL SITE MODEL

2.1 General Details

Table 2.1, below, summarises the Site's general setting and is taken from the preliminary risk assessment report.

Table 2.1 - General Site Details

National Grid Reference	The National Grid Reference (NGR) for the Site was indicated to be 386358mE 401397mN (approximate centre).
Area of Development	Approximately 0.98 ha.
Topography	Topographic data indicated that the Site lies broadly at an elevation of between 72.5 to 73.0m AOD.
Boundary Development	The Site is positioned between Church Lane and Moss Brook Road within a predominantly residential area. Given the irregular shape to the Site, boundary conditions vary, but generally the Site was observed to be bounded by residential property. A children's daycare nursery is also present towards the north-eastern boundary, and a dog's rehoming charity is located to the south. To the south-east is an area of open wooded ground that lies within a valley.
Invasive Species	There is evidence of numerous Japanese Knotweed stands within the boundaries to the Site. Further assessment and treatment in accordance with current guidance will need to be undertaken in consultation with a specialist ecologist/contractor given the risk this poses to development. Remedial works in this regard will need to be completed prior to any other construction taking place.

2.2 Anticipated Ground Conditions & Other Considerations

A summary of the pertinent ground conditions thought likely to be encountered at the Site, in addition to salient published environmental data that could affect the Site, is given in Tables 2.2 and 2.3, below and overleaf.

Table 2.2 - Geology and Hydrogeology

Radon	Third party data indicated that <1% of properties exceed the Radon Action Level in the area. No radon protective measures were indicated to be required in construction on this basis, although this should be confirmed with Building Control as they may have different requirements.
Recorded bedrock Faults & other Linear Features	The inferred position of a normal geological fault is mapped as crossing centrally through the Site in a broadly north-west south-east direction.

Table Contd./

Infilled or Made Ground Deposits	Third party information did not record any artificial deposits within the boundary to the Site.
Superficial Geology	Data obtained from the BGS stated that the Site is underlain by glacial till (Diamicton). Such deposits are typically poorly sorted sediments with a wide range of clast sizes from clay to boulders, often suspended within a matrix of mud and/or sand. Their composition may include rudaceous, arenaceous, and/or argillaceous materials.
Solid Geology	The solid geology underlying the Site to the north of the indicated fault line was mapped as being deposits of the Manchester Marls Formation, whilst to the south the bedrock was identified as being sandstone of the Collyhurst Sandstone Formation. For a full description of these soils, reference should be made to the preliminary risk assessment.
Groundwater	On the basis of the Site's setting and indicated geology, shallow-depth groundwater was anticipated within the made ground and superficial deposits.
Coal	Salient information obtained from the Coal Authority indicated that there were no records of past underground mining within the zone of likely physical influence, no probable unrecorded shallow workings at <30m below ground level, no mine entries within 100m, no on-Site coal outcrops, or any records of coal mining subsidence.
Natural Cavities	There are no recorded natural cavities within at least 500m.
Mining Cavities	There are no recorded mining cavities within at least 1km.
Non-coal Mining	There are no records of non-coal mining within at least 1km.
Natural Ground Subsidence (within 50m)	There was a 'Very Low' reported risk rating for shrink swell clay soils, running sands, collapsible deposits, and landslides hazards, and a 'Negligible' risk rating for compressible deposits and the ground dissolution of soluble rocks hazards.
Mass Movement Deposits	Information reviewed at the preliminary risk assessment stage indicated that there were no records of mass movement deposits within 500m of the Site, whilst the hazard rating for slope instability (landslide potential) within 50m was very low. Furthermore, the available data indicated that there were no records of landslip permeability (i.e. the estimated rate of vertical movement of water from the ground surface through the unsaturated zone of any landslip deposit) within 50m.
UXO	Information obtained from Zetica (Appendix A) suggested that the Site lies within a low risk zone for Unexploded Ordnance.

Table 2.3 - Environmental Data

Landfill

Records indicated the presence of former landfill activity within 250m of the Site at the following locations:

- Operated by Manchester City Council. Inert, industrial, commercial, household, special and liquid waste site at Moston Brook, Northampton Road, Harpurhey. Dated 1974-1977, from 103m south, and
- Operator unknown. Ground workings and refuse heap. Address unknown. Dated 1979, from 217m south.

2.3 Plausible Source-Pathway-Receptor Linkages for Contamination

Current UK legislation on contaminated land is set out in Part 2A of the Environmental Protection Act 1990 ^[8], which was retrospectively inserted by Section 57 of the Environment Act 1995 ^[9]. The Contaminated Land Regulations 2000 ^[10] were amended in 2005. The Environmental Protection Act 1990: Part 2A Contaminated Land, Statutory Guidance, Edition 2 (2006) promulgates the revised statutory guidance with respect to the operation of the Contaminated Land Regime following the implementation of the Contaminated Land Regulations, 2005. The definition of contaminated land is central to the operation of Part 2A. Legislation adopts the principle of a 'suitable for use' approach for the assessment of contaminated land, the rationale reflected in the site-specific risk assessment and determination of remedial strategy. Action is only required if unacceptable risks are posed to human health or to the environment, taking into account the current land use and geo-environmental setting. The legislation places a responsibility on the Local Planning Authority to determine whether the land under its jurisdiction is contaminated by consideration of whether:

- The presence of substances (potential contaminants) are present at concentrations that are causing significant harm or have the significant possibility of causing significant harm;
- There are receptors which may be harmed (e.g. the water environment, human health, buildings, fauna and flora), and/or
- There is in existence a pathway between the identified sources and receptors.

To qualitatively assess the level of risk at the Site from soil and/or any waterborne contamination the above rationale was applied. This approach is consistent with the preliminary risk assessment procedure defined in LCRM. The following section summarises Groundsmiths' understanding of the surface and sub-surface features at the Site, the potential sources of contamination, transport pathways and receptors in order to support the identification and assessment of plausible potential contaminant linkages that needed to be investigated.

Sources

A potential source is defined as 'a contaminant which is in, or under the land and has the potential to cause harm to human health or to cause contamination of controlled waters'.

In reviewing the Site's general history, it was indicated on the first edition OS plans dating back to 1848 that it comprised a mixture of open field and semi-wooded valley with two surface water features running through it. Subsequent development occurred within parts of the Site, with this consisting of two residential properties (Brook Villas and The Glen) and their associated grounds. The presence of ground surface alteration with some embankments was mapped within parts of the Site up to the 1930s, and again from c.1950; in addition to this, some refuse tipping was noted.

Subsequent construction for some garaging occurred at a later date within the northern part of the Site, but with the largest overall change appearing to be in the mid to late 1970's. At this time, it was noted that large-scale infilling of the 'valley' occurred (although details are very limited to non-existent), resulting in a relatively flat and level area. More recent OS mapping from c.2003 showed the Site to have been cleared, and for it to be in use for the keeping and riding of horses; a manège, some stabling, and paddock areas were created for this purpose. Planning information from c.2018/2019 suggested that an apartment unit was to be built on-Site, with this triggering some limited clearance works at the time. This development never materialised, however. Recent walkover at the preliminary risk assessment stage indicated that most of the equine infrastructure remains in place, albeit in a derelict condition, and for much self-seeded vegetation (and invasive plant species) to have taken hold.

Locally to the northern part of the Site was identified a transformer, with this being within a brick-built housing. It was noted, however, that it was 8-9m from the Site's boundary and has sensitive land use immediately adjacent to it (providing a buffer). It was considered that it presented only a low risk to development and that soils testing for PCBs would only be necessary if unforeseen gross contamination associated with it was encountered during development; it is listed in the tables below, but not carried through to ground investigation.

On the basis of the Site's setting and the unknown origin of the anthropogenic materials to be encountered, it was considered that contamination (including asbestos materials associated with the small garages) could be present with concentrations being at levels above allowable GAC threshold values for the Site's intended end use. Within the context of the CSM therefore, the following potential sources and contaminants that were thought likely to be associated with the Site are summarised in Table 2.4, below and overleaf (a revised assessment of the CSM is given in Section 6, below, with that being based on the outcome of Site-specific investigation and analytical testing undertaken).

Table 2.4 - Summary of Potential Sources and Contaminants

Potential Sources	Potential Contaminants of Concern (not limited to)
Potentially contaminated made ground and/or shallow underlying natural strata	Metals, metalloids, inorganic contaminants, phytotoxic contaminants, sulphate, PAHs (e.g. Benzo(a)pyrene), TPH, Monoaromatics, VOC, SVOC, and asbestos
Former development where garages were once present	Asbestos containing materials (profiled sheeting)

Table Contd./

Potential Sources	Potential Contaminants of Concern (not limited to)
Substation to the east of the Site	PCB's
Sources of ground gas (e.g. deep made ground, on- and off-Site refuse tipping)	CO ₂ and CH ₄

Migration Pathways

Migration pathways are routes by which contaminant sources may come into contact with receptors. Potential pathways for different types of contaminants vary depending on the properties of the contaminant, the mechanism of its release and the nature of the receptor. The principal potential contaminant pathways by which sensitive receptors were anticipated to become exposed to potential contamination at the Site are summarised in Table 2.5, below.

Table 2.5 - Summary of Plausible Migration Pathways

Potential Sources	Potential Pathways
Potentially contaminated made ground and/or shallow underlying natural strata, off-site substation, and previous area of garages	Direct ingestion, dermal contact, dust, fibres, and/or vapour inhalation
	Direct ingestion and/or dermal contact with liquid contaminants
	Leaching and direct contact with potable water supply pipes
	Leachable contaminants via surface run-off, vertical and lateral migration via any permeable strata with the potential to impact controlled waters receptors
	Soft landscaping (to garden curtilage and public open spaces)
Sources of ground gas (e.g. deep made ground, on- and off-Site refuse tipping)	Migration of gases and/or accumulation in void spaces via transport through service conduit, any permeable made ground and/or any permeable underlying natural strata

Receptors

A receptor is the potential target of the source contaminant, to which either significant harm or deterioration in quality may be caused. The potential sensitive receptors with respect to the potential contamination hazards identified above are considered in Table 2.6, below.

Table 2.6 - Summary of Potential Sensitive Receptors

Potential Receptor	Comment
Human Health	Site end-users in the residential with home-grown produce end use scenario (this being the primary risk scenario for Site end users) and where any public open spaces are proposed

Table Contd./

Potential Receptor	Comment
Human Health (Contd./)	Site operatives (during construction phase only) Future operatives involved with any in-ground works
Construction	Potable water supply pipes Foundations and service conduit
Controlled Waters	'Secondary Undifferentiated and 'Principal' aquifer soils

Environmental Risk Assessment

Risk assessment and the procedure of identifying sources, pathways, and receptors is recognised as an approach to determine the extent and significance of contamination either within the context of Part 2A (when assessing current site status or when considering the acquisition of an existing development) or the planning process (for the redevelopment of an existing site, or when considering the acquisition of a site for redevelopment purposes). Either way, the 'suitable for use' approach is adopted when assessing risk and the source-pathway-receptor assessment defines the conceptual model for the site. The statutory guidance describes a risk assessment methodology in terms of 'significant contaminants' and 'contaminant linkages', using the 'source-pathway-receptor' scenarios for the site. Contaminant linkages are formed when there is a linkage between a contaminant source and a receptor by means of a pathway. The existence of a contaminant linkage is dependent on-site use, as well as environmental conditions. If no contaminant linkages can be proven, then the risks may be discounted. However, it is not to say that remediation is required even if contamination is proven.

The identified potential contaminants and receptors for the Site were considered in relation to the pathways that may link them. The risk classification was estimated in accordance with those methods prescribed by Rudland et al (2001) ^[11]. Risk is regarded as a combination of the likelihood of an 'event' occurring and its severity: both elements must be considered when assessing risk. The method for risk assessment, or evaluation, is purely qualitative. As defined in CIRIA C552 (Tables 6.3 and 6.4), the magnitude of the potential 'severity' of risk occurring may be assessed against:

- **Severe (acute):** short term risk to human health likely to result in significant harm as defined under Environmental Protection Act 1990, Part 2A. Short term risk of pollution to sensitive water receptor (may result in death).
- **Medium (chronic):** long term risk and significant harm to human health, contamination of sensitive water resource or significant change to an ecosystem or specific organism (may result in death).
- **Mild (chronic, but applicable to less sensitive receptors):** contamination of non-sensitive water resource but significant damage to crops, buildings, structures and services or the environment.
- **Minor (not significant):** harm, which may result in financial loss, or expenditure to resolve. Non-permanent effects to human health. Easily repairable effects of damage to

buildings, structures and services.

Similarly, the classification of the magnitude of the 'probability' of the risk occurring may be assessed against:

- **High Likelihood:** a contaminant linkage exists and an event appears very likely in the short term, or almost inevitable in the long term, or contamination is causing harm at the receptor. Urgent action is required.
- **Likely:** a contaminant linkage exists and it is probable that an event will occur. An event may not occur, but it is possible in the short term and likely over the long term.
- **Low Likelihood:** a contaminant linkage exists and it is possible that an event will occur. It is not certain that an event will occur over time, but it is less likely in the short term.
- **Unlikely:** a contaminant linkage exists but it is not possible to say if an event will occur even over a very long time.

Following completion of the severity and probability assessment, classifications can be compared to indicate the actual risk each contaminant linkage presents: this can only be undertaken where there is a possibility of there being an active linkage. The risk categories which can be assigned are presented in Table 2.7, below, and range between 'very high' to 'very low' (NB - it is not possible to classify an identified risk as 'no-risk').

Table 2.7 - Risk Categorisation

		Consequence			
		Severe	Medium	Mild	Minor
Probability	Highly Likely	Very High	High	Moderate	Moderate / Low
	Likely	High	Moderate	Moderate / Low	Low
	Low Likelihood	Moderate	Moderate / Low	Low	Very Low
	Unlikely	Moderate / Low	Low	Very Low	Very Low

Source: Table 6.5, C552 (2001).

- **Very High** – there is a high probability that severe harm could arise or that severe harm is occurring. Urgent investigation and remediation are likely to be required.
- **High** – harm is likely to occur, and that urgent investigation and remediation may be needed in the short term, but are likely over the longer term.
- **Moderate** – harm could occur. It is unlikely to be severe, most probably relatively mild. Investigation is normally required to clarify the risk with some remedial works being required in the longer term.
- **Low** – it is possible that harm could occur, but if it did, at worst it would be mild.
- **Very Low** – low possibility of harm arising, and that if it does it is not likely to be severe.

The identified potential contaminants and receptors for the Site were considered in relation to the potential pathways that may link them; the resultant contaminant linkages as identified at the preliminary risk assessment stage are summarised in Table 2.8, below and overleaf.

Table 2.8 - Summary of Environmental Risk (Current Site Condition without Mitigation)

Potential Sources	Potential Receptors	Plausible Pathways	Probability	Severity	Risk Rating
Potentially contaminated made ground and/or shallow-underlying natural strata, off-site substation, and previous area of garages	<u>Human Health</u> Site end-users, inc. maintenance and site workers (short term risk during redevelopment)	Direct ingestion, dermal contact with soil or inhalation of dust and/or vapour (Site end user)	Likely	Mild	Moderate / Low
		Inhalation of asbestos fibres in made ground soils (Site end user)	Likely	Severe	High
		Direct ingestion, dermal contact with soil or inhalation of dust and/or vapour from any substation-derived contamination (Site end user)	Unlikely	Medium	Low
		Direct ingestion, dermal contact with soil or inhalation of dust and/or vapour (In-ground worker)	Likely	Mild	Moderate / Low
		Inhalation of asbestos fibres in made ground soils (In-ground worker)	Likely	Severe	High
		Direct ingestion, dermal contact with soil or inhalation of dust and/or vapour from any substation-derived contamination (In-ground worker)	Unlikely	Medium	Low
		Direct ingestion and/or dermal contact with liquid contaminants (Site end user / In-ground worker)	Unlikely	Mild	Very Low
	Potable Water Supply Pipes	Direct contact/leaching (tainting)	Likely	Mild	Moderate / Low
	Vegetation	Uptake via root system in soft landscaping	Likely	Mild	Moderate / Low
	Foundations	Direct contact/leaching	Likely	Mild	Moderate / Low
	Controlled Waters	Vertical and/or lateral migration	Unlikely	Mild	Very Low
Ground gas sources	Site End Users	Inhalation (via ingress and accumulation into buildings)	Likely	Medium	Moderate

3 INTRUSIVE SITE INVESTIGATION

3.1 Rationale

The overall objectives of the investigation were to assess and characterise the nature of the ground conditions underlying the accessible parts of the Site to quantify the identified geotechnical and environmental risks postulated in the preliminary CSM. This was based on the anticipated condition of the underlying soils and the anticipated levels of potential contaminants of concern in relation to the identified plausible source-pathway-receptor linkages.

3.2 Objectives

The specific objectives of the investigation were to:

- Investigate the general nature and thickness of the made ground and the depth to, condition, and nature of the underlying natural strata to facilitate foundation design.
- Determine the geotechnical parameters of the underlying natural strata via in situ testing (to refusal) and laboratory based analysis, as required.
- Report the presence of any buried obstructions and/or other excavation difficulties encountered during the works.
- Investigate the shallow-depth hydrogeological regime beneath the Site.
- Identify the nature and concentration of any contamination (including asbestos associated with former garaging) within individual soil matrices, including sulphate analysis to assist with buried concrete design, and undertake Waste Acceptance Criteria testing for soils disposal purposes. Risk to development from the off-Site substation was not identified past the LCRM: Stage 1 Risk Assessment stage.
- Investigate the general level of risk associated with any on- and off-Site fugitive ground gases, and
- Provide general advice in relation to any environmental or geotechnical issues associated with the Site and/or any other recommendations needed to facilitate the proposed development, including, where necessary, identifying any additional phases of investigation, assessment, or remediation that may need to be carried out.

3.3 Scope of Investigation

The scope of works completed at this time is summarised in Table 3.1, overleaf, whilst the locations of the exploratory holes are shown on the appended investigation locations plan, Ref. 0524-02-001.

Table 3.1 - Summary of Site-Specific Ground Investigation Works

Element of Work	Date Completed	Investigation Position Reference	No. of Positions	Maximum Recorded Depth (m bgl)	Installations	Rationale
Percussive boring with in-situ SPT	4 th October 2024	BH1 – BH8	8	6.0	GW1 – GW4	To provide general geotechnical and environmental coverage for foundation design and any remediation
Dynamic Probing	30 th September – 1 st October 2024	DP1 – DP6	6	14.0	-	
Cable Percussive Boring with in-situ SPT	30 th September – 9 th October 2024	CP1 – CP6	6	22.6	-	

Intrusive fieldwork was undertaken in general accordance with the requirements of BS 5930:2015+A1:2020, BS 10175:2011+A2:2017, BS EN 1997-1:2004+A1:2013 ^[12] and BS EN 1997-2:2007 ^[13].

Strata descriptions of the soils encountered are in general compliance with BS EN ISO 14688-1:2002+A1:2013 ^[14], BS EN ISO 14688-2:2004+A1:2014 ^[15] and BS EN ISO 14689:2003 ^[16]. The individual strata depths and reduced levels recorded on the investigation logs are those from existing ground elevations. All survey data is based on that supplied by Groundtech Surveys Ltd.

3.4 Testing

Environmental

Environmental sampling was undertaken for the purposes of collecting representative samples of the on-Site soils for laboratory analysis. The intention of the testing was to establish the nature, concentration, and spatial distribution of any contamination (including asbestos) present within the individual soil matrices encountered.

Soil samples were recovered from within the following approximate depth range: ground level-GL-0.5m bgl, 0.5-1.0m bgl and then at 1.0m centres thereafter, or as ground conditions required/allowed. All environmental soil samples were collected in a combination of 500ml plastic tubs with sealable lids, 250ml glass amber jars and 60ml glass VOC jars. Care was taken to minimise cross contamination between sampling events.

Where analysis was scheduled, testing of all samples was undertaken at the premises of i2 Analytical Ltd. The analytical strategy adopted for the investigation was designed to provide an overall assessment of contaminant concentrations within the identified soil matrices, taking account of the potential contaminants of concern indicated in the preliminary CSM. The testing of the following principal analytes was therefore undertaken:

- 32 No. CLEA standard suite for metals/metalloids (including As, Ba, Bo, Cd, Cr, Cu, Hg, Pb, Ni, Zn), Cyanide (free and total) and Thiocyanate.
- 32 No. pH, Soil Organic Matter and Total Organic Carbon.
- 32 No. Sulphates (Total and Water Soluble) and Sulphide.
- 15 No. Total Potential Sulphate.
- 32 No. Speciated Polycyclic Aromatic Hydrocarbon.
- 17 No. Speciated Total Petroleum Hydrocarbon.
- 17 No. VOC including Monoaromatics and Oxygenates (BTEX).
- 9 No. SVOC
- 32 No. Electrical Conductivity & Redox Potential.
- 32 No. Asbestos identification and screen.
- 32 No. Monohydric Phenol (Total), and
- 5 No. Full Waste Acceptance Criteria (Single Stage 10:1 leachate extraction).

Geotechnical

With respect to the general material composition of the natural on-Site soils encountered, the following laboratory geotechnical tests were carried out:

- 17 No. Natural Water (Moisture) Content, and
- 17 No. Plasticity Indices (Atterberg Single Point).

All laboratory testing was carried out in accordance with current British Standard guidance ^[17,18] and other in-house procedure by i2 Analytical Ltd.

In-situ standard penetration testing ('SPT') ^[19] was undertaken at 1.0m centres in all fourteen percussive boreholes to establish general ground strength with depth (to refusal wherever possible). Furthermore, dynamic probe testing ('DPSH') ^[20] was also completed at six positions to further establish ground strength and penetration resistance with depth to refusal; refusal for both SPT and DPSH was taken to be where N or $N_{10} = 50$.

3.5 Proven Ground Conditions

NOTE: The account given herein is based on the ground conditions observed during the investigation only at the positions that could be reached and completed. It is important to note that there is likely to be lateral and vertical variation in the reported ground and groundwater conditions between each of the investigation positions given the variable nature of the soils to be encountered at this Site. This should be allowed for at the detailed design-phase stage.

A generalised summary of the lithologies encountered is given in Table 3.2, overleaf. For a full description of the ground conditions recorded at each investigation position, reference should be made to the individual investigation records provided in Appendix B.

Schematic cross sections through the Site are appended as plan, Refs. 0524-02-002, 0524-02-003, and 0524-02-004.

Table 3.2 - Summary of General Soils and Groundwater Profile

Lithology	Typical Descriptions (not limited to)
Made Ground (Reconstituted Ground)	- Loose dark brown clinker, sand and mixed gravel over brown clay with fragments of brick, concrete and tarmac; - Dark brown-black loam over clinker, sand and brick; - Brown-grey clay with mudstone fragments, clinker, brick, concrete, sand and carbonaceous material; - Black-dark grey clay with ash, gravel, brick, clinker, slag, concrete and plastic; - Black very sandy clay with gravel and brick; - Black clay with timber (sleeper), sand, gravel, brick and occasional plastic; - Dark grey-black very sandy clay with gravel, brick, concrete and large cobbles.
Diamicton (of variable consistency)	- Firm becoming stiff brown mottled grey slightly sandy slightly gravelly CLAY with carbonaceous fragments; - Stiff becoming very stiff orange-brown mottled grey slightly sandy slightly gravelly CLAY; - Very stiff dark brown mottled grey slightly gravelly thinly laminated CLAY; - Very stiff red-brown mottled grey slightly sandy CLAY; - Brown-grey slightly clayey SILT.
Manchester Marls Formation	Not encountered on the basis of field observations.
Collyhurst Sandstone Formation (interbedded with clay horizons of variable consistency)	- Medium dense brown silty SAND - Dense becoming very dense brown SAND; - Very dense brown silty SAND; - Very dense brown SAND with occasional horizons and laminations of stiff brown CLAY; - SANDSTONE (not visibly recorded).

As indicated in the aforementioned preliminary assessment report, it was expected that the Site was to be underlain by made ground soils associated with previous development, although the thickness, composition, and environmental condition was unknown at that time. Beneath these, it was indicated that the natural undisturbed strata would comprise interbedded and discontinuous layers and horizons of material consistent with Devensian Diamicton, with either mudstone of the Manchester Marls Formation or sandstone of the Collyhurst Sandstone Formation below. Shallow-depth groundwater was anticipated within both the made ground and superficial deposits too.

Made Ground

On the basis of the ground investigation, it may be reported that the Site is underlain by a mantle of made ground, but for this to be of variable thickness and composition. In all cases, the quality of the made ground was very poor. For the purposes of this Report, the made ground conditions have been divided into two distinct areas, as follows:

Area north of the infilled 'valley'

Investigation positions located within this part of the Site comprise BH1, BH2, BH3, BH4, and possibly boreholes BH7 and BH8 (and the corresponding dynamic probe positions, where completed).

In general, made ground across this area was noted to be relatively thin at between 0.6m and 1.1m in thickness and to broadly comprise a dark brown clinker, loam, and clay/sand matrix with inclusions of much gravel, brick fragments, concrete fragments, and some localised tarmac. Most of the investigation positions were relocated to allow penetration into the underlying natural strata, although boreholes BH7 and BH8 were terminated on obstructions at a depth of between 1.0-2.0m bgl. No evidence of in-ground construction associated with the former small garages was recorded, and there was no obvious evidence of asbestos sheeting fragments within the soils either.

Infilled 'valley'

Across the area of infill, the nature of the made ground soils to be encountered were largely proven by cable percussive boring (CP1 to CP6), although some shallow percussive boreholes and dynamic probe positions were also completed. The primary reason why cable percussive boring was used was because pre-investigation trial excavation works undertaken by the Client identified the presence of numerous in-ground obstructions (e.g. cobble setts, concrete kerbstone, and other anthropogenic material) within at least the upper 3.0m. Penetration through these would be required to assess the deeper soils.

In general, the made ground soils across the infilled part of the Site were noted to be stratified, comprising thick interbedded layers of soft black sandy gravelly clay with ash, clinker, some slag waste, bricks, concrete, timber, plastic, and the cobble setts. The overall thickness, as proven, was between 8.4m (CP1) and 11.3m (CP2).

Diamicton

Beyond the area of infill, Diamicton soils were recorded from shallow depth in boreholes BH1, BH2, BH3, and BH4, whilst within the area of fill these soils were encountered at much greater depth (in all six cable percussive boreholes). It was noted to predominantly comprise, as a unit, a sandy to very sandy cohesive deposit with gravel and cobbles of various natural lithologies, although based upon field observations, it is evident that it consists of clays with differing consistencies. Within the shallow-depth boreholes the upper horizon was noted to typically be firm becoming stiff, whilst the underlying soils were typically stiff becoming very stiff; this would be anticipated given the usual weathering profile for clay soils, including glacial material. Where proven at depth within the fill area, the soils profile was similar, but typically very stiff.

Manchester Marls Formation

On the basis of the ground investigation data, it is considered that no soils consistent with the typical description of the Manchester Marls Formation (*... red, locally-green, slightly sandy, slightly pebbly calcareous mudstone with frequent thin or lenticular highly fossiliferous dolomitic limestones or red-stained non-magnesian limestones*) were encountered.

Collyhurst Sandstone Formation

From the base of the Diamicton to the top of the sandstone bedrock, the soils encountered in the deep cable percussive boreholes are considered to represent a zone of transition. Whilst intact and solid bedrock was recorded by the drillers at the positions of boreholes CP2 (at 21.8m bgl) and CP4 (at 21.1m bgl), the bulk of the observed overlying soils were noted to comprise layers of medium dense and dense brown silty sand, some having occasional interbedded c.1.0m thick horizons of stiff and/or very stiff sandy gravelly clay within them.

Within this Report, it is tentatively considered that the sand signifies a relatively thick highly weathered upper zone of the Collyhurst Sandstone Formation, rather than them being an underlying part of the Diamicton. This determination was based on the overall thickness of the sand layers (some in excess of c.4.0-5.0m) and their observed composition (i.e. there being no erratics, being of fine to medium grain, and being well sorted). Similar conditions, albeit not as thick, have been reported within the Chester Formation to the west ^[21].

Groundwater

It may be reported that no significant groundwater was recorded in any of the boreholes apart from position CP4 at a depth of 8.6m bgl. Seasonal variation due to fluctuations in groundwater levels should be anticipated, however.

4 GEOTECHNICAL FIELD TESTING & MATERIAL PROPERTIES

Test data obtained from the ground investigation works completed for the Site has been assessed in order to allow for the classification of the on-Site cohesive soils and to identify the presence of any typical ranges, trends, and/or anomalies as may exist. The following data was assessed:

- Liquid and plastic limits (Atterberg).
- Water (moisture) contents.
- In Situ Standard Penetration tests, and
- In Situ Dynamic Probe tests.

4.1 Soil Classification

Shrinkable soils such as clays are subject to changes in volume as their water (moisture) content increases or decreases, this being affected by seasonal change and/or other factors such as the water demand of trees. The resulting shrinkage or swelling of soil can cause subsidence or heave damage to foundations, the structures they support, and underground services.

Geotechnical laboratory index testing in conjunction with water content determination was carried out on representative samples of the Diamicton and some of the clays present within the weathered sandstone deposits so that a basic assessment of the cohesive fraction could be established. The fine soil component represented by clay and silt and containing clay minerals (both alone and/or in mixture with coarser material) are typically classified according to their plasticity characteristics. This is determined by Atterberg Limits tests which are carried out on fine and any medium and fine sand particles to measure the liquid limit and plastic limit, this being in accordance with those methods prescribed in BS1377-2: 1990+Amendment No.1. The degree of plasticity of fine soils is classified using the following terms: non-plastic; low; intermediate, and high (after BS EN ISO 14688-2+A1: 2004+A1:2014). All tests to determine the water content, liquid limit, plastic limit, and the plasticity index of the soil samples recovered were performed by i2 Analytical Ltd. The results of the testing for the dataset are summarised in Tables 4.1 and 4.2, below and overleaf, whilst a copy of the individual laboratory certification (Refs. 24-047007-1 and 24-047783-1) is presented in Appendix C.

Table 4.1 - Summary of Atterberg Limits Results - Diamicton

Determinand	No. of Samples [^]	Depth Range (m bgl)	Range (%) (mean value)	Comment
Water Content (W)	12	1.0 – 12.5	15.6 – 26.8* (19.2)	Typical range of values for glacial till deposits.
Liquid Limit (wL)			32 – 43 (37.5)	
Plastic Limit (Wp)			14 – 21 (18.0)	
Plasticity Index (Ip)			15 - 22** (19.5)	

Table Contd./

Determinand	No. of Samples [^]	Depth Range (m bgl)	Range (%)	Comment
Passing 425µm test sieve	12	1.0 – 12.5	78 - 98	Most samples as tested contained some gravel.

* Moisture content of the samples at the time they were received by the laboratory.

** Plasticity index as determined by the laboratory, not the modified plasticity index¹

[^] One sample (CP2-DS1, 7.5m) was taken from within the clayey made ground, whilst another (CP2-DS4, 15.0m) was identified as being non-plastic. Both of these have been excluded from the dataset.

Table 4.2 - Summary of Atterberg Limits Results – Collyhurst Sandstone Formation (Cohesive)

Determinand	No. of Samples [^]	Depth Range (m bgl)	Range (%) (mean value)	Comment
Water Content (W)	3	9.5 – 20.3	12.5 – 19.1* (16.2)	Typical range of values for low to intermediate plasticity weathered bedrock deposits.
Liquid Limit (wL)			31 – 37 (33.6)	
Plastic Limit (Wp)			14 – 18 (16.0)	
Plasticity Index (Ip)			15 - 21** (17.6)	
Passing 425µm test sieve			90 - 100	One sample as tested contained some gravel.

* Moisture content of the samples at the time they were received by the laboratory.

** Plasticity index as determined by the laboratory, not the modified plasticity index.

[^] One sample (CP2-DS1, 7.5m) was taken from within the clayey made ground, whilst another (CP2-DS4, 15.0m) was identified as being non-plastic. Both of these have been excluded from the dataset.

For the shallow Diamicton, the range of water contents for the samples analysed was between 15.6% and 26.8% as a complete dataset. These values are very similar to those measured within the glacial soils to be encountered on other development sites across the district, although further general assessment of the data to divide it down into different soil types, based on either consistency, depth, or both, is not considered practicable in this instance given the observed homogeneous nature of the underlying soil mass and the lack of clear soil boundaries within it. As indicated, the soils typically exhibit (locally firm) stiff characteristics with other higher strength (very stiff) material within. For the cohesive part of what have been assumed to be the weathered part of the Collyhurst Sandstone deposits, water content was found to be lower at 12.5% to 19.1%. There was no data comparison available for the Collyhurst Sandstone Formation in the BGS Geotechnical Database ^[22].

¹ In accordance with current guidance (e.g. NHBC Standards ^[23]) shrinkable soils may be classified as containing more than 35% fine particles and having a modified plasticity index of 10%, or greater. Soils which fall below 10% may be regarded as being non-plastic.

A graphical representation of the measured water contents is provided as Figure 1, below. This suggests that there is no particular or well defined reduction in water content with increasing depth, as is sometimes observed within Diamicton material. Although reduced water content is noted for the deeper bedrock soils, the data is somewhat limited given the samples that could be recovered. Overall, however, there appears to be little difference.

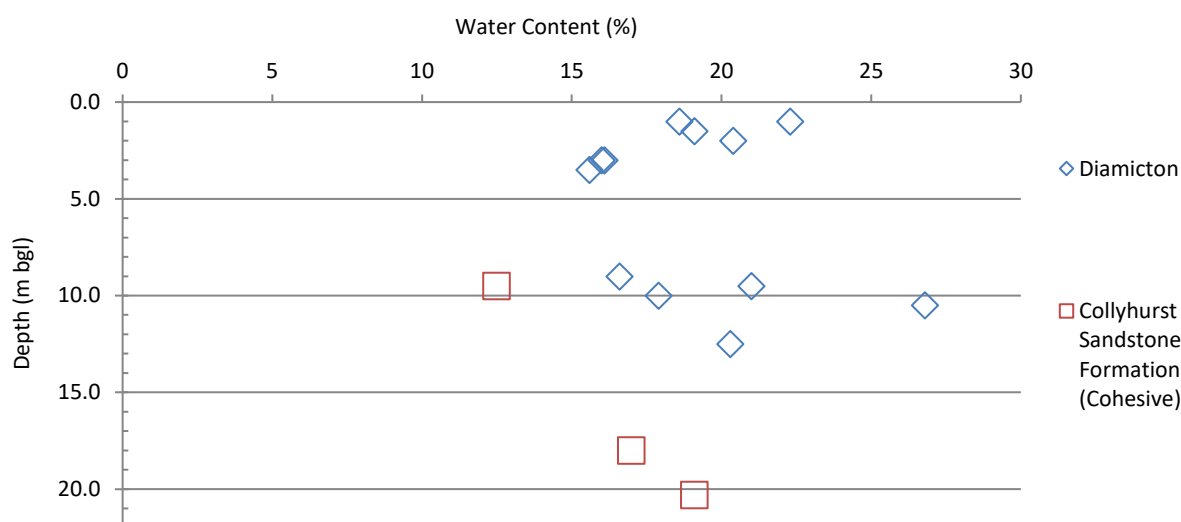


Figure 1 - Summary of Water Content (%) with Depth (m bgl)

As with the measured range in water contents within the Diamicton, there also appears to be no particular distinction between the other index values, notably given the overlap between the water content and the plastic limit values (see Figure 2, below). On the basis of plasticity therefore, it would be expected for the underlying glacial and bedrock soils as a whole to exhibit a typically moderate to high strength profile; this is consistent with the general field descriptions and observations made during the investigation, but variation should be expected.

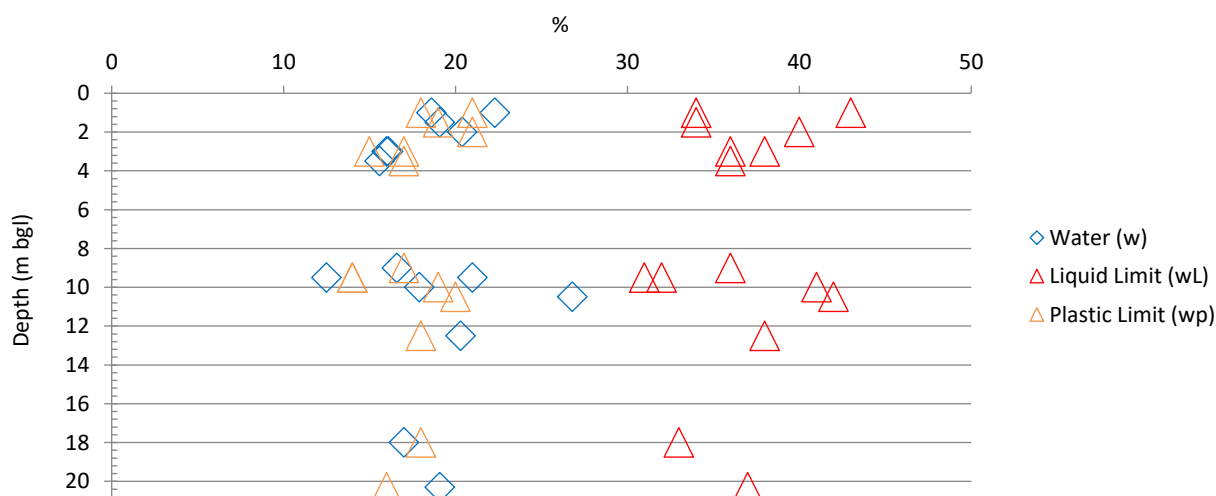


Figure 2 - Summary of Plasticity Data with Depth (m bgl)

4.2 Consistency & Liquidity Indices

Field observations indicate that the cohesive soils exhibit variable albeit typically high undrained shear strengths. Correlation of the laboratory results in accordance with BS EN ISO 14688-2:2002+A1:2013 to determine the Consistency Index (I_c) of the cohesive fraction for these has been undertaken, where:

$$I_c = (w_L - w) / I_p$$

I_c = Consistency Index; w_L = Liquid Limit; w = Water Content; I_p = Plasticity Index

A summary of the data, ordered in relation to sample depth, is given in Table 4.3 below. A visual representation of the data is also provided as Figure 3, overleaf. It is cautioned that variation between sampling positions could occur. The given classifications should, therefore, be assumed to be an approximation of strength only.

Table 4.3 - Summary of Consistency Index Values for Clays and Silts

Sample	Depth (m bgl)	Water Content (%)	Liquid Limit (%)	Plasticity Index (%)	Consistency Index (I_c)*	General Field Observed Consistency
<i>Diamicton</i>						
BH1-DS1	1.0	18.6	34	16	0.96	Firm becoming stiff
BH2-DS1	1.0	22.3	43	22	0.94	Stiff becoming very stiff
BH3-DS1	1.5	19.1	34	15	0.99	Firm becoming stiff
BH4-DS1	2.0	20.4	40	19	1.03	Stiff becoming very stiff
BH1-DS2	3.0	16	36	21	0.95	Very stiff
BH2-DS2	3.0	16.1	38	21	1.04	Very stiff
BH4-DS2	3.5	15.6	36	19	1.07	Very stiff
CP1-DS1	9.0	16.6	36	19	1.02	Stiff becoming very stiff
CP4-DS1	9.5	21	32	18	0.61	Very stiff
CP3-DS1	10.0	17.9	41	22	1.05	Very stiff
CP6-DS1	10.5	26.8	42	22	0.69	Firm becoming stiff to very stiff
CP4-DS3	12.5	20.3	38	20	0.89	Very stiff
<i>Collyhurst Sandstone Formation (Cohesive)</i>						
CP5-DS1	9.5	12.5	31	17	1.09	Very stiff
CP4-DS7	18.0	17	33	15	1.07	Very stiff
CP4-DS9	20.3	19.1	37	21	0.85	Stiff

FOR GUIDANCE ONLY:

* I_c : <0.25 = Very soft; 0.25 - 0.5 = Soft; 0.5 - 0.75 = Firm; 0.75 - 1.0 = Stiff; >1.0 = Very Stiff (BS EN ISO 14688-2:2002+A1:2013, Table 6).

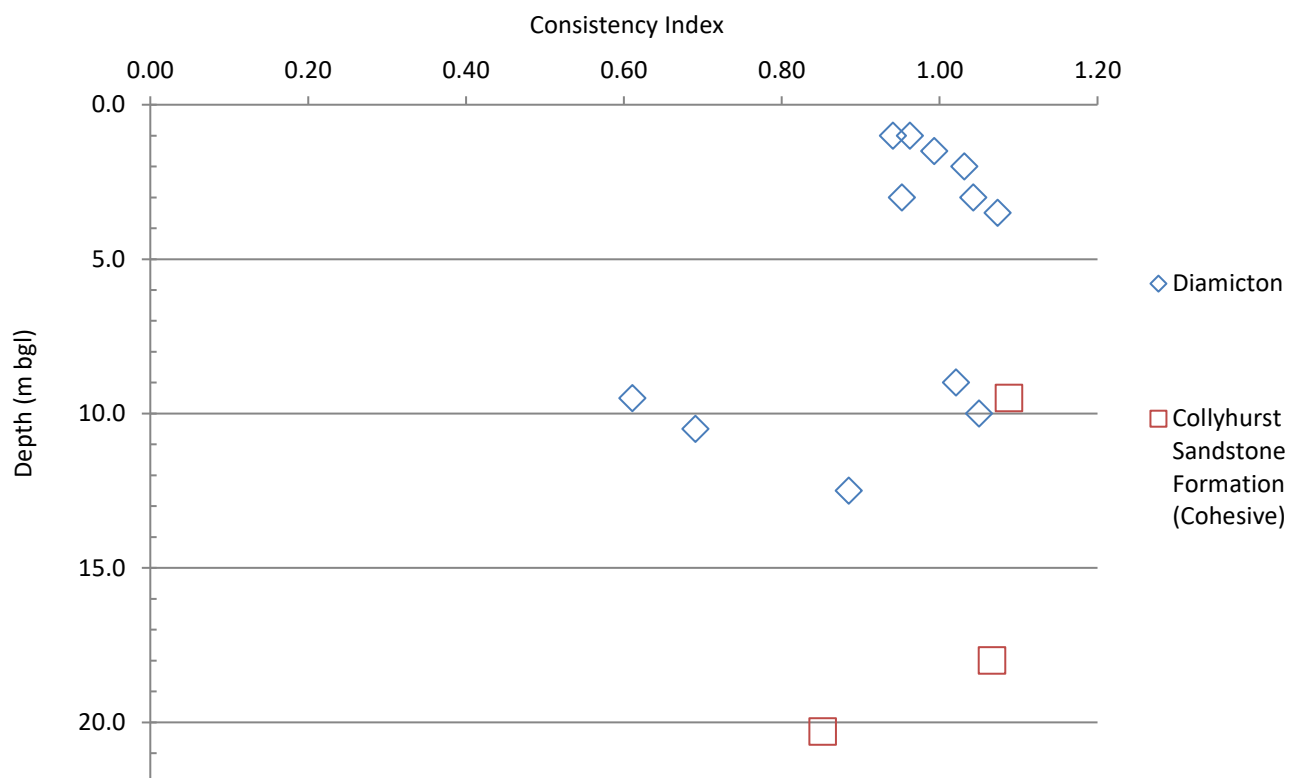


Figure 3 - Consistency Index with Depth (m bgl)

For comparison, soil classification was assessed in accordance with the Liquidity Index. The liquidity index is a measure of soil consistency and strength at a given water content, this being the numerical difference between the natural water content and the plastic limit (expressed as a percentage ratio of the plasticity index), where.

$$I_L = (w - w_p) / I_p$$

I_L = Liquidity Index; w = Water Content; w_p = Plastic Limit; I_p = Plasticity Index

A summary of the data, ordered on the basis of depth, is given in Table 4.4, overleaf. For comparison, in situ SPT data, and the liquidity index to undrained shear strength correlation is provided for information.

Table 4.4 - Summary of Liquidity Index Values of Clay Soils

Sample	Depth (m bgl)	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Liquidity Index (I_L)*	SPT (N)^*	Estimated Undrained Strength (c_u) from SPT^^ (kPa)
<i>Diamicton</i>								
BH1-DS1	1.0	18.6	34	18	16	0.04	12	54
BH2-DS1	1.0	22.3	43	21	22	0.06	18	81
BH3-DS1	1.5	19.1	34	19	15	0.01	9	40.5
BH4-DS1	2.0	20.4	40	21	19	-0.03	17	76.5
BH1-DS2	3.0	16	36	15	21	0.05	24	108
BH2-DS2	3.0	16.1	38	17	21	-0.04	50	225
BH4-DS2	3.5	15.6	36	17	19	-0.07	23	103.5
CP1-DS1	9.0	16.6	36	17	19	-0.02	37	166.5
CP4-DS1	9.5	21	32	14	18	0.39	50	225
CP3-DS1	10.0	17.9	41	19	22	-0.05	31	139.5
CP6-DS1	10.5	26.8	42	20	22	0.31	18	81
CP4-DS3	12.5	20.3	38	18	20	0.12	50	225
<i>Collyhurst Sandstone Formation (Cohesive)</i>								
CP5-DS1	9.5	12.5	31	14	17	-0.09	36	162
CP4-DS7	18.0	17	33	18	15	-0.07	27	121.5
CP4-DS9	20.3	19.1	37	16	21	0.15	17	76.5

FOR GUIDANCE ONLY:

* Suggested parameters for liquidity index (I_L) comparison are given in Waltham, A.C. (2009) *Foundations of Engineering Geology: Third Edition* as: >0.5 = Soft; $0.2 - 0.5$ = Firm; $-0.1 - 0.2$ = Stiff; $-0.4 - -0.1$ = Very Stiff; < -0.4 = Hard.

^* Uncorrected numerical in situ SPT 'N' value recorded in the field.

^^ Estimated undrained strength based on the Stroud Correlation [24], conservatively assuming 4.5x uncorrected SPT (N).

4.1 Volume Change Potential

The plasticity index results have been assessed in accordance with NHBC guidance. The Standards issued by the NHBC allow for an assessment of the index data so that a modified plasticity index (I'_p) may be calculated; *this is expressed as the plasticity index multiplied by the percentage of particles less than 425µm*. The resultant Volume Change Potential (VCP) is expressed using the following terms: High, Intermediate or Low. For pure clay soils and other soils with 100% of particles less than 425µm the modified result will be the same, however, for mixed materials where gravelly clay soils are derived from weathered underlying bedrock material, such as sandstone, the use of the modified plasticity index can often result in a more economic foundation design. A summary of the VCP for the samples tested is given in Table 4.5, overleaf.

Table 4.5 - Summary of Volume Change Potential

Sample	Depth (m bgl)	Plasticity Index (%)	% Passing 425µm	I_p^*	Volume Change Potential
<i>Diamicton</i>					
BH1-DS1	1.0	16	98	15.68	Low
BH2-DS1	1.0	22	95	20.90	Intermediate
BH3-DS1	1.5	15	82	12.30	Low
BH4-DS1	2.0	19	88	16.72	Low
BH1-DS2	3.0	21	90	18.90	Low
BH2-DS2	3.0	21	78	16.38	Low
BH4-DS2	3.5	19	91	17.29	Low
CP1-DS1	9.0	19	88	16.72	Low
CP4-DS1	9.5	18	88	15.84	Low
CP3-DS1	10.0	22	88	19.36	Low
CP6-DS1	10.5	22	91	20.02	Intermediate
CP4-DS3	12.5	20	94	18.80	Low
<i>Collyhurst Sandstone Formation (Cohesive)</i>					
CP5-DS1	9.5	17	90	15.30	Low
CP4-DS7	18.0	15	100	15.0	Low
CP4-DS9	20.3	21	100	21.0	Intermediate

* <10% = Non-plastic. 10-19% = Low. 20-39% = Intermediate. 40% & greater = High (after NHBC: 2019).

The result of the VCP assessment indicate that the underlying Diamicton and bedrock soils have a typically low plasticity, but that some soils exhibit intermediate characteristics. The highest reported VCP of these should therefore be adopted in construction where foundations lie within influencing distance of existing, removed, or proposed trees and planting.

4.2 Dynamic Probing

The use of superheavy dynamic probing (DPSH) is a recognised method to quickly investigate ground conditions with differing driving resistance and to identify buried features such as rock ledges, oversized clastic material, variations in high wall geometry, or other such obstructions. The simplest application of dynamic probing, however, is to identify where refusal on potential founding strata is achieved (e.g. where end bearing piles could be sited) or to determine whether penetration is actually possible to a given depth, or not. To support the general borehole information, probing was undertaken at the positions of DP1 to DP4 across the northern part of the Site, and at positions DP5 and DP6 within the infill area, to assess further the strength profile of the made ground, Diamicton, and the underlying soils with depth to the point of refusal (where possible). The position of the tests is indicated on the appended investigation locations plan and the schematic cross sections.

All tests were carried out in general accordance with BS EN ISO 22476-2 with the number of blows being recorded for every 100mm penetration (N_{10}); refusal of each test was recorded as being where $N_{10} = 50$ for 100mm was achieved. The individual results of the probing are presented in Appendix B (a graphical plot of the penetration resistance is also given against depth for each of the tests) whilst a summary the results is given in Table 4.6, below.

Table 4.6 - Summary of Dynamic Probe Results

Investigation Position	Depth to Refusal (m bgl)	Comment
DP1	6.0	Refusal achieved within the Diamicton
DP2	9.0	Refusal achieved within the Diamicton
DP3	7.8	Refusal achieved within the Diamicton
DP4	8.4	Refusal achieved within the Diamicton
DP5	No refusal achieved at 14.0	-
DP6	No refusal achieved at 14.0	-

The overall dataset for the dynamic probing indicates that refusal was recorded at a depth of between 6.0m bgl and 9.0m bgl across the northern part of the Site, but that refusal within the area of deep fill was not achieved in DP5 and DP6. This is likely to be associated with the thinning of the Diamicton, given the former 'valley' topography of the Site, and subsequent penetration through into the underlying weathered zone (sand) of the bedrock beneath, which is more variable and offered less resistance. In general, however, and for the northern area, the data indicates that the average N_{10} values were less than 10 for 100mm to a depth of around 6.0m bgl, but then increased consistently with every meter of penetration to refusal at 50 for 100mm (although there was no consistent depth of refusal). For DP5 and DP6, the average N_{10} values within the filled area were typically 5 for 100mm or less to the recorded base of the made ground (the nearest cable percussive borehole positions indicated a made ground thickness of 9.5m in CP3 and 8.8m in CP5), below which penetration counts gradually increased to an average of 28 for 100mm at the terminal depth of 14.0m bgl within the weathered bedrock material. Of note, SPT counts in borehole CP3 attained $N = 45$ at a depth of 11.5m bgl in the Diamicton (suggesting that refusal was perhaps close), whilst for CP5 the SPT counts refused at $N = 50$ at each of the following tests carried out at 1.5m centres throughout the weathered bedrock material to a terminal depth of 22.5m bgl.

4.3 In Situ Standard Penetration Testing

Standard Penetration Testing ('SPT') was carried out in each of the percussive boreholes to determine a strength profile of the underlying soils with increasing depth. All (uncorrected) penetration data is presented on the individual borehole records in Appendix B, whilst a graphical representation of the data, presented as 'step diagrams', is also provided.

In providing brief commentary on the SPT data, N values measured during the investigation of the northern Site area (BH1 to BH4) at each of the incremental test depths ranged between: 9 and 18 at 1.0m bgl (average = 12.2); 17 and 32 at 2.0m bgl (average = 23.8); 23 and 50 at 3.0m bgl (average = 31.3); 16 and 32 at 4.0m bgl (average = 23.7), 20 and 35 at 5.0m bgl (average = 25.7), and 50 at 6.0m bgl. These average SPT values indicate that the strength profile of the Diamicton from 2.0m bgl is consistent with increasing depth, but neither largely reducing or increasing until refusal was achieved. Of note, the depth that refusal was achieved during SPT testing (e.g. in BH2 and BH4) was less than the depth that refusal in the corresponding dynamic probe position was.

For the infilled area, SPT counts recorded in CP1 to CP6 within the made ground were found to be highly variable from single figures to $N = 50$ to a depth of c.8.0-9.0m bgl. It wasn't until penetration through the made ground was achieved that SPT N values increased consistently and in a manner concomitant with undisturbed natural material. As indicated above, there is a relatively thick mantle of sand above what may be considered engineering rockhead, so the SPT testing is reflective of both that material and the interbedded horizons of clay that also exist.

General estimated undrained shear strength (c_u) values of the cohesive soils based on SPT N data using the Stroud Correlation, which allows for a conservative conversion of SPT N by a factor of 4.5, suggests that c_u versus water content shows an underlying trend for a decline in strength as the water content increases, as would be expected of clay soils. A plot of this relationship is given as Figure 4, below.

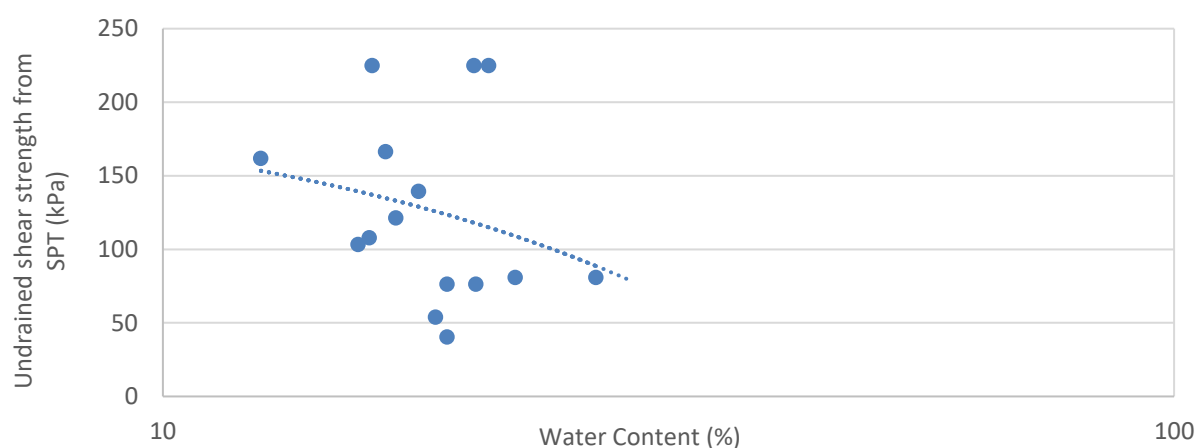


Figure 4 – Undrained Shear Strength with Moisture Content

Made ground soils aside, it should be noted that there is much scatter within the SPT dataset which is most probably associated with localised variations in the degree of weathering and the impact of granular layers and/or lithorelicts on the tests. As with consistency and liquidity data, interpretation of in situ penetration test results is not definitive and should be regarded as a guide only given the expected variations that will occur between test positions, depths, and the fabric of the soils the tests are carried out in. It is evident, however, that there is a general increase in strength with vertical depth within the natural soils, which concurs with the observed increase recorded in other parameters.

As with the dynamic probing results, it is considered that caution should be applied when using the data given the variation in the character of the soils encountered and the variability/uncertainty in the bearing capacities they offer. Data should therefore be assessed within the context of all other Site-based observations and in relation to the development proposals. Notwithstanding the made ground, which is clearly very poor and offers no engineering strength in which dwellings may be constructed, the potential for differential settlement within the natural strata should be anticipated under load, although the exact rate of any settlement would be very difficult to predict since the soils are not wholly uniform in nature and would likely

contain soft layers, granular layers, and oversized materials at random depths. Combined, these could have an effect on material behaviour and settlement characteristics.

5 ENVIRONMENTAL TESTING

5.1 Preamble

Representative disturbed samples of the made ground and the underlying natural strata as encountered were selected for laboratory chemical analysis. These samples were analysed for the suite of contaminants outlined in Section 3.4 above. A summary of the pertinent test results is given in the following tables, whilst a copy of the individual certification (Ref. 24-046672-1, 24-046674-1, and 24-047471-1) is presented in full in Appendix D.

5.2 Guidance for Laboratory Analytical Results - Assessment Criteria

Soil – Human Health

Change to UK human health risk assessment has seen the introduction of DEFRA's Category 4 Screening Levels (C4SL) ^[25] and the LQM/CIEH Suitable 4 Use Levels (S4UL) ^[26]. Both sets of guidance aim to provide Generic Assessment Criteria ('GAC') on the basis of updated assumptions relating to the modelling of human exposure to soil contaminants for the standard land uses: residential (with or without home-grown produce), allotments, commercial and public open space. With reference to the Site, the results of the chemical testing appended herein have been assessed as part of an environmental risk assessment against a number of potential receptors, considering risks to human health, environmental quality, and the built environment. In this instance, comparison against the residential with home-grown produce GAC values was undertaken; these values are provided in Appendix E for reference.

The general consensus between contaminated land practitioners has been that C4SL values, which are based on the 'Low Level of Toxicological Concern', are less cautious than the revised GAC values published by LQM/CIEH and may not, therefore, be wholly applicable for use outside the context of Part 2A Statutory Guidance. Although both publications in no way undermine the validity of existing Environment Agency guidance presented in, for example, SR2 ^[27], SR3 and the existing CLEA software, Groundsmiths are of the mind that the LQM/CIEH values, which are based on Health Criteria that represents minimal or tolerable levels of risks to health (as described in the Environment Agency's SR2 guidance) but incorporates the updated exposure assumptions presented in DEFRA's C4SL guidance, provide a better starting point from which to generate GAC that can be applied to development sites and are 'suitable for use' under the planning system.

It should be noted that both the C4SL and S4UL GAC values are based on sandy 'loam'. The C4SL values are derived for loam soils having a Soil Organic Matter (SOM) content of 6%, although more often than not soils on development sites are different in nature and have SOM contents much less than this. Whilst this is not a problem for metals and metalloids, as their environmental behaviour is not dependent on soil type or SOM content and may be applied directly, the algorithms used to model plant uptake and volatilisation for organic contaminants (such as PAH for instance) do take account of SOM in the soil; it is considered, therefore, that the application of SOM at 6% by default may lead to sites being incorrectly assessed in some instances.

In the same way that the LQM/CIEH values take account of SOM at 1%, 2.5% and 6% for organic contaminants (which better reflects soils routinely encountered in the UK), Groundsmiths adjust the GAC values we apply to contaminated land assessment in CLEA Version 1.071 ^[28], utilising the toxicological updates presented in the aforementioned documents. Our approach adopts the

same SOM grouping as LQM/CIEH, but with some further minor adjustments to reflect a granular component. On the basis of the observed ground conditions recorded during the investigation and the measured SOM values reported by the laboratory, a conservative value of 1.0% has been adopted for the assessment of organic contaminants in the natural strata whilst for the made ground a value of 2.5% is used. These GAC values will be more conservative when applied to cohesive deposits though, given the effects of retardation.

5.3 Laboratory Analytical Results

A summary of the complete laboratory chemical test results is presented on the master datasheet in Appendix D, whilst an individual breakdown of the results is given in Tables 5.1 to 5.4, below and overleaf.

Table 5.1 - Inorganic Contaminant Concentrations (Made Ground)

Contaminant of Concern	GAC [^] (mg/kg) Cc	Contaminant Concentration Range (mg/kg)	Sample Size (n)	UCL ₉₅ (mg/kg)	No. Of Samples >GAC	Outliers (mg/kg)	Result
Metals							
Arsenic	37*	7.2 - 94	22	38.13	1	94	≈≥Cc
Barium	1,300^^	130 - 720	22	na	0	na	<Cc
Boron	290**	0.3 - 2.0	22	na	0	na	<Cc
Cadmium	22*	<0.2 (dl) - 12	22	na	0	na	<Cc
Chromium (III)	910**	20 - 42	22	na	0	na	<Cc
Chromium (VI)	21*	<1.8 (dl)	22	na	0	na	<Cc
Copper	2,400**	6.7 - 2000	22	na	0	na	<Cc
Mercury (inorganic)	40**	<0.3 (dl) - 3	22	na	0	na	<Cc
Nickel	130**	16 - 43	22	na	0	na	<Cc
Lead	200*	12 - 810	22	438.16	11	810	≥Cc
Selenium	250**	<1.0 (dl) - 1.4	22	na	0	na	<Cc
Zinc	3,700**	39 - 870	22	na	0	na	<Cc

[^] Published residential with home-grown produce GAC values applied for 1-6% SOM (Cc = Critical Concentration).

(dl) Laboratory detection limit.

na Not applicable as contaminant concentrations are below individual GAC values.

* DEFRA (2014). Development of Category 4 Screening Levels (SP1010).

** LQM/CIEH (2015). S4UL for Human Health Risk Assessment.

^^CL:AIRE (2010). Soil Generic Assessment Criteria for Human Health Risk Assessment. ISBN 978-1-905046-20-1.

Table 5.2 - Inorganic Contaminant Concentrations (Natural Strata)

Contaminant of Concern	GAC [^] (mg/kg) Cc	Contaminant Concentration Range (mg/kg)	Sample Size (n)	UCL ₉₅ (mg/kg)	No. Of Samples >GAC	Outliers (mg/kg)	Result
Metals							
Arsenic	37*	6.4 - 15	10	na	0	na	<Cc
Barium	1,300^^	62 - 230	10	na	0	na	<Cc
Boron	290**	0.5 - 1.6	10	na	0	na	<Cc
Cadmium	22*	<0.2 (dl) - 0.6	10	na	0	na	<Cc
Chromium (III)	910**	17 - 32	10	na	0	na	<Cc
Chromium (VI)	21*	<1.8 (dl)	10	na	0	na	<Cc
Copper	2,400**	11 - 33	10	na	0	na	<Cc
Mercury (inorganic)	40**	<0.3 (dl)	10	na	0	na	<Cc
Nickel	130**	16 - 56	10	na	0	na	<Cc
Lead	200*	13 - 42	10	na	0	na	<Cc
Selenium	250**	<1.0 (dl) - 1.9	10	na	0	na	<Cc
Zinc	3,700**	43 - 95	10	na	0	na	<Cc

[^] Published residential with home-grown produce GAC values applied for 1-6% SOM (Cc = Critical Concentration).

(dl) Laboratory detection limit.

na Not applicable as contaminant concentrations are below individual GAC values.

* DEFRA (2014). Development of Category 4 Screening Levels (SP1010).

** LQM/CIEH (2015). S4UL for Human Health Risk Assessment.

^^CL:AIRE (2010). Soil Generic Assessment Criteria for Human Health Risk Assessment. ISBN 978-1-905046-20-1.

Table 5.3 - Speciated PAH Contaminant Concentrations (Made Ground)

Contaminant of Concern	GAC [^] (mg/kg) Cc	Contaminant Concentration Range (mg/kg)	Sample Size (n)	UCL ₉₅ (mg/kg)	No. Of Samples >GAC	Outliers	Result
Naphthalene	2.3	<0.05 (dl) - 25	22	9.29	4	25	≥Cc
Acenaphthylene	400	<0.05 (dl) - 5.8	22	na	0	na	<Cc
Acenaphthene	490	<0.05 (dl) - 32	22	na	0	na	<Cc
Fluorene	390	<0.05 (dl) - 28	22	na	0	na	<Cc
Phenanthrene	220	<0.05 (dl) - 230	22	99.85	1	230	<Cc
Anthracene	5,400	<0.05 (dl) - 61	22	na	0	na	<Cc

Table Contd./

Contaminant of Concern	GAC [^] (mg/kg) Cc	Contaminant Concentration Range (mg/kg)	Sample Size (n)	UCL ₉₅ (mg/kg)	No. Of Samples >GAC	Outliers	Result
Fluoranthene	560	<0.05 (dl) - 240	22	na	0	na	<Cc
Pyrene	1,200	<0.05 (dl) - 210	22	na	0	na	<Cc
Benzo(a)anthracene	11	<0.05 (dl) - 98	22	45.90	6	98	≥Cc
Chrysene	22	<0.05 (dl) - 110	22	48.39	5	110	≥Cc
Benzo(b)fluoranthene	3.3	<0.05 (dl) - 110	22	50.91	15	110	≥Cc
Benzo(k)fluoranthene	93	<0.05 (dl) - 40	22	na	0	na	<Cc
Benzo(a)pyrene	2.7	<0.05 (dl) - 100	22	46.19	15	100	≥Cc
Indeno(1,2,3-cd)pyrene	36	<0.05 (dl) - 47	22	20.69	1	47	<Cc
Dibenz(a,h)anthracene	0.28	<0.05 (dl) - 12	22	4.93	16	12	≥Cc
Benzo(g,h,i)perylene	340	<0.05 (dl) - 57	22	na	0	na	<Cc

[^] [CLEA/LQM/CIEH, 2015] Calculated for a residential with home-grown produce end-use scenario in CLEA v1.071. GAC range for 2.5% SOM unless stated otherwise. Values will be more conservative where soils are cohesive due to the effects of retardation.
(dl) - Laboratory detection limit. (Cc = Critical Concentration).

na - Not applicable as contaminant concentrations are below or equal to individual GAC values.

Table 5.4 - Speciated PAH Contaminant Concentrations (Natural Strata)

Contaminant of Concern	GAC [^] (mg/kg) Cc	Contaminant Concentration Range (mg/kg)	Sample Size (n)	UCL ₉₅ (mg/kg)	No. Of Samples >GAC	Outliers	Result
Naphthalene	1	<0.05 (dl) - 1.2	10	0.71	1	1.2	<Cc
Acenaphthylene	170	<0.05 (dl)	10	na	0	na	<Cc
Acenaphthene	200	<0.05 (dl) - 1.7	10	na	0	na	<Cc
Fluorene	165	<0.05 (dl) - 1.1	10	na	0	na	<Cc
Phenanthrene	95	<0.05 (dl) - 6.8	10	na	0	na	<Cc
Anthracene	2,300	<0.05 (dl) - 1.9	10	na	0	na	<Cc
Fluoranthene	280	<0.05 (dl) - 7.3	10	na	0	na	<Cc
Pyrene	620	<0.05 (dl) - 6.2	10	na	0	na	<Cc
Benzo(a)anthracene	7.5	<0.05 (dl) - 3	10	na	0	na	<Cc
Chrysene	15	<0.05 (dl) - 3.3	10	na	0	na	<Cc
Benzo(b)fluoranthene	2.6	<0.05 (dl) - 3.2	10	1.88	1	3.2	<Cc

Table Contd./

Contaminant of Concern	GAC [^] (mg/kg) Cc	Contaminant Concentration Range (mg/kg)	Sample Size (n)	UCL ₉₅ (mg/kg)	No. Of Samples >GAC	Outliers	Result
Benzo(k)fluoranthene	77	<0.05 (dl) - 1.4	10	na	0	na	<Cc
Benzo(a)pyrene	2.2	<0.05 (dl) - 2.9	10	1.7	1	2.9	<Cc
Indeno(1,2,3-cd)pyrene	27	<0.05 (dl) - 1.4	10	na	0	na	<Cc
Dibenz(a,h)anthracene	0.24	<0.05 (dl) - 0.23	10	na	0	na	<Cc
Benzo(g,h,i)perylene	315	<0.05 (dl) - 1.5	10	na	0	na	<Cc

[^] [CLEA/LQM/CIEH, 2015] Calculated for a residential with home-grown produce end-use scenario in CLEA v1.071. GAC range for 1.0% SOM unless stated otherwise. Values will be more conservative where soils are cohesive due to the effects of retardation.

(dl) - Laboratory detection limit. (Cc = Critical Concentration).

na - Not applicable as contaminant concentrations are below or equal to individual GAC values.

Metals & Metalloids

Made Ground

A single elevated arsenic concentration of 94mg/kg was measured within the made ground sample BH6-ES1 recovered from the infill area at a depth of 0.5m bgl, although all of the other twenty-one made ground samples recorded concentrations less than GAC (37mg/kg). For lead, however, eleven samples (50% of the dataset) recorded concentrations in excess of the allowable value of 200mg/kg. A summary of the statistical assessment of the data is provided in Table 5.5, below, whilst the statistical output for each of the contaminants of concern is provided in Appendix D.

Table 5.5 - Inorganic Contaminant Data (Made Ground)

Contaminant of Concern	GAC (mg/kg) Cc [^]	Measured Elevated Concentration Range (mg/kg)	Sample Mean of Dataset	Upper Confidence Limit (95 th %ile) mg/kg	Distribution	Statistical Approach
Arsenic	37	94	21.55	38.13	Non-normal	Chebychev
Lead	200	210 - 810	250.54	438.16	Non-normal	Chebychev

[^] Published residential with home-grown produce GAC values applied for 1-6% SOM (Cc = Critical Concentration).

For arsenic, the data shows that the 95th percentile value is 38.13mg/kg, which marginally exceeds the GAC. Although the measured elevated concentration of 94mg/kg is an outlier within the dataset, it is considered that there is no particular reason why it should be excluded. That said, arsenic does not appear to be a widespread contaminant of concern.

For lead, the 95th percentile value of the dataset was determined as being 438.16mg/kg, which is far in excess of the allowable GAC for this contaminant. As with arsenic, a single concentration (810mg/kg in this instance) was identified as being an outlier, although again it is considered that there is no particular reason why it should be excluded, particularly when many other high lead concentrations were measured. Lead is considered to be a widespread contaminant of concern.

Natural Strata

No elevated inorganic contaminant concentrations were measured above the allowable residential GAC values within any of the natural strata samples tested.

Organics – PAH

Made Ground

Eight PAH congeners (Naphthalene, Phenanthrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, and Dibenz(a,h)anthracene) were recorded to elevated concentrations above the allowable residential GAC values within sixteen of the twenty-two samples (~73% of the dataset) tested. A summary of the statistical assessment of the data is provided in Table 5.6, below, whilst the statistical output for each of the contaminants of concern is provided in Appendix D.

Table 5.6 - PAH Contaminant Data (Made Ground)

Contaminant of Concern	GAC (mg/kg) Cc ^	Measured Elevated Concentration Range (mg/kg)	Sample Mean of Dataset	Upper Confidence Limit (95 th %ile) mg/kg	Distribution	Statistical Approach
Naphthalene	2.3	4.1 - 25	2.98	9.29	Non-normal	Chebychev
Phenanthrene	220	230	36.71	99.85	Non-normal	Chebychev
Benzo(a)anthracene	11	13 - 98	17.94	45.90	Non-normal	Chebychev
Chrysene	22	27 - 110	18.66	48.39	Non-normal	Chebychev
Benzo(b)fluoranthene	3.3	3.4 - 110	20.19	50.91	Non-normal	Chebychev
Benzo(a)pyrene	2.7	2.8 - 100	18.23	46.19	Non-normal	Chebychev
Indeno(1,2,3-cd)pyrene	36	47	18.16	20.69	Non-normal	Chebychev
Dibenz(a,h)anthracene	0.28	0.29 - 12	1.89	4.93	Non-normal	Chebychev

^ [CLEA/LQM/CIEH, 2015] Calculated for a residential with home-grown produce end-use scenario in CLEA v1.071. GAC range for 2.5% SOM unless stated otherwise. Values will be more conservative where soils are cohesive due to the effects of retardation.

Outliers for all PAH congeners identified to in excess of their respective GAC values were noted. As with the inorganic contaminants, however, there is no reason why they should be excluded from the dataset, and therefore remained for statistical purposes.

Of the congeners that reported elevated concentrations above GAC, it was ultimately found that phenanthrene and indeno(1,2,3-cd)pyrene fell below critical concentration (GAC) at the statistical assessment stage. These two PAH's are therefore considered to present no particular risk moving forward, although the others are considered to represent a Site-wide risk.

Organics (Other)

All concentrations of phenol were measured at less than the laboratory limits of detection (<1.0mg/kg) for all made ground and natural strata samples.

Elevated TPH concentrations for the EC16-EC21 Aromatic fraction were recorded in two samples of made ground (BH3-ES1, 0.5m and BH4-ES1, 0.5m) at 810mg/kg and 830mg/kg respectively. These exceed the GAC of 540mg/kg. Furthermore, sample BH3-ES1, 0.5m recorded an elevated concentration of 1,700mg/kg for the EC21-EC35 fraction, compared with the allowable GAC value of 1,400mg/kg. No other elevated TPH concentrations were measured within the overall dataset (seventeen samples) and therefore appear to be localised. No particular risk is anticipated.

All BTEX, MTBE and VOC concentrations were below the allowable residential GAC values (where these are available). Risk from these is not anticipated.

For SVOC, some relatively low level concentrations of various compounds were identified in seven samples (BH5-ES2, 2.0m, BH6-ES2, 1.5m, CP2-ES1, 0.5m, CP3-ES1, 1.0m, CP4-ES2, 1.5m, CP6-ES1, 1.0m, and BH3-ES2, 2.0m) as indicated in Table 5.7, below.

Table 5.7 - SVOC Data (Made Ground & Natural Strata)

Determinand	GAC (mg/kg) Cc	LoD (mg/kg)	Measured Concentration Range (mg/kg) above background detection	Comment ^
2-Methylnaphthalene	None available	0.1	0.1 – 0.4	Produced from coal tar and used to make dyes, resin, and textile auxiliaries. Also indicated to be present in asphalt and in combustion residues. Its presence is consistent with the elevated naphthalene concentration detected in some of the made ground samples.
Dibenzofuran		0.2	0.2 – 0.6	Limited information available, but indicated to be present in coal tar and oils.
Carbazole		0.3	0.4	Present in combustion residues (e.g. clinker and ash).
Anthraquinone		0.3	0.3 – 0.8	Limited information available, but appears to be largely associated with dyes and pigments?

^ Information sourced from PubChem (Ref. <https://pubchem.ncbi.nlm.nih.gov>) based on closest match in database.

Asbestos

At the time of the works access to areas previously occupied by the former small garages was very poor, obscured by a lot of dense vegetation and trees, and within the central part of the Site, invasive species. The objective with respect to the identification of any asbestos contamination, therefore, was for a general Site-wide assessment to be made based on the soil matrices encountered.

Whilst no obvious evidence of asbestos sheeting (or fragments of) was noted in the samples recovered, positive (loose) asbestos fibre identification was made by the laboratory in five of the twenty-two made ground samples (~23% of the dataset) tested, with these being BH2-ES1 (0.5m), BH5-ES2 (2.0m), BH6-ES1 (0.5m), CP3-ES1 (1.0m) and CP4-ES1 (0.5m).

This indicates that asbestos material is present within the made ground generally across the northern area, and where the garages were once located (e.g. BH2), and to depth within the infilled area (e.g. BH5). Given the results of the testing, other asbestos fibres are anticipated to be present within the made ground soils elsewhere on a Site-wide basis and therefore such contamination should be considered to present a risk to the proposed development as a whole without mitigation.

5.4 Contamination & Performance of Cementitious Products

Samples were analysed for general inorganics including water soluble sulphate so that an assessment of risk could be made in relation to those guidelines prescribed in BRE Special Digest 1 ^[29]. A copy of the laboratory test certification is presented in Appendix D, whilst a summary of the dataset is given in Table 5.8, below.

Table 5.8 - Summary of Sulphate & Sulphide Concentrations

Analytical Parameter	Units	Allowable Concentration	Concentration Range	
			Made Ground	Natural Strata
pH	pH units	<5	7.5 – 11.8	7.1 – 8.2
Total Sulphate (as SO ₄)	mg/kg	2,400	120 – 4,500	170 – 450
Water Soluble Sulphate (as SO ₄)	mg/kg	-	36 – 3,800	26 – 390
Water Soluble Sulphate (as SO ₄)	g/l (mg/l)	0.5	0.0178 (17.8) – 1.9 (1,900)	0.013 (13.0) - 0.195 (195)
Total Potential Sulphate	%	0.24	0.12 – 0.57	0.023 – 0.22
Sulphide	mg/kg	-	<1.0 (dl) – 73	<1.0 (dl) – 7.2

(dl) – laboratory detection limit.

A qualitative assessment of the data was carried out in accordance with Sections C4 and C5 of BRE SD1, to assess whether the soil conditions at the Site would be aggressive to any new buried concrete products. In accordance with Table C2 of BRE SD1 and assuming a worst case water soluble sulphate concentration (based on a 2:1 water/soil extract) of 1,900mg/l for the made ground, a Design Sulphate Classification of DS3 and an ACEC of AC-2s indicated. This is based on classification for a brownfield location and having a largely static groundwater regime at pH >5.5.

Whilst risk for new in-ground concrete products to be exposed to sulphate ions is not expected within the northern area or where natural ground is to be encountered generally (oxidisable

sulphide concentrations of between 0.002% SO₄ and 0.185% SO₄ are postulated), due consideration to the potential for risk to be associated with the made ground should be allowed for at the detailed design-phase stage given that they have been proven to yield elevated concentrations of sulphate and Total Potential Sulphate to 0.57%.

Due consideration will also need to be given to the durability and structural strength of all in-ground concrete products to be used. Design parameters for concrete should be discussed with the Designing Engineer, utilising the laboratory data presented herein. The Designing Engineer should refer to BS 8500-1^[30] or any other guidance to determine the correct concrete mix, as required.

5.5 Waste Acceptance Criteria (WAC)

Where arisings are generated during redevelopment works, and they are intended for disposal to landfill, there is a requirement to determine if they would be classified as inert, non-hazardous, or hazardous. Similarly, this would apply if soils to be removed as part of any remedial activity were to be disposed to landfill.

Given that it is a statutory requirement to ensure that wastes are characterised to meet specific acceptance criteria if disposal to landfill is to be undertaken, Waste Acceptance Criteria (WAC) testing was carried out on representative samples of the on-Site soils. Technical Guidance WM3² 'Guidance on the Classification and Assessment of Waste, (1st Edition)', which was introduced on the 1st July 2015 and is adapted from the third edition of Technical Guidance WM2, sets out the requirement for classification. The classification assesses the composition of the material and determines the concentrations of hazardous substances within it, in relation to particular thresholds. Five samples were scheduled for full WAC (single stage 10:1 leachate) analysis to determine if soils likely to go to landfill (such as foundation arisings) meet the acceptance criteria for inert waste disposal. This testing is recommended by the Environment Agency and replaced the traditional two stage batch test.

A summary of the samples tested for WAC is given in Table 5.9, below and overleaf. A copy of the individual WAC test results is provided in Appendix D for reference.

Table 5.9 - Summary of Soils Tested for WAC

Sample	Typical Description*
BH1-ES2 (0.5)	MADE GROUND: Loose clinker, sand, mixed gravel, and fragments of brick and concrete (RECONSTITUTED GROUND).
BH2-ES2 (1.5)	Very stiff dark brown CLAY. Medium to high undrained shear strength. High undrained shear strength. Low plasticity (DIAMICTON).
BH4-ES1 (0.5)	MADE GROUND: Loose dark brown clinker, sand and mixed gravel over brown clay with fragments of brick, concrete and tarmac (RECONSTITUTED GROUND).

² WM3 provides guidance on waste classification and the assigning of classification codes (also referred to as List of Waste or European Waste Catalogue codes) for hazardous and non-hazardous waste materials.

Sample	Typical Description*
BH4-ES2 (1.5)	Stiff becoming very stiff orange-brown mottled grey sandy slightly gravelly CLAY. Gravel is subangular sandstone. Medium to high undrained shear strength. Low plasticity (DIAMICTON).
BH5-ES1 (1.0)	MADE GROUND: Brown-grey clay with mudstone fragments, clinker, brick, concrete, sand and carbonaceous material (RECONSTITUTED GROUND).

* Where soils are to be disposed, classification data and the general spectrum testing presented herein will need to be submitted to the disposal site(s) for individual assessment. Any other specific requirements of the receiving site(s) would need to be met as required, prior to material disposal.

5.6 UKWIR

UK Water Industry Research ('UKWIR')^[31] published guidance in relation to the selection of appropriate water supply pipes to be laid at brownfield sites. This guidance supersedes the Water Regulations Advisory Scheme ('WRAS') Information and Guidance Note 9-04-03 "Laying Pipes in Contaminated Land", which has been withdrawn.

In general accordance with the testing requirements of the UKWIR guidance, analysis of numerous representative samples of the made ground and underlying natural strata were recovered from depths between 0.5m bgl and 6.0m bgl³. Notwithstanding the general suite chemical testing reported above, testing for UKWIR comprised those determinands summarised in Table 5.10, below; reference should be made to the full set of data tabulated in Table 5.11 as required (see Appendix D) for individual concentrations [NOTE: since not all contaminants assessed under UKWIR were assumed to be present at the initial risk assessment stage, not all determinands have values that may be assigned to them].

Table 5.10 - Summary of UKWIR Contaminant Data

Determinand	PE Threshold (mg/kg)	Laboratory Limit of Detection	Concentration Range (mg/kg)	
			Made Ground	Natural Strata
Total VOC	0.5	0.005	<dl - 0.057	<dl
Total BTEX and MTBE	0.1	0.005	<dl - 0.057	<dl
Total SVOC (excluding PAH)	2.0	Variable	<dl - 1.9	<dl - 0.1

Table Contd./

³ UKWIR guidance states that water pipes are normally laid between 0.75m and 1.35m from finished ground level to crown of pipe. Samples taken for testing shall represent a) the soil in which the pipes are to be laid, and b) those to at least 500mm below the underside of the proposed pipes. Where proposed pipe depths are unknown at the time of investigation, soil samples representative of the ground conditions between surface level and 1.5m below finished ground level shall be taken as a minimum.

Determinand	PE Threshold (mg/kg)	Laboratory Limit of Detection	Concentration Range (mg/kg)	
			Made Ground	Natural Strata
EC5-EC10 Aliphatic and Aromatic Hydrocarbons	2.0	Variable	<dl	<dl
EC10-EC16 Aliphatic and Aromatic Hydrocarbons	10.0	1 (EC10-12) 2 (EC12-16)	<dl – 26.8 <dl – 197.0	<dl <dl – 6.0
EC16-EC40 Aliphatic and Aromatic Hydrocarbons	500	8 (EC16-35 Aliphatic) 10 (EC16-35 Aromatic)	<dl – 730.0 <dl – 2,510.0	<dl <dl
Phenol (from SVOC)	2.0	0.2	<dl	<dl
Cresols and Chlorinated Phenol (from SVOC)**	2.0	0.1-0.3	<dl	<dl
Ethers	0.5	Variable	-	-
Nitrobenzene	0.5	0.3	<dl	<dl
Ketones	0.5	-	-	-
Aldehydes	0.5	-	-	-
Corrosiveness^^ (Electrical conductivity, redox potential (Eh) and pH)	Conductivity (µS/cm)	10	210 – 2,100	110 – 200
	Redox (mV)	-800	171.3 – 242.3	219.0 – 235.9
	pH (pH units)	No LoD	7.7 – 11.8	7.8 – 8.2

<dl – Laboratory limit of detection.

**Sum of 2-Chlorophenol, 2-Methylphenol, 4-Methylphenol, 2-Nitrophenol, 2,4-Dimethylphenol, 2,4-Dichlorophenol, 4-Chloro-3-Methylphenol, 2,4,6-Trichlorophenol and 2,4,5-Trichlorophenol.

^^For wrapped steel (ground is corrosive if pH is <7 and conductivity is >400µS/cm); for wrapped ductile iron (ground is corrosive if pH is <5, redox is not neutral and conductivity is >400µS/cm); for copper (ground is corrosive if pH is <5 or >8 and redox is positive).

5.7 Ground Gas

Ground gas monitoring is currently underway, utilising the piezometers installed as part of the ground investigation. Once the monitoring period has been completed, all results will be

provided under separate cover with any recommendation for mitigation being made at that time.

6 PHASE 2 ENVIRONMENTAL APPRAISAL

A phase of intrusive ground investigation has been completed at the Site, with this being to facilitate the proposed development. The following updated CSM is therefore based on the ground investigation data presented herein.

The revised CSM provided below summarises Groundsmiths' current understanding of the surface and sub-surface features to the Site, the identified contaminant sources and concentrations, their potential transport pathways, and receptors.

Ground Conditions & Contamination Status

Japanese Knotweed is present at various locations within the boundary to the Site and therefore prevented full access. This will need to be remediated in accordance with current guidance. Further consultations should be made as required to achieve this.

The ground investigation completed within the remit of this assessment identified the presence of anthropogenic soils associated with previous development, with underlying undisturbed glacial (till) deposits and, at depth, deposits of the Collyhurst Sandstone Formation. The surficial soils across the northern part of the Site comprise poor quality granular and cohesive made ground to a maximum depth of about 1.0m bgl, whilst these deepen towards the central and southern parts of the Site and extend to about 11.0m bgl. All made ground soils encountered are characteristic of loosely end-tipped and poorly compacted material, and include much deleterious debris (plastic, timber, metal wastes, cobbles etc). The underlying natural Diamicton are [locally firm] stiff to very stiff sandy slightly gravelly clays with erratics, whilst the top of the Collyhurst Sandstone Formation is represented by a thick layer of weathered deposit (sand with stiff to very stiff clay horizons) before sharply transitioning into solid bedrock at c.21.0-22.0m bgl. The base of the sandstone cannot be proven.

No significant perched or shallow groundwater was recorded during the investigation so contaminant mobility and migration will be very low.

Contaminant levels within the on-Site made ground materials indicate the presence of widespread lead and PAH to in excess of GAC values, some localised shallow-depth arsenic and TPH, and elevated sulphate. Asbestos fibres were also found to be present within the made ground in a sporadic manner, and are therefore expected to be identified elsewhere in that matrix, although it was not possible to determine whether such contamination was related to the former garaging; some investigation positions were achieved within the areas of such previous development, although it is evident that there is a more Site-wide issue with the made ground soils.

Contaminant levels within the underlying natural strata were predominantly measurable at less than the limits of laboratory detection, save for some very localised PAH. No asbestos was recorded in the natural strata samples tested.

The presence of lead, PAH, asbestos, and the other contaminants within the made ground indicates that those soils may be considered to present a potential moderate to high risk to Site end users in their current condition and will therefore be a driver for soils remediation in development where soft landscaping is proposed and made ground material will remain in situ.

Risk from the underlying natural strata is not expected on the basis of the laboratory test results. Risk from sulphate within the made ground soils also exists with respect to new buried concrete products; protective measures will be required in construction.

Risk from ground gases is to be confirmed following the completion of on-Site monitoring. Should any protective measures commensurate with BS8485 ^[32] need to be provided in construction, such recommendations will be given at that time. It would be prudent to allow for Characteristic Situation 2 conditions (with this being to mitigate against elevated CO₂ and the presence of any vapours) until confirmed otherwise.

Revised Conceptual Site Model & Risk Assessment

Within the context of this Report, a revised risk assessment has been undertaken on the basis that the 'suitable for use' approach remains aligned with the Site being redeveloped for a residential with home-grown produce end use.

The identified potential contaminants and receptors have been considered in relation to the pathways that may link them, having taken account of the findings of the intrusive ground investigation presented herein. The resultant contaminant linkages are presented in Table 6.1, overleaf.

Table 6.1 - Revised Environmental Risk (Current Site Condition without Mitigation)

Potential Sources	Potential Receptors	Plausible Pathways	Probability	Severity	Revised Risk Rating	Comment
Contaminated and potentially contaminated made ground deposits (including made ground soils in areas of former garaging)	<u>Human Health</u> Site end-users, inc. maintenance and site workers (short term risk during enabling works / construction)	Direct ingestion or dermal contact with soil, dust, and/or vapour inhalation (Site end user)	Likely	Medium	Moderate	The made ground soils encountered across the Site have been found to contain elevated concentrations of lead, PAH, and other contaminants. The measured contaminant concentrations within the made ground soils suggest an overall moderate risk to human health when assessed in accordance with CIRIA C552. Significant damage would not be expected, but a direct contaminant linkage to Site end users exists without mitigation (See Section 7, below). Risk from asbestos is anticipated as the positive identification of loose fibres has been made in the made ground soils, including where former garaging was once located.
		Direct ingestion or dermal contact with soil, dust, and/or vapour inhalation (In-ground worker)	Likely	Medium	Moderate	
		Direct ingestion and/or dermal contact with liquid contaminants	Unlikely	Mild	Very Low	
		Inhalation of asbestos fibres (Site end user), including that associated with former garaging	Likely	Severe	High	
		Inhalation of asbestos fibres (In-ground worker), including that associated with former garaging	Likely	Severe	High	
	<u>Construction</u> (Potable Water Supply Pipes)	Direct contact/leaching (tainting)	Likely	Mild	Moderate/Low	Measures compliant with BS8588:2017 (e.g. Protecta-Line) will be required. Consultation should be made with the water provider given the Site's brownfield status.
	<u>Construction</u> (Foundations)	Direct contact/leaching	Low Likelihood	Mild	Low	Sulphate resistant substructure concrete will be required.
	Vegetation	Uptake via root system in soft landscaping	Low Likelihood	Medium	Moderate/Low	See Section 7, below.

Sources & Potential Source	Potential Receptors	Plausible Pathways	Probability	Severity	Revised Risk Rating	Comment
Contd./	Controlled Waters	Vertical and/or lateral migration	Unlikely	Mild	Very Low	No particular risk to controlled waters receptors is anticipated based on the Site's setting.
Ground gas sources	<u>Human Health</u>	Inhalation (via ingress and accumulation into buildings)	Likely	Medium	Moderate	The requirement for precautions in construction is to be confirmed following the completion of ongoing monitoring.

7 CONCLUSIONS

7.1 Contamination – Risk Evaluation

Soil - Human Health Receptors – Site End Users

Having reviewed the Site's history, its environs, and the investigation-specific data acquired within the remit of this study, it is apparent that anthropogenic activity has had a significant impact on the condition of the Site.

The ground investigation completed identified the presence of made ground soils associated with previous development, with underlying undisturbed glacial (till) deposits and, at depth, weathered sandstone/sandstone bedrock of the Collyhurst Formation. The surficial soils across much of the Site comprise poor quality granular and cohesive material with much brick, clinker, ash, sand, and other inclusions to relatively shallow depth, in addition to there being a large expanse of former 'valley feature' that was infilled many decades ago. Made ground here was proven to be c.11.0m deep and to comprise a similar quality of soil, more clay, and for there to be large concrete, wooden sleeper, and numerous cobble sett obstructions buried within.

The made ground soils encountered yielded variable contaminant concentrations with spatial extent and depth, but principally elevated lead and PAH to far above allowable residential with home-grown produce thresholds (these being based on DEFRA's Category 4 Screening Levels, the LQM/CIEH Human Health Values, and/or other in-house derived GAC's calculated by Groundsmiths for organic contaminants). Furthermore, some localised TPH and sulphate is evident within the made ground materials as are loose asbestos fibres; there was no obvious sign of free product, oils, or fuels in any of the soils observed during the investigation though.

Whilst it is understood that a high level of Site enabling works and made ground removal (by about 1.0m thickness) is to be undertaken prior to construction, namely to facilitate clearance of all previous development and allow treatment of the invasive plant species that exists, the identified and elevated inorganic and organic contaminant concentrations to above GAC threshold are considered to present a potential moderate risk to Site end users where such soils remain in areas of soft landscaping (i.e. gardens and public open space) without mitigation; Remedial activities to address the risks will therefore be required on a Site-wide basis.

Notwithstanding the above, concentrations of general inorganic and organic contaminants of concern were largely below critical concentrations for the underlying natural strata and are unlikely to present any risk to Site end users. No asbestos fibres were recorded in these samples either.

Soil - Human Health Receptors – In-ground Construction Workers

Consideration should be given to the level of risk workers involved with Site enabling works and other in-ground construction will be exposed to, given the increased potential for general dermal contact and the ingestion/inhalation of contaminated dusts.

It should be noted that UK contaminated land assessment tools available to practitioners (i.e. CLEA V1.071) cannot be used as the basis to assess the acute (short term exposure) risk that groundworkers or other such personnel in close contact with soils may experience during

construction activities. On this basis, it is not practicable to generate allowable threshold limits for potential contaminants of concern as is ordinarily undertaken to determine whether a Site requires remediating, or not.

Given that Site-wide made ground soils have been identified, all works to be undertaken should be specifically assessed as part of a normal health and safety evaluation to mitigate the exposure of workers to any emissions as may be released during enabling and construction activities.

Asbestos

The laboratory data indicates that fibres were identified in a percentage of the made ground soil samples tested. It is possible that the asbestos contamination identified could be derived from previous on-Site development such as the garages, or perhaps inherent to the materials imported as fill instead? Either way, risk from asbestos fibres in the made ground is considered to be high, and as indicated above, remediation to address this risk will need to be implemented as part of the development.

Unforeseen Contamination

As with any development site there is the potential for hotspots or other areas of contamination that have not currently been identified to be encountered. This is unavoidable and may only come to light during clearance and enabling works, although it is expected for other contaminated materials to be present given the nature of the Site and what has already been proven.

If other contaminated or suspected contaminated soil were encountered during development, these would need to be investigated further on a separate basis, with an appropriate level of testing and risk assessment being carried out.

Soil Remediation

Contaminated made ground has been identified, which presents a potential risk to Site end users without mitigation. It is considered that all soft landscaped areas in development will need to be capped with a minimum 600mm inert soil cover where made ground soils are to remain in situ. Furthermore, a break layer will need to be placed at the interface with any residual made ground given the potential for asbestos fibres to remain. LCRM Stage 3 proposals and verification methodology will need to be submitted to the LPA in the form of a standalone Remedial Strategy, with this being in accordance with the requirements of Manchester City Council ('MCC') ^[33].

Ground Gas

As indicated herein, ground gas monitoring is currently ongoing to assess risk associated with on-Site and potential off-Site sources as identified.

Specific remediation proposals and verification methodology for any gas protection measures to be introduced would need to be submitted to the LPA as part of the Remedial Strategy. These works would need to be undertaken in accordance with the requirements of MCC and

the Standards they refer to, if found to be required. Allowance should be made for the provision of measures to Characteristic Situation 2 of BS8485 until confirmed otherwise.

Radon

Third party reporting indicates that no radon precautions are required in construction. Consultation with Building Control should be made as required as they may have different requirements.

Controlled Waters Receptors

No particular risk is anticipated in relation to controlled waters receptors as very little water was encountered during the investigation. No further assessment of the underlying groundwater conditions is considered necessary.

7.2 Construction – Risk Evaluation

Potable Water Supplies

Water providers are required to maintain the safety of staff, contractors, and customers. On this basis, water providers work with a range of trigger values when laying mains pipes or services in contaminated ground, in the same way that assessment is made by contaminated land practitioners.

Testing to full UKWIR was not considered necessary on the basis of the identified source-pathway-receptor linkages, although a broad spectrum of testing in addition to extensive redox/electrical conductivity, and pH determination has been completed to assess the contaminative status of the Site. On the basis of the available data, and the general brownfield nature of the Site, it is considered that measures compliant with BS8588:2017 (e.g. Protecta-Line) will be required throughout the development.

It is recommended that the results of the chemical testing and details of the development proposals are provided to the utility company for their comment, prior to installation of any pipework.

Sulphate Attack

A Design Sulphate Classification of DS3 is indicated on the basis of the laboratory data, with the Aggressive Chemical Environment Class being AC-2s.

Although no evidence of gypsum crystals, red-brown ferric oxide, or yellow-brown hydrated ferric oxide was recorded on any of the soils encountered, elevated sulphate concentrations and Total Potential Sulphate have been measured. Due consideration for new in-ground concrete products to be exposed to sulphate ions within the made ground should be made as required. Further consultation should be made with the Designing Engineer with respect to the final concrete mix to be adopted.

Stress Relief

Risk associated with stress relief is considered to be very low.

Mining

Risk associated with either recorded or unrecorded probable shallow coal mining is not expected on the basis of available information.

Anticipated Foundation Type

The foundations to be adopted will need to be based on the placement of dwellings in relation to the ground conditions encountered. On this basis, and with cognisance to the likely imposed loads and required settlement tolerances of the development, it is anticipated that dwellings located within the northern periphery of the Site (assuming natural undisturbed ground can be reached at normal founding depths) would likely be on traditional reinforced spread foundations, whilst for the remainder of the Site (i.e. where the made ground thickens or is very deep) a piled foundation solution would need to be adopted. Further consultation with the Designing Engineer will need to be made to progress a workable foundation schedule, but in summary, the following general information is given:

Spread Foundations

Where traditional spread foundations can be used, these shall be taken down through any loose, soft, or otherwise unsuitable materials to be founded on strata having sufficient bearing capacity at a minimum depth as directed by the Designing Engineer.

The widening and strengthening and/or deepening of foundations in accordance with current engineering standards would be required if foundations were found to straddle strata of different type, and/or where areas of softer or weaker ground were encountered at founding depth. In addition to this, the depth of footing could potentially vary across the Site, so other adjustments to final depth may need to be based on excavation as construction progresses and in discussion with Building Control.

Piled Foundations

Foundations will need to be designed to insulate the supported structures from any potential ground movement and to withstand any lateral loading, down-drag (i.e. negative skin friction) in addition to resisting any uplift/tension that may be generated within the surrounding soils in the post-development case.

All piling works will need to be undertaken from a suitably designed and installed piling mat, taking into consideration the poor on-Site ground conditions.

Due consideration will need to be given to the nature and thickness of the made ground, the obstructions that are present, and the bearing strata beneath. Independent field tests will need

to be completed by the piling contractor to confirm the design type, depths, production parameters, diameters, and load/compressive strength tests for each part of the Site.

Bearing Capacity Assessment

All necessary bearing capacity assessments should be completed by the Designing Engineer (or others) to ensure that the serviceability limit state of the structures is not compromised in any way. Although considered to be a relatively low risk, this should take account of the amount of total and/or differential settlement that could potentially occur. Due consideration should also be given to the fault line that is indicated to pass through the Site (at depth and beyond the realistic limit of any ground investigation).

Ground Slab

It is anticipated that the ground floors in construction will be suspended (e.g. beam and block). Due consideration should be made for the provision of all relevant ground gas precautions to CS2 of BS8485 until confirmed otherwise.

Heave Precautions

The geotechnical test results indicate that the on-Site cohesive soils have a worst-case intermediate Volume Change Potential ('VCP') when assessed in accordance with the Modified Plasticity Index.

Precautions in construction would need to be taken where foundations lie within influencing distance of existing, removed and/or proposed planting and trees when in cohesive soils (as defined by NHBC Standards, Chapter 4.2) or where seasonally desiccated soils are present at the time of construction. Further consultation should be made with the Designing Engineer to ensure that the correct level of protection is provided, with this being in conjunction with the foundation solutions to be adopted.

Retaining Walls

No retaining walls should be needed in development given the topography of the Site.

Slopes

Given that the Site is located on an infilled valley feature, the south-eastern boundary of the Site lies at the crest of the infill materials used, before falling away steeply into the heavily vegetated valley. Observations made within this part of the Site indicate that the soils are very poor, non-retained, and likely to be very unstable. This could have implications for piling, pavement and other construction. All further stability assessments should be undertaken as required, prior to construction commencing, with any remedial works identified being carried out.

Excavations & Obstructions

It should be anticipated for the instability of loose and/or weathered soils in excavation to be encountered, particularly during periods of wet weather, where excavations are deep, or where

they are left open for protracted periods of time. Preliminary excavation within the made ground to the infilled valley feature revealed side collapse and much general instability, with this being attributed to both the debris that is present within and the non-compacted nature of the soil.

Excavations, particularly where weak or weathered soils are encountered, will need to be undertaken with care as it would be expected for these soils to deteriorate once exposed. All necessary supports to any excavation faces shall be provided as required, or battered to a safe angle if there is sufficient space to do this.

Further assessment of excavation stability or other such cut faces should be undertaken as necessary if problems are encountered. It could be that some remedial works comprising the reworking of the soils is required, including where they need to be replaced with compacted granular materials.

No entry into unsupported excavations should be allowed without an appropriate risk assessment. All excavation works shall be carried out in accordance with current HSE guidance, 'Structural Stability During Excavation' ^[34].

Superstructure Precautions

The need for superstructure precaution, such as masonry reinforcement, is not anticipated, although further consultation should be made with the Designing Engineer as required.

Surface Water Drainage

It should be noted that it would be inappropriate for unstable, potentially unstable, and/or contaminated strata to receive point-source flows of water from dedicated soakaways. It should also be noted that soakaways should not be used where they lie within at least 5m of roads, foundations, and/or other sensitive development.

Given that the Site is underlain by unstable and contaminated made ground, with stiff natural soils beneath that have negligible infiltration potential, it is anticipated that a piped drainage connection to an existing sewer will be needed. Further consultation with a specialist drainage consultant should be made.

If it was decided that soakaways were suitable for part of the Site, infiltration testing in accordance with BRE365 ^[35] would need to be completed.

All drainage proposals will be subject to obtaining the necessary approvals from the Regulatory Authorities.

Pavement

Due consideration will need to be given to the construction requirements of future trafficable areas across the Site.

Within the northern part, where the underlying natural strata is present at relatively shallow depth, it is anticipated for usual road construction methods to be deployed. At this time,

however, it is recommended that a design CBR value of 2.5% (perhaps less) should be assumed until Site-specific testing has been carried out. The design of future trafficable areas will need to be such that it allows for the effects of the soft underlying and variable soils that exist and for the potential reduction in the strength of any replacement material to its long-term CBR value.

Where the made ground thickens and/or is deep and will remain beneath the pavement alignment, ground improvement will be required to facilitate construction as the soils are very poor, soft, and would be expected to settle in a differential manner under load; this could lead to cracking, unevenness, or failure. Although further and detailed consultation will need to be undertaken prior to construction, it is anticipated at this stage that a high degree of excavation, sorting, reworking, and compaction of the made ground within future trafficable areas will need to be undertaken to the satisfaction of all parties. The depth of turnover and the specification to be adopted is unknown.

Further to the above, having observed the condition of the made ground, it would be considered prudent to implement a polymeric geogrid (and potentially the introduction of asphalt reinforcement) within the makeup of the pavement to improve its load carrying capacity as it would not be possible to re-engineer made ground at greater depths. It is understood that Tensar, and other providers, manufacture products that would likely be applicable. Further consultation should be made as required.

Frost susceptibility should be assumed.

All necessary in situ testing in compliance with Manchester City Council (Highways) requirements will need to be undertaken.

8 REGULATORY APPROVAL

The conclusions presented herein are considered reasonable on the basis of available information and the assessment of the Site as carried out by Groundsmiths. However, it remains the responsibility of the Client to ensure that the Site poses no significant risk to any sensitive receptors and that it remains aligned with the proposed end-use and assessment framework adopted in this Report.

If at any time in the future, additional information comes to light that puts into doubt the accuracy of the professional opinion or third party information presented herein, then it may be necessary to revisit the assessment.

Works undertaken cannot be guaranteed to gain approval by the regulators as the acceptability of the levels of risk presented may depend on the viewpoint of the Local Planning Authority and their Consultees. A copy of this Report should therefore be made available for comment and approval, prior to undertaking any irrecoverable works associated with the Site.

9 REPORTING LIMITS

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The findings and opinions provided in this Report are given in good faith and are subject to the limitations and constraints imposed by the methods and information sources described.

Factual information contained within the Report has been obtained from a variety of sources. Where third party data has been used, Groundsmiths assumes that this is reliable but cannot independently confirm this as the validity and accuracy of this information is outside our control. No guarantee can therefore be given as to the completeness of the information gathered during the study and no responsibility is accepted for errors or omissions in the third party information used. Groundsmiths' professional judgement and experience is however used to ensure that uncertainties are reduced to a level appropriate to the site conditions, the purpose of the assessment and the resources devoted to it by the Client.

Whilst every effort has been made to carry out an assessment that enables a realistic characterisation of the environmental and geotechnical parameters to be identified, the likelihood of significant variation in actual ground and groundwater conditions between investigation positions cannot be discounted. The findings and opinions presented in this Report are relevant to the time this assessment was undertaken but should not necessarily be relied upon to represent conditions at a substantially later date. Further information, supplementary ground investigation, construction activities, change of site use, or the passage of time may reveal conditions that were not indicated in the data presented herein and therefore could not have been considered in the preparation of this Report. Where such information might impact upon stated opinions, Groundsmiths reserve the right to modify the opinions expressed in this Report.

Where opinions expressed in this Report are based on current available guidelines and legislation, no liability can be accepted for the effects of any future changes to such guidelines and legislation. New information or improved practices and changes in legislation may require reinterpretation of the Report as a whole, or in part.

The recommendations presented in this Report are based on the site-specific assessment but utilising third party-provided information as appropriate. They are, however, limited to those that could be reasonably made at the time the assessment was undertaken. Where assessments of site areas affected in particular ways are given, these are approximate.

This Report does not constitute an archaeological, ecological, or arboriculturalist / invasive plant species survey. Any comment given in relation to these is for information only. Further assessments to assess these may be required as part of any planning condition and should therefore be undertaken by suitably qualified experts as required.

Groundsmiths reserve the right to edit and / or retract any conclusion or recommendation made in this Report should any further information, with respect to the Site, become available.

Groundsmiths disclaim any obligation to update the Report for events taking place after the time during which the assessment was carried out.

Groundsmiths do not provide or purport to provide legal advice. Should the Client require such advice then that of lawyers should be sought.

Groundsmiths accept no responsibility if any findings given in this Report are not implemented by the Client or their agents.

Groundsmiths accept no responsibility if any further works, as requested by the Local Planning Authority in the discharge of their duty of care, are not implemented by the Client or their agents.

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