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Plot 8 First Street, Manchester

Geotechnical and Geoenvironmental Assessment

For: Ask Property Developments Ltd

Job No: 1011906

Doc Ref: 1011906.RPT.GL.004

Latest Revision: -

Date: 30/06/2016

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Project Name:	Plot 8 First Street, Manchester
Client:	Ask Property Developments Ltd
Report Title:	Geotechnical and Geoenvironmental Assessment
Job Number:	1011906

Document Revision History

Revision Ref	Issue Date	Purpose of issue / description of revision

Document Validation (latest issue)

30/06/2016	Recoverable Signature	30/06/2016
X	X	X
Principal author	Checked by	Verified by
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Executive Summary

Executive Summary	
The Site	The site consists of a disused parcel of land, approximately 1.7 ha in size, located immediately north-east of the Mancunian Way / A5103 junction, within the southern extents of Manchester City Centre.
Context and Brief	Cundall was commissioned by Ask Property Developments Ltd. to prepare an Interpretive Geotechnical & Geoenvironmental Assessment for the proposed development, interpreting and summarising the intrusive ground investigation works and in the context of the requirements for the proposed development.
Proposed Development	The proposed development consists of the construction of residential apartment blocks up to 23 storeys in height, with ground floor commercial units. Site preparatory works will be required and areas not covered by structures will received soft landscaping and similar areas of public open space.
Ground Conditions	Ground conditions typically consist of hardstanding or topsoil overlying deeper, variable, made ground up to 3.75 m thick. This is underlain by granular Glaciofluvial deposits, further underlain by cohesive stiff Glacial Till. Completely weathered bedrock is present across much of the site, absent locally, with competent sandstone rockhead of the Chester Pebble Beds at around 12 to 15 m below ground level.
Groundwater	A shallow groundwater body is located within the Glaciofluvial Deposits and is recorded at approximately +31.5m OD.
Geotechnical Design Considerations	The column loads from the proposed building are very high and therefore shallow foundations are unsuitable. CFA and/or rotary bored piles would provide a suitable solution, end bearing in the underlying competent rock for high capacities. Due to the variable made ground a ground bearing flor slab is not recommended, requiring either re-engineering of site material or a piled floor slab. A CBR value of 3% should be adopted for pavement design and in-situ testing carried out on the formation to confirm this.
Geoenvironmental Risk Assessment	Elevated levels of lead and the presence of asbestos within the made ground at the site present a risk to human health. A suitable remediation strategy will need to be employed in order to prevent significant harm occurring, and this is likely to mainly concern control of dust/asbestos fibre release. No significant risks to the wider environment were noted.
Ground Gas Protection Measures	No significantly elevated levels of carbon dioxide or methane were noted during monitoring, and gas flow levels were also low. A Characteristic Situation 1 (CS-1) for the site is considered appropriate and therefore no specific ground gas measures are required.
Ground Aggressivity	The design sulphate class for concrete in contact with soil at the site is assessed to be DS-1 and the Aggressive Chemical Environment for Concrete (ACEC) is classified as AC-3z.
Obstructions and Groundwater Control	The possible remains of former basements and an air raid shelter at the site were noted as part of desk top studies and exploratory holes encountered obstructions and voids which suggest they are present. Allowances should be made for partial or full breaking of of these features and/or probing before any piling works begin. Excavations above 31.5m OD are not likely to require groundwater control, though deeper excavations may suffer significant inflows of water and need suitable control measures.
Unexploded Ordnance (UXO)	Prior to intrusive works a detailed UXO risk assessment was undertaken which required the use of a UXO banksman during the GI. Two boreholes were required to be stopped due to the detection of possible UXO. A factual report detailing further recommendations is being prepared by the UXO banksman provider and will be provided under separate cover.
This Executive Summary is intended as a summary of the geotechnical and geoenvironmental assessment of the site in the context of the current development proposals based on information received by Cundall at the time of production and should be read in conjunction with the main Report text.	

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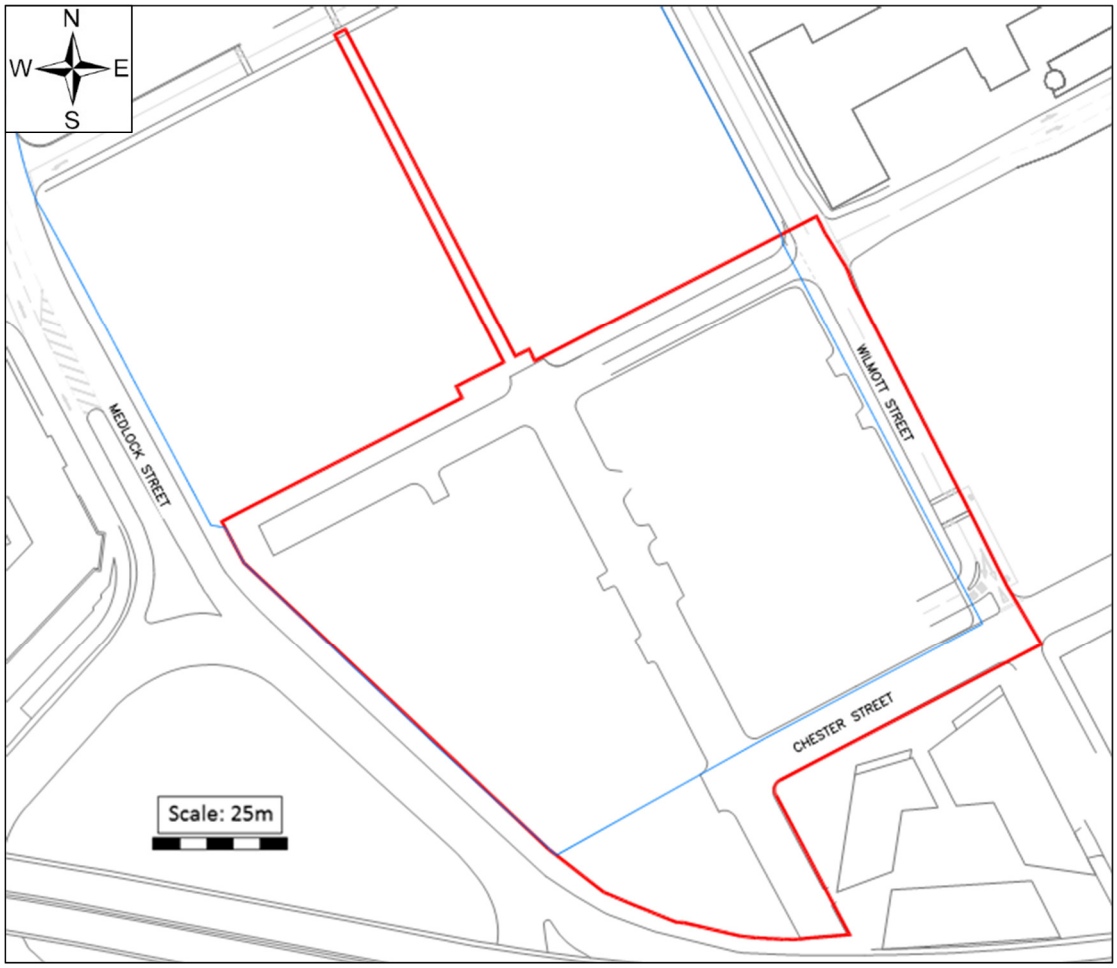
1. Introduction

1.1 Context and Purpose

Cundall was commissioned by Ask Property Developments Ltd (the Client) to scope and manage an intrusive ground investigation and subsequently prepare an Interpretive Geotechnical and Geoenvironmental Assessment (Phase II) for the proposed redevelopment of Plot 8, First Street, Manchester, a disused parcel of land located immediately north-east of the Mancunian Way / A5103 junction, within the southern extents of Manchester City Centre (the Site). The site's location and approximate extent is shown in Figure 1.

Figure 1 – Site Location Plan



1.2 The Scheme

Current schematic proposals for the site are illustrated as Figure 2 and comprise the following:

- Site preparatory works including Newcastle Street becoming a 'pedestrian only' highway.
- The construction of a residential apartment complex extending to 23 stories in height.

- The inclusion of some retail / commercial use at ground level within the residential complex.
- Landscaping within the development is proposed to include limited green spaces (soft landscaping) within the centre of the complex constructed on a raised podium slab, as well as paved access routes and hard-surfaced public realm.

Figure 2 – Architects Representation of Development Scheme

1.3 Sources of Information

The following reference sources were reviewed in order to provide background information, with relevant information used during the preparation of this report. Where additional sources of background information have been used, these are stated in the text.

1. Capita Symonds (12 June 2012) 'Phase 2 Ground Investigation & Assessment, First Street South' Report Reference 17617, SI102, Issue 2. Referred to as 'Capita 2012' throughout this report.
2. Cundall (26 January 2016) Preliminary Geotechnical and Geoenvironmental Assessment, report reference 1011906.RPT.GL.001 Revision B. Referred to as 'Cundall 2016' throughout this report.
3. Geotechnical Engineering Ltd. (June 2016), Plots 6, 7 & 8 First Street, Manchester, Factual Report on Ground Investigation, Report Ref. 31847. Referred to as 'Geotechnical 2016' throughout this report.

The following technical references have also been consulted whilst preparing the report:

- Stroud, M. A. (1975), The Standard Penetration test in insensitive clays and soft rocks, Proceedings of the European Symposium on Penetration Testing.
- Stroud, M. A. (1988) The Standard Penetration Test – Its Application and Interpretation (originally published in the Proceedings of the Geotechnology Conference on Penetration Testing in the UK).
- Jamiliokowski et al., (1972), New developments in field and laboratory testing of soils. Proceedings of the 11th International Conference on Soil Mechanics and Foundation Engineering.
- Tomlinson, M. J. (2001), Foundation Design and Construction, 7th Edition.
- Bieniawski, Z. T. (1989), Engineering Rock Mass Classifications.
- Franklin, J, A, & Dusseault, M. B (1989), Rock Engineering.

1.4 Limitations

The investigation of the site has been carried out to provide sufficient information on the geotechnical and geoenvironmental characteristics of the ground and groundwater at the development site and to provide a reasonable assessment of the environmental risks together with engineering and development implications.

The opinions provided and recommendations given in this report are based on a visual site inspection, reference to accessible referenced historical records, the information provided by third parties, the results of ground investigations as detailed in the text and the factual data provided by the specialist ground investigation contractor. Whilst every effort has been made to interpret the conditions between the investigation locations, such information is only indicative and liability cannot be accepted for its accuracy. There may be exceptional ground conditions elsewhere on the site which have not been disclosed by this investigation and which have therefore not been taken into account in this report. The test results that have been obtained can only be regarded as a limited but likely representative sample range, assessed against current guidelines. The possibility of the presence of contaminants, possibly in higher concentrations elsewhere on the site or the presence of encountering ground conditions at variance with the logs elsewhere on the site cannot be discounted. The scope of the investigation was selected based on the preliminary development proposals provided by the Client and may be inappropriate to another form of development.

2. Site Setting

2.1 Site Description

The site comprises an irregular shaped parcel of land extending to an area of approximately 1.7 ha. The site is bounded by adopted public highways to all aspects, namely Hulme Street to the north, Wilmott Street to the east, Chester Street to the south-east, Mancunian Way to the south-west and Medlock Street to the west. The site is generally surrounded by dense commercial and residential properties with some of these being in the process of development and / or regeneration.

The site is currently disused but can be divided into the following uses:

- The western portion of the site comprising former car parking.
- The southwest corner, currently occupied by grassed land and mature trees.
- The southeast corner, comprising former car parking.
- The north eastern corner, disused and encapsulated by high fences (hoarding).
- The northern extents comprising the former adopted highway of Newcastle Street.

The site is predominately hard surfaced with tarmac with grass surfacing present in the far south-west and an area of rough ground in the northeast. The site falls slightly (by approximately 1.00 m) from south to north.

2.2 Previous Geoenvironmental Assessment

Capita Symonds prepared a Phase 2 Ground Investigation and Assessment report (Reference 1, Section 1.3) for the site in June 2012 and a review of this document was included as part of the Preliminary Geotechnical and Geoenvironmental Assessment by Cundall in January 2016 (Reference 1, Section 1.3).

The factual data contained in the Capita report has been utilised in the preparation of this report to supplement the additional factual GI data obtained during the recent investigation undertaken by Geotechnical Engineering Limited (Reference 3, Section 1.3).

The Capita intrusive investigation comprised the following scope:

- Three Cable Percussive Boreholes with rotary core follow on.
- Five windowless sample probeholes
- Six machine excavated trial pits
- The installation of gas and groundwater monitoring wells in selected exploratory holes along with four return gas/groundwater monitoring visits following completion of the fieldwork

- Sampling and laboratory testing of soil and groundwater

A review of the raw test data collected by Capita was undertaken as part of the Cundall 2016 report using published ATRISK^{SOIL} and CIEH S4ULs screening criteria for the soil analysis and Environmental Quality Standards / Water Supply (Water Quality) Regulations for the soils leachate analysis. The assessment of the data indicated the following:

- The data set is limited with some areas of the site not fully investigated and some materials (specifically the Made Ground soils) not wholly characterised.
- Localised elevated concentrations of heavy metals within the Made Ground soils (specifically Lead) were recorded.
- No significantly elevated concentrations of leachable heavy metals or hydrocarbons were recorded.
- The site does not appear on this initial review to be significantly affected by any off site sources of contamination.
- No assessment with respect to potable water supply pipes has been undertaken.
- Water soluble sulphate concentrations are all below 500 mg/l.
- No significant ground gas concentrations or flows were recorded.

2.2.1 Potential Contaminative Sources Affecting the Site

Following review of the above data and information collected as part of the Cundall 2016 report (Reference 1 Section 1.3) the following potential sources of contamination were identified by Cundall:

- On-site Made Ground associated with the previous phases of development at the site, potentially containing localised elevated concentrations of heavy metals.
- Elevated concentrations of contaminants may exist within the Made Ground at the site located in areas not previous investigated.
- Fly-tipped materials.

3. Purpose and Scope of Ground Investigation

3.1 Purpose

Whilst the previous investigations provided a useful indication of ground conditions at the site, and provided useful data for inclusion in this assessment where relevant, they were prepared for a different scheme and there were a number of aspects that required further assessment / substantiation. These included (but were not limited to):

- A more robust understanding of the solid geology beneath the site for pile design.
- Additional in-situ testing for pavement design.
- Additional investigation for buried obstructions.
- Service location investigation.
- Detailed UXO risk assessment.
- Additional ground gas monitoring and risk assessment.
- Substantiation of the contaminative status of the site, including asbestos analysis.

3.2 Scope

An additional ground investigation was scoped by Cundall and subsequently undertaken by Geotechnical Engineering Ltd. The intrusive works were carried out under the technical monitoring of Cundall.

The investigation and laboratory testing were carried out in general accordance BS 5930:2015, BS 1377, BS EN 1997 and BS 10175:2011, BS EN ISO 14688, BS EN ISO 14689 and BS EN ISO 22475-1. The fieldwork was carried out between 11 and 29 April 2016.

In summary, the ground investigation comprised the following:

- Eight cable percussion boreholes with rotary follow-on (CP/RC101 to CP/RC108).
- Fourteen mechanically excavated trial pits (TP101 to TP114).
- Ninety eight hand excavated trial pits for asbestos screening.
- Eleven trial pits excavated using Vac-Ex (vacuum excavation) to confirm presence of a gas main (off site but immediately adjacent).
- Six in situ California Baring Ratio (CBR) tests (CBR/OP101 to CBR/OP106).

- The installation of combined gas / groundwater monitoring standpipes in three boreholes (CP/RC101, CP/RC102 and CP/RC104).
- A programme of post-site works gas and groundwater monitoring, comprising two monitoring visits over a month's duration to supplement the four visits conducted by Capita over a two month period in 2012.
- Geotechnical and chemical (contamination) testing of soil and rock samples.

An outline summary of the ground investigation results is presented in the following sections. For detailed descriptions of ground conditions at individual exploratory hole positions, reference should be made to the Geotechnical Engineering Ltd. factual report (Reference 3 Section 1.3) dated June 2016.

An Exploratory Hole Location Plan, indicating the locations of both the Capita and Geotechnical Engineering Limited exploratory holes is presented as Drawing 1011906.DWG.GL.009.

4. Recorded Ground Conditions

4.1 Soil Stratigraphy

Published geological mapping indicates the site to be immediately underlain by superficial deposits comprising Glaciofluvial Sheet Deposits (sand and gravel) overlying Glacial Till (clay, sand, gravel, cobbles and boulders) beneath the majority of the site. The Glaciofluvial Sheet Deposits were indicated to be absent beneath the far south eastern extents. The solid geology is indicated to comprise the Chester Pebble Beds Formation (sandstone). Made Ground was anticipated at surface.

The stratigraphy encountered at the exploratory hole positions is generally in keeping with the published geology and is summarised in Table 1. Full details of the ground conditions encountered are recorded in the exploratory hole records, forming part of both the Capita report and the Geotechnical factual report.

Table 1 – Encountered Soil Stratigraphy

Stratum	Description	Elevation of Top of Stratum (m OD)	Stratum Thickness (m)
Made Ground	Hardstanding (all Capita, 2012): 0.1 m reinforced concrete in CP/RC102; tarmac in TP102 & WS101	30.80 to 35.10	0.05 to 0.35
	Topsoil (WS103 &WS104: CS, 2012) dark brown sandy gravelly clay.		0.2 to 0.40
	MADE GROUND comprising variable clay, sand, and gravel containing occasional brick and concrete cobbles, ash, wood and infrequent wire.		0.20 to 3.75
Glaciofluvial Deposits	Fine to medium brown gravelly (predominately sub-rounded quartzite) SAND to SAND & GRAVEL occasional clay layers and clayey pockets	30.10 to 34.20	1.35 to 5.10
Glacial Till	Stiff to very stiff sandy, gravelly CLAY	27.10 to 32.60	1.80 to 7.80
Completely Weathered Bedrock	Completely weathered sandstone recovered as very dense slightly gravelly, slightly clayey to clayey SAND to very dense reddish brown fine grained SAND. Gravel is sub-rounded to rounded sandstone and mudstone (Locally Absent)	21.35 to 26.20	0.50 to 4.15
Competent Bedrock	Extremely weak to medium strong reddish brown fine grained SANDSTONE with sub horizontal and sub-vertical fractures.	19.30 to 21.90	Not proven

An Exploratory Hole Location Plan noting all of the Capita and Geotechnical exploratory holes is presented as 1011906.DWG.009. Indicative geological cross sections through the site are presented as Drawings 1011906.DWG.010 through to 1011906.DWG.013.

4.2 Determination of Engineering Rockhead

The geological sequence at the site does not transition directly from the overlying glacial materials into what may be considered 'competent' rock. Instead, there is generally a weathering profile consisting of completely weathered rock at the top, which will act more like a soil, grading towards a more competent material which will behave as a rock. In order to allow geotechnical design a distinction between these two units must be made. In this report, completely weathered rock is the term used to for material described in the Geotechnical logs as a sand, and this material will be treated for geotechnical design purposes as a granular material with no unconfined compressive strength. Where the Geotechnical logs describe the material as a sandstone (i.e. a rock), this material will be considered as a competent rock for geotechnical design purposes, and be given an unconfined compressive strength.

4.3 Buried Obstructions

As part of the recent Cundall report (Reference 2 Section 1.3), historical fire insurance mapping was reviewed. Plans dated 1968 are presented as Figure 3 and indicate the presence of a former air raid shelter and two basement structures within the site area.

In order to confirm the positioning of the former structures and whether or not the associated basement slabs had been fully broken out, a number of exploratory holes were sited in close proximity to the former buildings identified on the fire insurance mapping (Figure 3). The resulting thicknesses of fill and/or obstruction depths from the Cundall 2016 investigation are summarised as Figure 4 in the context of the development proposals, and, indicate that elements of all three buildings remain buried below the site.

Figure 3 – Extract of 1968 Fire Insurance Plan

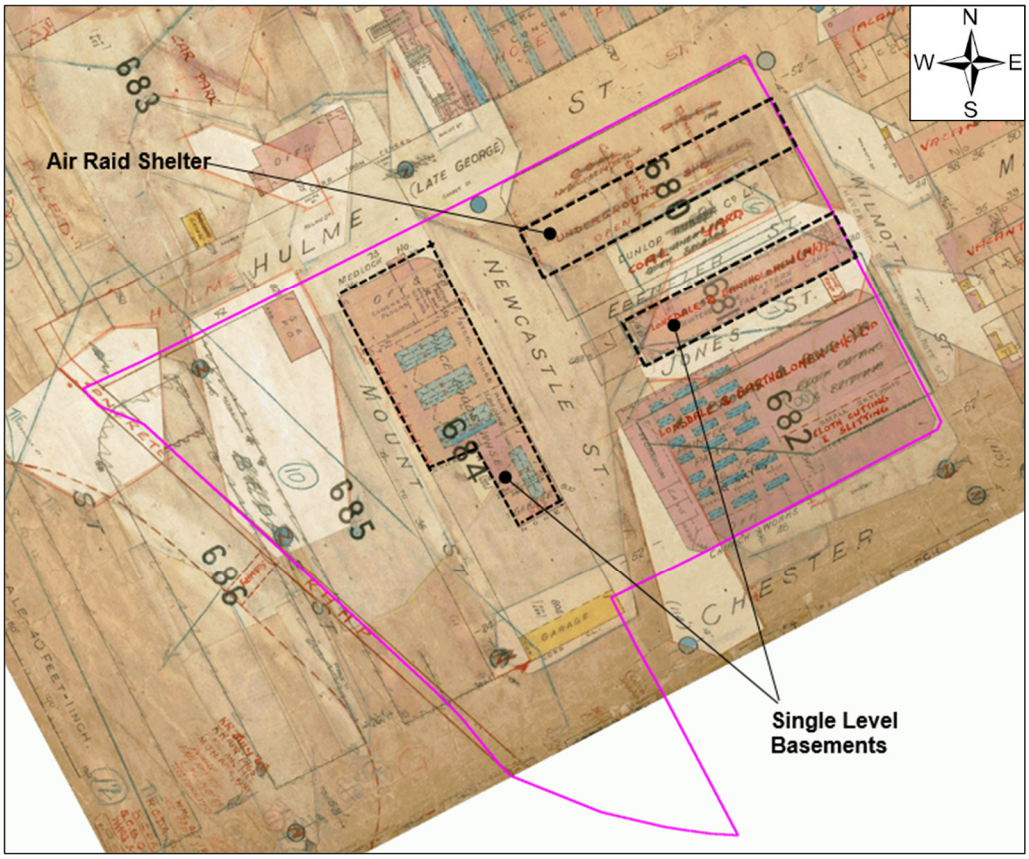
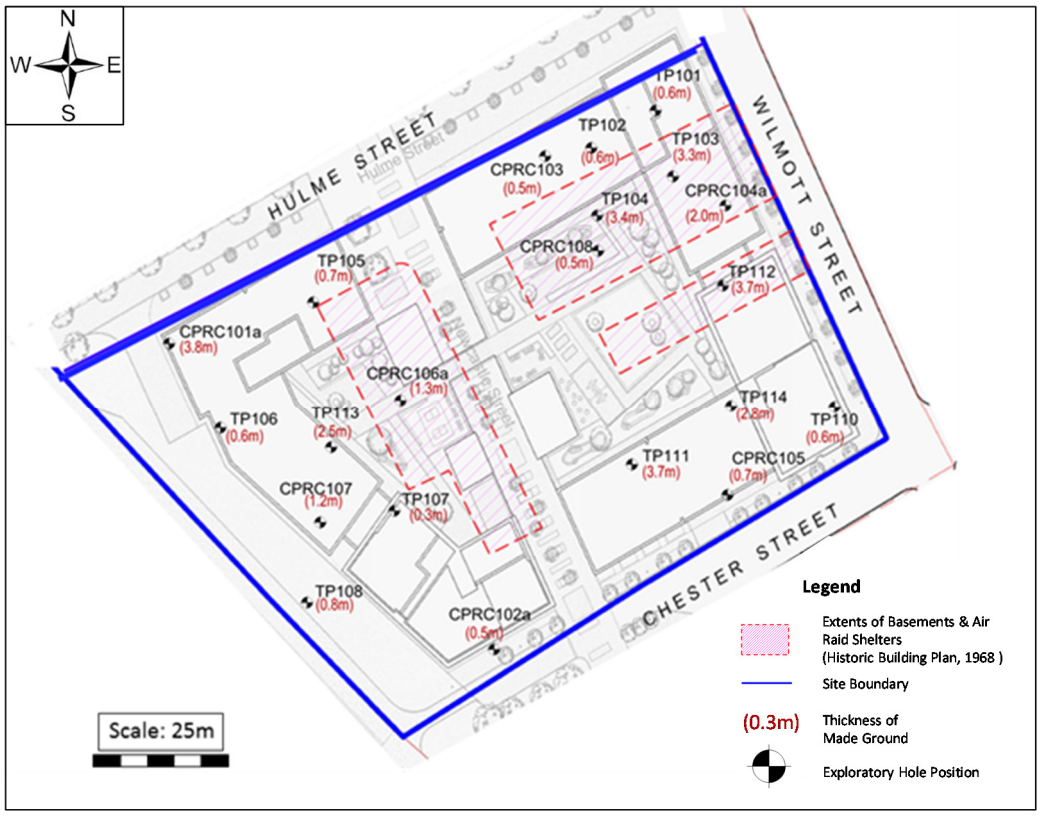


Figure 4 – Possible Obstruction Positions



4.4 Groundwater Levels

Groundwater strikes and results of groundwater level monitoring associated with both phases of investigation works are summarised as Table 2 and Table 3.

Table 2 – Observed Groundwater Strikes

Exploratory Hole Reference	Ground Investigation	Ground Water Strike (m bgl)*1	Elevation of Ground Water Strike (m OD)	Stratum
WS101	Capita, 2012	4.00	29.8*2	Glaciofluvial Deposits
WS102	Capita, 2012	4.80	29.33*2	Glaciofluvial Deposits
WS103	Capita, 2012	4.90	29.24*2	Glaciofluvial Deposits
WS104	Capita, 2012	2.60	32.1*2	Glaciofluvial Deposits
WS105	Capita, 2012	5.00	29.7*2	Glaciofluvial Deposits
CP/RC 102	Geotechnical, 2016	4.97	29.4	Glaciofluvial Deposits
CP/RC 102A	Geotechnical, 2016	5.02	29.7	Glaciofluvial Deposits
CP/RC 103	Geotechnical, 2016	3.81	29.9	Glaciofluvial Deposits
CP/RC 105	Geotechnical, 2016	4.96	29.8	Glaciofluvial Deposits
CP/RC 107	Geotechnical, 2016	4.37	29.7	Glaciofluvial Deposits

N/I - Not Indicated on borehole logs

*1 Strike without 20 minutes of monitoring

*2 Levels determined from Drawing Reference 001 in the Capita (2012) report.

Table 3 – Results of Groundwater Level Monitoring

Exploratory Hole Reference	Base of Monitoring Installation		Strata Response Zone	Observed Groundwater					
				(m bgl)				(m OD)	
	(m bgl)	(m OD)		10/02/2011	15/03/2011	25/03/2011	01/04/2011	05/05/2016	18/05/2016
CPR101*1	20.26	13.9*3	Intact Bedrock	8.64	8.74	8.62	8.62	-	-
CPR102*1	20.07	14.6*3	Intact Bedrock	9.19	9.72	9.86	9.94	-	-
CPR103*1	20.27	14.7*3	Intact Bedrock	9.19	9.27	9.18	9.24	-	-
WS101*1	3.98	29.8*3	Glaciofluvial Deposits	3.92	3.92	3.92	3.91	-	-
WS103*1	4.74	29.14*3	Glaciofluvial Deposits	4.69	4.72	4.69	4.67	-	-
WS105*1	4.92	29.7*3	Glaciofluvial Deposits	4.83	4.91	4.91	4.88	-	-
CP/RC 101B*2	3.50	30.4	Made Ground and Glaciofluvial Deposits	-	-	-	-	31.5	Dry
CP/RC101B*2	15.0	18.9	Glacial Till, Weathered Bedrock, and Intact Bedrock	-	-	-	-	28.1	28.1
CP/RC 102A*2	5.60	29.1	Glaciofluvial Deposits	-	-	-	-	31.0	29.6
CP/RC 104A*2	6.00	28.3	Glaciofluvial Deposits and Glacial Till	-	-	-	-	30.5	29.8

*1 Capita, 2012

*2 Geotechnical, 2016

*3 Levels determined from Drawing Reference 001 in the Capita (2012) report.

5. Ground Engineering Properties

5.1 Characteristic Parameters for Geotechnical Design

Characteristic parameters for geotechnical foundation design are summarised in Table 4. Details of how these values were derived is provided in the following sections.

Table 4 – Characteristic Parameters for Geotechnical Design

Stratum	γ (kN/m3)	c_u (kPa)	φ' (°)	UCS (Mpa)
Made Ground	18	--	--	--
Glaciofluvial Deposits	20	--	34	--
Glacial Till (Cohesive)	22	See Figure 5	30	--
Completely Weathered Bedrock	20	--	35	--
Competent Bedrock	--	--	--	8.0

5.1.1 Made Ground

Bulk Density

A bulk density of 18kN/m^3 is assumed for Made Ground. This is generally consistent with generic values published in BS8002:2015 for engineered fill.

5.1.2 Glaciofluvial Deposits

Bulk Density

A bulk density of 20kN/m^3 is assumed for the Glaciofluvial Deposits. This is generally consistent with generic values published in BS8002:2015 for medium dense granular materials containing gravel.

Internal Angle of Friction

BS8002:2015 suggests that the peak angle of internal friction for sands and gravels is equal to 30 + A + B + C, where A is a measure of angularity, B is a measure of gradation and C is a measure of density. Values of A, B & C are derived as follows:

- The exploratory records describe the Glaciofluvial Deposits as being 'sub-rounded' (Capita Symonds, 2012) and 'sub-rounded to rounded' (Geotechnical Engineering Services, 2016). In accordance with Table 3 of BS8002, A is therefore considered to be equal to 0.

- As part of the recent and previous ground investigation works, the Glaciofluvial Deposits were submitted for particle size distribution testing. The resulting test data indicates a coefficient of uniformity of between 6 and 100, which suggests the deposit to be 'medium to multi graded'. In accordance with Table 3 of BS8002, B is therefore considered to be equal to 4.

- A characteristic SPT 'N' value for this strata is taken as 15. In accordance with Table 3 of BS8002, C is therefore considered to be equal to 0.

On the basis of the above, a φ' value of 34° is considered to be appropriate for the Glaciofluvial Deposits.

5.1.3 Glacial Till (Cohesive)

Bulk Density

A characteristic bulk density of 22 kN/m^3 has been assumed for the cohesive Glacial Till in line with the undrained triaxial laboratory tests. These indicated a range of bulk densities of between 20.9 to 22.5kN/m^3 with a mean bulk density of 22 kN/m^3 based upon a total of ten tests.

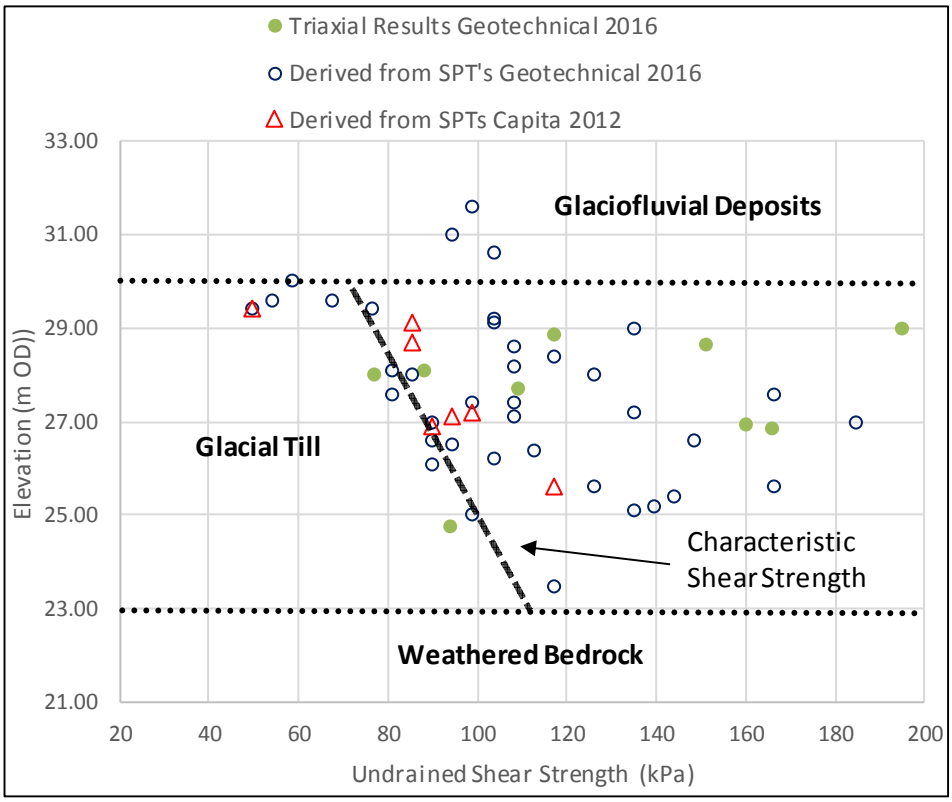
Plasticity

As part of the recent and previous ground investigation works, a total of ten samples of clayey Glacial Till were submitted for plasticity testing. The resulting test values indicate Plasticity Index (PI) to vary between 10 and 20%. For the purpose of this assessment, a characteristic PI value of 20% has been assumed.

Shear Strength

Stroud (1975) suggests that c_u is directly proportional to SPT N, and that the correlation factor (F_1) varies according to PI. Assuming the PI for clayey Glacial Till to be equal to 20%, and using an associated correlation factor of 5.3, the resulting shear strengths are shown in Figure 5.

Figure 5 – c_u Profile for Cohesive Glacial Till



The φ' value for cohesive glacial till is assumed to be equal to 30°. This value is consistent with typical values published in BS8002 based upon a range of PI of between 15 and 20 %.

5.1.4 Glacial Till (Granular)

Bulk Density

A bulk density of 20kN/m³ is assumed for the granular Glacial Till. This is broadly in keeping with generic values published in BS8002:2015 for medium dense to dense granular materials containing gravel.

Internal Angle of Friction

BS8002:2015 suggests that the peak angle of internal friction for sands and gravels is equal to 30 + A + B + C, where A is a measure of angularity, B is a measure of gradation and C is a measure of density. Values of A, B & C are derived as follows:

- The exploratory records describe the granular Glacial Till as being slightly clayey sand with very little gravel content. On this basis, A is therefore considered to be equal to 0.
- No gradation testing has been undertaken on the granular Glacial Till. On the basis that the material is likely to be 'uniform' in nature, B is considered to be equal to 0.

- A characteristic SPT 'N' value for this strata is taken as 30. In accordance with Table 3 of BS8002, C is therefore considered to be equal to 2.

On the basis of the above, a φ' value of 32° is considered to be appropriate for the Granular Glacial Till.

5.1.5 Completely Weathered Bedrock

Bulk Density

A bulk density of 20kN/m^3 is assumed for the completely weathered bedrock. This is broadly in keeping with generic values published in BS8002:2015.

Shear Strength

BS8002:2015 suggests that the peak angle of internal friction for the completely weathered bedrock is equal to 30 + A + B + C, where A is a measure of angularity, B is a measure of gradation and C is a measure of density. Values of A, B & C are derived as follows:

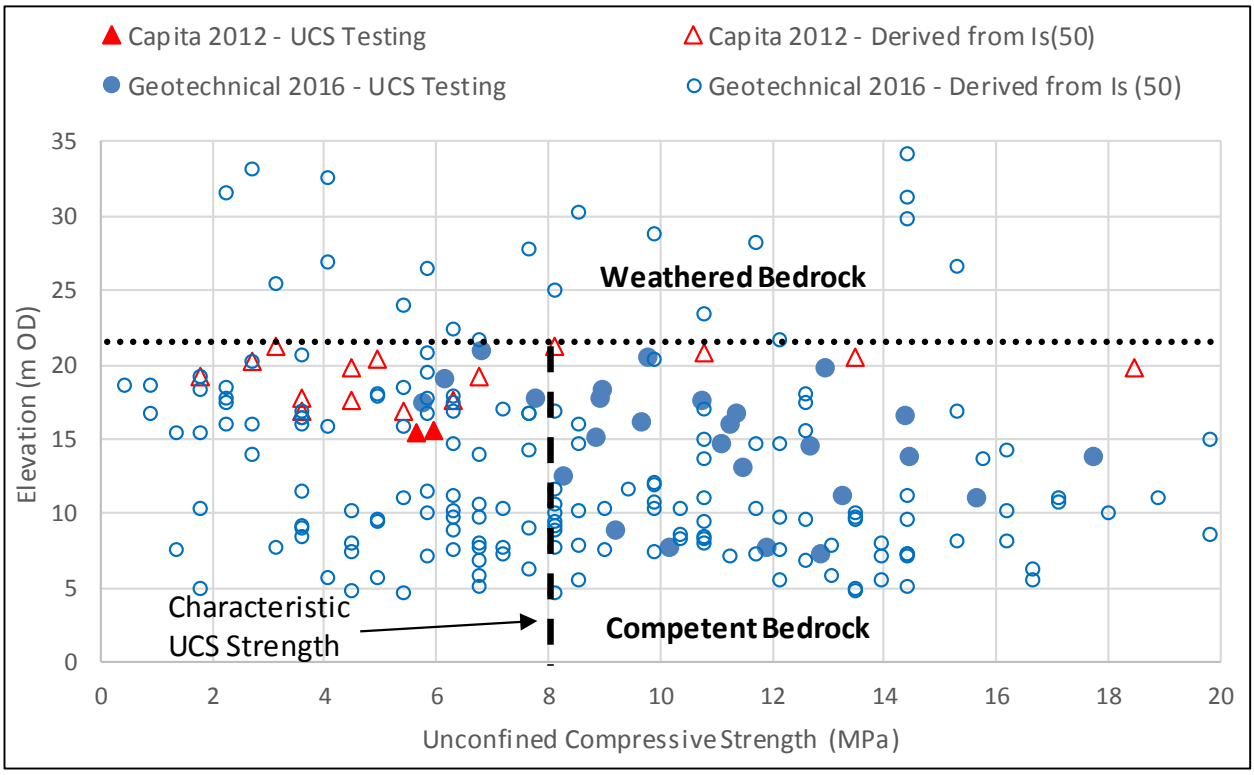
- The exploratory records describe the weathered deposits as being medium-grained sand with very little gravel content. On this basis, A is therefore considered to be equal to 0.
- No gradation testing has been undertaken on the weathered deposits. On the basis that the material is likely to be 'uniform' in nature, B is considered to be equal to 0.
- A characteristic SPT 'N' value for this strata is taken as +50. In accordance with Table 3 of BS8002, C is therefore considered to be equal to 6.

On the basis of the above, a conservative φ' value of 35° is considered to be appropriate for the completely weathered bedrock.

5.1.6 Competent Bedrock

As part of the Capita and Geotechnical ground investigations, a combined number of 197 intact rock samples were submitted for point load index testing and a further 28 samples of intact core were submitted for unconfined compressive strength (UCS) testing. A summary of these tests is presented as Figure 9.

Figure 6 – UCS Profile for Competent Bedrock



It is assumed that UCS is equal to approximately 24x $Is_{(50)}$, where $I_{s(50)}$ denotes the result of point load index testing as referenced in Bieniawski (1989) and Franklin & Dusseault (1989) for sandstone. However, compared to the UCS testing results, a correlation factor of 24 is deemed too low. As a result a correlation factor of 45 has been taken in order to better relate point load testing results with those of the UCS tests, as shown in Figure 6. A conservative characteristic UCS of 8 MPa has been adopted to account for the high degree of scatter within the results obtained.

5.2 Characteristic Groundwater Level

On the basis of the groundwater strikes and stabilised groundwater levels observed during the most recent phase of investigation, the site is anticipated to be underlain by two separate groundwater bodies, namely, locally perched water within the Glaciofluvial stratum and the regional groundwater table deeper within the Principal Aquifer bedrock. The two groundwater bodies are likely to be hydraulically separated by the low-permeability Glacial Till.

The shallow groundwater body is located within the Glaciofluvial Deposits and is recorded at approximately +31.5m OD.

5.3 Ground Aggresivity

Water soluble sulphate and pH testing undertaken as part of both phases of intrusive investigation undertaken at the site are summarised in Table 5.

Table 5 – Results of Geo-Chemical Testing

Investigation	Exploratory Hole Reference	Sample Depth (m)	pH	Sulphate Concentration (as SO_4) in 2:1 extract (mg/l)
Made Ground (Granular)				
Geotechnical, 2016	CP/RC101A	1.20	8.9	69
Geotechnical, 2016	CP/RC103	0.00	8.3	110
Geotechnical, 2016	CP/RC104A	0.30	9.8	200
Geotechnical, 2016	CP/RC104A	1.20	8.8	40
Geotechnical, 2016	CP/RC106A	1.00	8.3	220
Geotechnical, 2016	CP/RC108	0.30	9.6	330
Made Ground (Cohesive)				
Geotechnical, 2016	CP/RC101B	1.00	8.5	10
Glaciofluvial Deposits				
Capita Symonds, 2012	CPR 101	2.1	4.9	200
Capita Symonds, 2012	CPR 102	3.5	7.4	<100
Capita Symonds, 2012	CPR 103	3.7	7.3	<100
Geotechnical, 2016	CP/RC101A	4.20	8.1	46
Geotechnical, 2016	CP/RC102A	4.20	8.2	17
Geotechnical, 2016	CP/RC103	3.20	8.0	55
Geotechnical, 2016	CP/RC104A	2.60	8.3	10
Geotechnical, 2016	CP/RC105	0.65	4.9	74
Geotechnical, 2016	CP/RC105	2.75	4.9	51
Geotechnical, 2016	CP/RC101B	10.20	8.9	21
Geotechnical, 2016	CP/RC102	2.20	8.3	10
Geotechnical, 2016	CP/RC102	4.20	8.5	10
Geotechnical, 2016	CP/RC105	12.70	8.8	10
Glacial Till				
Capita Symonds, 2012	CPR 101	5.1	6.9	<100
Capita Symonds, 2012	CPR 101	7.5	7.9	<100
Capita Symonds, 2012	CPR 102	5.8	8.0	<100
Capita Symonds, 2012	CPR 102	9.5	8.3	<100
Capita Symonds, 2012	CPR 103	6.5	8.0	<100

Investigation	Exploratory Hole Reference	Sample Depth (m)	pH	Sulphate Concentration (as SO_4) in 2:1 extract (mg/l)
Capita Symonds, 2012	CPR 103	12.0	8.3	<100
Geotechnical, 2016	CP/RC105	12.70	8.5	31
Geotechnical, 2016	CP/RC108	6.00	8.4	79

5.4 Road Pavement Design

As part of the most recent phase of investigation, ten in-situ California Bearing Ratio (CBR) tests were undertaken along the central north-south axis of the site. The results are summarised in Table 6.

Table 6 – CBR Test Results

Exploratory Hole Reference	Test Depth (m)	Test Stratum	CBR Value (%)
CPR101	0.40	Made Ground (Granular)	6.7
CPR102	1.00	Made Ground (Granular)	0.7
CBR 102	0.3	Made Ground (Cohesive)	4.1
CBR 103	0.5	Made Ground (Granular)	17
CBR 104	0.5	Made Ground (Granular)	2.8
CBR 105	0.35	Made Ground (Cohesive)	6.9
CBR 106	0.6	Made Ground (Granular)	3.3
CBR 107	0.20	Made Ground (Granular)	19
CBR 108	0.50	Made Ground (Granular)	17
CBR 109	0.30	Made Ground (Granular)	31

6. Ground Gas Risk Assessment

6.1 Introduction and Monitoring

In the current ground investigation, monitoring wells for ground gas were installed in three boreholes (CP/RC101B as nested wells, CP/RD102A and CP/RC104A) to substantiate and further assess the ground gas regime at the site. In total, six rounds of gas monitoring have been undertaken, with four performed during the previous Capita Symonds investigation in Jan 2011. Full monitoring details are given in the Capita Symonds report and the Geotechnical Engineering Ltd factual report, however are summarised in Table 7.

Table 7 – Ground Gas Monitoring Results

BH No	*WS101 (Response Zone: Glaciofluvial Deposits)								
Date	Atmospheric Pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)	
								CO_2	CH_4
10/02/2011	1005	0.8	20.6	<0.1	0.0	0.0	0.1	0.0008	<0.0001
15/03/2011	1009	<0.1	20.5	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
25/03/2011	1001	0.2	20.7	<0.1	0.0	0.0	<0.1	0.0002	<0.0001
01/04/2011	988	<0.1	20.7	<0.1	0.0	0.0	0.1	<0.0001	<0.0001
BH No	***WS103 (Response Zone: Glaciofluvial Deposits)**								
Date	**Atmospheric Pressure (mbars)**	**CO_2 (%v/v)**	**O_2 (%v/v)**	**CH_4 (%v/v)**	**H_2S (ppm)**	**CO (ppm)**	**Gas Flow Rate (l/hr)**	**Gas screening value (l/hr)**	
								CO_2	**CH_4**
10/02/2011	1005	1.8	18.1	<0.1	0.0	0.0	1	0.018	<0.001
15/03/2011	1009	<0.1	20.5	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
25/03/2011	1001	1.2	20.1	<0.1	0.0	0.0	0.1	0.0012	<0.0001
01/04/2011	988	0.6	19.9	<0.1	0.0	0.0	1.6	0.0096	<0.0016
BH No	***WS105 (Response Zone: Glaciofluvial Deposits)**								
Date	**Atmospheric Pressure (mbars)**	**CO_2 (%v/v)**	**O_2 (%v/v)**	**CH_4 (%v/v)**	**H_2S (ppm)**	**CO (ppm)**	**Gas Flow Rate (l/hr)**	**Gas screening value (l/hr)**	
								CO_2	**CH_4**
10/02/2011	1005	<0.1	20.6	<0.1	0.0	0.0	-1.1	<0.0001	<0.0001
15/03/2011	1009	<0.1	20.5	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
25/03/2011	1001	<0.1	20.7	<0.1	0.0	0.0	-0.1	<0.0001	<0.0001
01/04/2011	988	<0.1	20.8	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
BH No	***CP101 (Response Zone: Sandstone Bedrock)**								
Date	**Atmospheric Pressure (mbars)**	**CO_2 (%v/v)**	**O_2 (%v/v)**	**CH_4 (%v/v)**	**H_2S (ppm)**	**CO (ppm)**	**Gas Flow Rate (l/hr)**	**Gas screening value (l/hr)**	
								CO_2	**CH_4**
10/02/2011	1005	<0.1	20.7	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
15/03/2011	1009	<0.1	20.5	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
25/03/2011	1001	<0.1	20.7	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
01/04/2011	988	<0.1	20.7	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001

BH No	*CP102 (Response Zone: Sandstone Bedrock)								
Date	Atmospheric Pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)	
								CO_2	CH_4
10/02/2011	1005	0.1	20.7	<0.1	0.0	0.0	<0.1	0.0001	<0.0001
15/03/2011	1009	<0.1	20.5	<0.1	0.0	0.0	0.3	<0.0003	<0.0003
25/03/2011	1001	0.3	20.1	<0.1	0.0	0.0	1.3	0.0039	<0.0013
01/04/2011	988	0.2	20.4	<0.1	0.0	0.0	0.1	0.0002	<0.0001
BH No	*CP103 (Response Zone: Sandstone Bedrock)								
Date	Atmospheric Pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)	
								CO_2	CH_4
10/02/2011	1005	<0.1	20.3	<0.1	0.0	0.0	0.5	<0.0005	<0.0005
15/03/2011	1009	<0.1	20.5	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
25/03/2011	1001	<0.1	20.6	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
01/04/2011	988	<0.1	20.8	<0.1	0.0	0.0	<0.1	<0.0001	<0.0001
BH No	**CP/RC101B (Response Zone: Made Ground & Glaciofluvial Deposits)								
Date	Atmospheric pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)***	
								CO_2	CH_4
05/05/16	1015	0.8	13.2	0.1	0.0	4.0	<0.1	0.0008	0.0001
18/05/16	1000	0.8	19.6	0.1	0.0	0.0	0.0	0.0008	0.0001
BH No	**CP/RC101B (Response Zone: Glacial Till and Sandstone Bedrock)								
Date	Atmospheric pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)***	
								CO_2	CH_4
05/05/16	1013	0.0	20.1	0.1	0.0	21	<0.1	N/A	0.0001
18/05/16	999	0.1	21.2	0.1	0.0	343	<0.1	0.0001	0.0001
BH No	**CP/RC102A (Response Zone: Glaciofluvial Deposits)								
Date	Atmospheric pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)***	
								CO_2	CH_4
05/05/16	1016	1.2	13.1	0.1	0.0	496	<0.1	0.0012	0.0001
18/05/16	999	2.8	12.7	0.1	0.0	19	<0.1	0.0028	0.0001
BH No	**CP/RC104A (Response Zone: Glaciofluvial Deposits and Glacial Till)								
Date	Atmospheric pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)***	
								CO_2	CH_4
05/05/16	1019	0.8	16.1	0.0	0.0	40	-2.6	0.0008	N/A
18/05/16	1000	0.9	14.3	0.0	0.0	6	<0.1	0.0009	N/A

*Capita Symonds, 2012
** Geotechnical Engineering Limited, 2016
***Note 1

6.2 Risk Assessment

The risk assessment is undertaken based on the gas monitoring undertaken as part of the previous Capita, 2012 site investigation and the recent monitoring as part of the Geotechnical, 2016 investigation.

The risk assessment is undertaken in the context of the design proposals and is based upon guidance including CIRIA C665 and BS8485:2015.

The maximum gas screening value calculated from all of the available monitoring results is 0.0448 l/hr, this calculation is based on the maximum CO_2 concentration of 2.8 % v/v within CP/RC102A (Geotechnical,

2016) and the highest recorded gas flow of 1.6 l/hr within WS103 (Capita, 2012). The maximum recorded methane concentration was 0.1 % v/v in CP/RC101B and CP/RC102A with non-detects typically recorded in other monitoring wells. A maximum methane concentration of 0.1 % v/v along with the highest flow rate of 1.6 l/hr results in a maximum gas screening value of 0.0016 l/hr for methane.

Where the CO_2 levels are recorded above 0.8 % v/v (Geotechnical, 2016) the oxygen levels are recorded to be depleted to levels between 12.7 % v/v and 19.6 % v/v. The lowest recorded oxygen level of 12.7% v/v was recorded within CP/RC102A (Geotechnical, 2016) also where the highest CO_2 gas reading of 2.8 % v/v was recorded.

Based on the results of the maximum gas screening value calculation the site will characterise as Characteristic Situation 1 (CS-1) where no specific ground gas protection measures are required in new buildings in accordance with CIRIAC665 /BS8485. However precautions will be required for any site staff undertaking works in deep excavations / confined spaces where air circulation is limited due to the localised presence of depleted oxygen.

7. Geoenvironmental Assessment

7.1 Geoenvironmental Preface and Assumptions

The proposed development comprises the following elements:

- The construction of a series of multi-storey residential apartment buildings.
- Newcastle Street becoming a 'pedestrian only' highway.
- The inclusion of some retail / commercial at ground level within the residential complex.
- Landscaping within the development is proposed to include limited green spaces (soft landscaping) within the centre of the complex constructed on a raised podium deck, as well as paved access routes and hard-surfaced public realm.

For the purpose of this assessment a 'Residential without home grown produce' end use has been considered the most appropriate. Should the scope / design of the development change significantly, further geo-environmental assessment may be required.

7.2 Environmental Sampling and Testing Strategy

7.2.1 Soils

Environmental testing primarily focused on substantiating the previous Capita, 2012 investigation and provide a detailed assessment of the risks posed by asbestos within made ground soils. The suite of analysis focused on the most likely occurring contaminants associated with the historic land use, identified through the Preliminary Geotechnical and Geoenvironmental Assessment. The analysis also included contaminants that can act as surrogate markers for other less common contaminants.

7.2.2 Groundwater

During the previous site investigation by three ground water samples were collected from CPR101 (15.00 m), CPR102 (15.00 m) and CPR103 (15.00 m) and analysed for metals and semi metals, Total Cyanide, pH and TPH. It was intended to undertake the collection of groundwater samples from well installations located within the made ground and Glaciofluvial Deposits during the recent site investigation, however, following the purging of the wells there was insufficient water within the wells to obtain any water samples so this strategy was not pursued. Therefore only groundwater sampling results from the previous site investigation are discussed further.

7.3 Visual and/or Olfactory Evidence of Potential Contamination

No significant olfactory evidence of contamination was noted during the intrusive investigation.

However, made ground was recorded in all locations across the site with inclusions of materials (for example brick, wood, slag and concrete,) that are considered to represent a potential source of contamination.

7.4 Risk Assessment Framework and Methodology

Reference should be made to the detailed information on the geo-environmental risk assessment framework and methodology presented in Appendix A.

The risk assessment undertaken is based on current UK legislative framework and best practice in the context of the proposed development. In order to put the laboratory measured chemical analysis results for the development site into context, the chemical data obtained during this site investigation has been assessed in relation to guideline values and other criteria commonly used for the assessment of land contamination, as summarised subsequently.

7.4.1 Land (Soil) Quality

The laboratory analysis results for soil samples have been compared against a scenario deemed to reflect the most sensitive receptors of the proposed development in a geoenvironmental context, namely a 'residential without home grown produce' scenario.

Residential without home grown produce use has been selected as, whilst retail/commercial properties are also proposed at the site (on the ground floor of the residential complex), the primary usage of the site will be for residential properties, and this is likely to comprise the most sensitive plausible scenario.

The soil organic matter results ranged from <0.1 mg/kg to 3.5 mg/kg. An overall soil organic matter arithmetic mean of 1.2% was calculated. Therefore, for the purpose of screening, reference was made to the published CIEH S4ULs screening thresholds for soil contaminants adopting their models of organic contaminants at 1%. Additionally the Atkins ATRISK^{SOIL} SSVs with a 1 % SOM have also been used in the absence of suitable S4ULs.

As all the screening criteria for metals assume 6% organic matter, C4SLs were adopted in preference to the CIEH S4ULs, where available, in accordance with current DCLG guidance.

7.4.2 Controlled Waters

The nearest surface water feature to the site is the River Medlock, located 162 m north of the site. The river is wholly culverted within the vicinity of the site; as an open culvert to the north west and north east, and as an enclosed culvert to the north.

The site is underlain by Glaciofluvial Deposits which are classified as a Secondary A Aquifer while the underlying Glacial Till would typically be classified as Unproductive strata and potentially act as an aquiclude. The underlying solid geology is classified as a Principle Aquifer.

Groundwater was encountered within five holes during the Capita, 2012 site investigation, at the following locations and depths:

- WS101 at 4.00 m bgl
- WS102 at 4.80 m bgl
- WS103 at 4.90 m bgl
- WS104 at 2.60 m bgl
- WS105 at 5.00 m bgl

During the post site work monitoring visits groundwater levels were recorded between 3.91 m bgl (WS101) and 9.94 m bgl (CP102).

Groundwater was encountered in five holes during the recent Geotechnical, 2016 site investigation, at the following locations and depths:

- CP/RC102 at 4.97 m bgl (29.47 m OD).
- CP/RC102A at 5.02 m bgl (29.63 m OD);
- CP/RC103 at 3.81 m bgl (29.86 m OD);
- CP/RC105 at 4.96 m bgl (29.79 m OD);
- CP/RC107 at 4.37 m bgl (29.68 m OD).

During the post site work monitoring visits in 2016, groundwater levels were recorded between 2.2 m bgl / 31.70 m OD (CP/RC101B -shallow well) and 5.85 m bgl / 28.05 m OD (CP/RC101B – deep well).

For the Tier 1 Controlled Waters assessment, the recorded groundwater concentrations (taken from the Capita Symonds report) and leachable soil concentrations (during both site investigations) have been compared primarily against UK Drinking Water Standards (DWS) with Environmental Quality Standards (EQS) for Freshwater used where DWS data was not available, this in line with current EA philosophy where the protection of groundwater resources is their current priority and is in the context of a Principal Aquifer at depth (Chester Pebble Beds). Additionally, it is noted that although the River Medlock is located only 162 m to the north of the site and down gradient, it is culverted thus breaking any potential pollutant linkage and therefore DWS was retained as the primary assessment criteria.

7.5 Analytical Test Results

During the previous investigation a total of five soil samples recovered from the exploratory holes were subjected to a range of analytical suites. Additionally a further fourteen soil samples recovered from the exploratory holes were subjected to a range of analytical suites during the Cundall investigation. The results of which are summarised in Table 8 against the adopted land use threshold values. A total of eleven samples

were subjected to leachability testing. The leachate test results (together with the selected Tier 1 assessment values and the determinants analysed for) are presented in Table 9.

7.5.1 Soil Test Results

Table 8 – Summary of Soil Chemical Test Results and Tier 1 Assessment

Contaminant	Units	Test Results Range	No. of Tests	Threshold Value for 'Residential without Home Grown Produce' Land Use	No. of Test Results above Threshold
Metals, semi-metals					
Arsenic	mg/kg	3.4-37	19	40*	-
Cadmium	mg/kg	<0.2 - <1.0	19	149*	-
Chromium III	mg/kg	7-40	19	910**	-
Chromium VI	mg/kg	<4.0	14	21*	-
Copper	mg/kg	4.8-200	19	7100**	-
Lead	mg/kg	9-990	19	310*	7 (WS101 at 0.5 m, WS105 at 0.3m, TP111 at 0.3 m, CP/RC101A at 0.6 m, CP/RC101B at 0.6 m, CP/RC101A at 3.3 m and CP/RC106A at 0.6 m)
Mercury	mg/kg	<0.3-3.6	19	56 (inorganic)**	-
Nickel	mg/kg	7-52	19	180**	-
Zinc	mg/kg	25-390	19	40000**	-
Inorganics					
pH	N/A	6.5-9.4	19	N/A	-
Cyanide Total	mg/kg	<1.0	19	34***	-
TPH					
Aliphatic C5-C6	mg/kg	<0.1	1	42**	-
Aliphatic C6-C8	mg/kg	<0.1	1	100**	-
Aliphatic C8-C10	mg/kg	<0.1	1	27**	-
Aliphatic C10-C12	mg/kg	<1.0	1	130**	-
Aliphatic C12-C16	mg/kg	<2.0	1	1100**	-
Aliphatic C16-C35	mg/kg	<8.0	1	650000**	-
Aromatic C5-C7	mg/kg	<0.1	1	370**	-
Aromatic C7-C8	mg/kg	<0.1	1	860**	-
Aromatic C8-C10	mg/kg	<0.1	1	47**	-
Aromatic C10-C12	mg/kg	<1.0	1	250**	-
Aromatic C12-C16	mg/kg	3.3	1	1800**	-
Aromatic C16-C21	mg/kg	14	1	1900**	-
Aromatic C21-C35	mg/kg	17	1	1900**	-
PAHs					
Acenaphthylene	mg/kg	<0.10-0.26	19	2900**	-
Acenaphthene	mg/kg	<0.10-0.44	19	3000**	-
Anthracene	mg/kg	<0.10-0.81	19	31000**	-
Benzo(a)anthracene	mg/kg	<0.10-3.6	19	11**	-
Benzo(a)pyrene	mg/kg	<0.10-2.0	19	5.3*	-
Benzo(b)fluoranthene	mg/kg	<0.10-3.3	19	3.9**	-
Benzo(ghi)perylene	mg/kg	<0.05-1.2	19	360**	-
Benzo(k)fluoranthene	mg/kg	<0.10-1.4	19	110**	-
Chrysene	mg/kg	<0.05-2.6	19	30**	-
Dibenzo(ah)anthracene	mg/kg	<0.10-0.22	19	0.31**	-
Indeno(123cd)pyrene	mg/kg	<0.10-0.86	19	45**	-
Fluoranthene	mg/kg	<0.10-5.3	19	1500**	-

Contaminant	Units	Test Results Range	No. of Tests	Threshold Value for 'Residential without Home Grown Produce' Land Use	No. of Test Results above Threshold
Fluorene	mg/kg	<0.10-0.41	19	2800**	-
Naphthalene	mg/kg	<0.10-0.93	19	2.3**	-
Phenanthrene	mg/kg	<0.10-4.3	19	1300**	-
Pyrene	mg/kg	<0.10-5.4	19	3700**	-
Others					
Soil Organic Matter	%	<0.1-3.5	14	N/A	-

N/A – Not applicable / No threshold value exists
PAHs & TPHs assume 1.0% Soil Organic Matter (SOM), Metals assume 6% (SOM
*SP1010 Screening Levels from Assessment of Land Affected by Contamination – Policy Comparison document Dec 2014 (C4SLs)
** LQM/CIEH S4ULs
*** Atkins ATRISK^{SOIL} Soil Screening Values

All soil samples tested returned determinand concentrations, with the exception of lead, below either their laboratory limits of detection or below their corresponding Screening Tier 1 Criteria for a 'residential without home grown produce' end use. Exceedances of Lead were recorded and these are summarised in drawing 1011906.DWG.GL.014 including the exploratory hole location and sample depth.

7.5.2 Asbestos Quantification Results

A total of eighty seven samples were tested for asbestos fibres in soil with asbestos recorded in seventeen samples.

All seventeen samples that screened positive for asbestos were subjected to asbestos quantification testing.

Of the seventeen quantification tests carried out, six samples recorded a percentage mass above the detection level of 0.001%. The majority of these six samples recorded a quantum at relatively low levels between 0.001 and 0.015%. However loose fibres associated with crocidolite asbestos was recorded towards the centre of site at location AOP8AF7 at 1.0 m bgl at a percentage mass of 1.485% w/w.

The location, asbestos type and percentage mass of these six samples are detailed in Drawing 1011906.DWG.GL.015.

7.5.3 Soil Leachate Results

Table 9 – Summary of Soil Leachate Test Results and Tier 1 Assessment

Contaminant	Units	Test Results Range	No of Tests	Threshold Value		No and location of Threshold Value Exceedances
				DWS	EQS	
pH (2)	N/A	7.3 - 9.1	8	N/A	6-9	**1 (CP/RC101B at 0.6 m)**
Arsenic	ug/l	0.4 - 19	11	10	50	**3 (CP/RC101A at 1.0 m, CP/RC101A at 3.3 m and TP112 at 1.3m)**
Chromium (2)	ug/l	<0.4 - 29	11	50	250	-
Cadmium	ug/l	0.05 – 0.09	11	5	5	-
Copper (2)	ug/l	<0.5 - 16	11	2000	10	**3 (CP/RC101A at 1.0 m, CP/RC101A at 3.3 m and TP112 at 1.3 m)**
Lead (2)	ug/l	<0.3 - 31	11	10	250	**4 (CP/RC101A at 1.0 m, CP/RC102A at 0.6 m, CP/RC101A at 3.3 m and TP112 at 1.3 m)**
Nickel (2)	ug/l	<0.3 – 1.7	11	20	200	-
Zinc (2)	ug/l	<0.4 - 21	11	5000	250	-
Mercury	ug/l	<0.5	11	1	1	-
Cyanide (2)	ug/l	<10 - 67	8	50	N/A	**1 (TP112 at 1.3 m)**
Sulphate as S04	mg/l	8.5 – 32.9	8	250	400	**-**
Acenaphthylene	ug/l	<0.01	8	N/A	N/A	-
Acenaphthene	ug/l	<0.01 – 0.41	8	N/A	N/A	-
Anthracene (3)	ug/l	<0.01 – 0.21	8	N/A	0.4	-
Benzo(a)anthracene	ug/l	<0.01 – 0.52	8	N/A	N/A	-
Benzo(a)pyrene (3)	ug/l	<0.01 – 0.35	8	N/A	**0.1**	**1 (TP112 at 1.3 m)**
Benzo(b)fluoranthene (4)	ug/l	<0.01 – 0.45	8	N/A	**0.03**	**1 (TP112 at 1.3 m)**
Benzo(ghi)perylene (4)	ug/l	<0.01	8	N/A	0.002	-
Benzo(k)fluoranthene (4)	ug/l	<0.01 – 0.26	8	N/A	**0.03**	**1 (TP112 at 1.3 m)**
Chrysene	ug/l	<0.01 – 0.54	8	N/A	N/A	-
Dibenzo(ah)anthracene	ug/l	<0.01	8	N/A	N/A	-
Indeno(123cd)pyrene (4)	ug/l	<0.01	8	N/A	0.002	-
Fluoranthene (3)	ug/l	<0.01 – 1.1	8	N/A	**1**	**1 (TP112 at 1.3 m)**
Fluorene	ug/l	<0.01 – 0.20	8	N/A	N/A	-
Naphthalene (4)	ug/l	<0.01 – 1.1	8	N/A	2.4	-
Phenanthrene	ug/l	<0.01 – 0.83	8	N/A	N/A	-
Pyrene	ug/l	<0.01 – 1.2	8	N/A	N/A	-
PAH Total (1)	ug/l	<0.2 – 7.2	8	0.1	N/A	-
Phenol	ug/l	<10	8	0.5	4.6	-
TPH (C10-C40) (5)	ug/l	<10	8	N/A	300	-

N/A – Not applicable / No threshold value exists.
DWS – UK Drinking Water Standards.
EQS – Environmental Quality Standards (Freshwater*)
(1) – The PAH (total) concentrations and the DWS for PAH are based on the sum of the 4 PAHs [benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene].
(2) – Freshwater threshold values based on an assumed hardness banding (CaC03) of 201-300 (Source DEFRA Hardness Map).
(3) – Maximum Allowable Concentration EQS
(4) – Annual Average EQS
(5) –EQS for Mineral Oil based on TPH (Total) concentrations

Soil leachate test results for Arsenic, Lead, Cyanide marginally exceed their respective Tier 1 assessment criteria (DWS).

Soil leachate test results for pH, Copper and PAHs, namely Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, and Fluorene marginally exceed their Tier 1 assessment criteria for EQS, in the absence of any DWS criteria for these contaminants.

7.5.4 Groundwater Test Results

Table 10 – Summary of Groundwater Test Results and Tier 1 Assessment

Contaminant	Units	Test Results Range	No of Tests	Threshold Value		No and location of Threshold Value Exceedances
				DWS	EQS	
pH (1)	N/A	7.0-7.6	3	N/A	6-9	**-**
Arsenic	ug/l	2.3-4.6	3	10	50	**-**
Selenium	ug/l	1.2-28	3	10	N/A	**2 CP101 (15 m bgl) and CP103 (15 m bgl)**
Chromium (1)	ug/l	17-19	3	50	250	-
Cadmium	ug/l	0.05-0.09	3	5	5	-
Copper (1)	ug/l	1.9-4.9	3	2000	10	**-**
Lead (1)	ug/l	<0.3	3	10	250	**-**
Nickel (1)	ug/l	5-11	3	20	200	-
Zinc (1)	ug/l	7-12	3	5000	250	-
Mercury	ug/l	<0.05	3	1	1	-
Cyanide (1)	ug/l	<0.05	3	50	N/A	**-**
TPH (C10-C40) (2)	ug/l	<10		N/A	300	-

N/A – Not applicable / No threshold value exists.
DWS – UK Drinking Water Standards.
EQS – Environmental Quality Standards (Freshwater*)
(1) – Freshwater threshold values based on an assumed hardness banding (CaC03) of 201-300 (Source DEFRA Hardness Map).
(2) –EQS for Mineral Oil based on TPH (Total) concentrations

The groundwater samples analysed from the Capita, 2012 report recorded concentrations below either the laboratory detection limits or below the DWS or EQS assessment criteria with the exception of Selenium.

7.6 Risk Assessment Discussion and Summary

7.6.1 Land (Soil) Quality

This risk assessment has been undertaken in general accordance with the risk assessment framework and methodology presented in Appendix A.

Lead

Elevated concentrations of Lead have been identified within the made ground at exploratory hole locations TP111 at 0.30 m, CP/RC101A at 0.60 m, CP/RC101B at 0.60 m, CP/RC101A at 3.30 m CP/RC106A at 0.60 m, WS101 at 0.50 m bgl and WS105 at 0.30 m bgl. Statistical analysis was therefore undertaken to determine whether the elevated concentrations could be considered part of the wider sample population, or where statistical outliers potentially represented contamination hotspots.

Mean Value Test

The laboratory test data was initially checked for completeness and in the context of the exploratory hole records to ensure it could be considered representative of the made ground at the site, and, in this context, no concerns were identified. A statistical test for Lead was subsequently applied to determine whether there was sufficient evidence that the true mean concentration was less than the relevant critical concentration for that component.

The Shapiro Wilk Test was carried out on the data set to determine which statistical test to apply. The Shapiro Wilk Test determined that the data set has come from a normally distributed population therefore the one sample t-test was performed. The results of the one sample t-test is shown in Table 11.

Table 11 – Data Distribution and UCL 95 Assessment - Lead

Samples	Non-detects	Assessed distribution	UCL 95	Critical Concentration (Threshold Value)	Outliers	Maximum Value
19	0	normal	147.06	310	7	990

The results of the statistical analysis for Lead shows that the Upper Confidence Limit of the true population mean is below the respective critical concentrations.

Maximum Value Test

As can be seen in Table 11 there are seven outliers, TP111 at 0.3 m bgl, CP/RC101A at 0.6 m bgl, CP/RC101B at 0.6 m bgl, CP/RC101A at 3.3 m bgl, CP/RC106A at 0.3 m bgl, WS101 at 0.5 m bgl and WS105 at 0.3 m bgl. However, it is considered that these locations are not 'true' outliers or 'hotspots' and that Lead is ubiquitous because:

- The exploratory hole log descriptions at these locations are generally consistent, and consistent with the made ground descriptions across the remainder of the site.
- These locations are not spatially restricted to a particular area and therefore do not represent geographic hotspots, in addition the exploratory techniques differ between sample locaitons ruling out cross contamination as a potential cause.

Therefore on the basis of the above:

- The risks to the site end users are considered to be **low** where hard-surfacing is used as this physical barrier is considered sufficient to break the pollutant linkage to the site end users. Under this scenario no further action is required.
- The risks to the site's end users are considered to be **low** where soft landscaping is proposed, as this will be constructed on raised podium slabs (within raised beds) and not in direct contact with the existing made ground. Under this scenario no further action is required.
- The risks to the general public during construction are considered to be **moderate** due to the risks of fugitive dust migrating off site and the close proximity of potential receptors and further action will be required to mitigate the risk.

- The risks to construction workers are considered to be **high.** It is assumed that in order to mitigate any construction stage risk that construction workers will adopt good hygiene procedures and the correct Personal Protective Equipment (PPE) is used, as employing these measures is considered sufficient to mitigate the identified risks.

Asbestos

Asbestos fibres were recorded during the site investigation within seventeen of the eighty seven samples tested. The asbestos quantification testing carried out recorded six samples to be above the detection limit of 0.001% w/w.

Therefore, on the basis of the above:

- The risks to the site's end users are considered to be **low** as the site is to be covered in hard-surfacing and the landscaping is to comprise raised podium slabs with planters and will not be in direct contact with the existing made ground. Under this scenario no further action is required.

- The risks to the general public during construction are considered to be **very high** due to the risks of asbestos fibres migrating off site and the close proximity of potential receptors. Therefore further action will be required to mitigate the risk.

- The risks to construction workers are considered to be **very high** due to the risks of liberation of asbestos fibres during the construction phase. It is assumed that in order to mitigate any construction stage risks that construction workers will adopt the appropriate personal protection equipment (PPE & RPE) and following correct occupational hygiene practices, and, that good construction practice is employed to mitigate dust / fibre migration during the works.

7.6.2 Assessment of Risk Through New Water Supply Pipes

A full suite of analysis and assessment, in accordance with UKWIR Report Reference Number 10/WM/03/21, has been undertaken to ascertain the risk posed to end users from the permeation of the proposed new potable water supply pipes within the proposed development. Four soil samples from between 0.8 m bgl and 1.3 m bgl were tested and the results of these analyses are summarised in Table 12.

Table 12 – UKWIR Test Results & Pipe Material Risk Assessment

Determinant	Units	Results Range	PE Threshold	PE pass / Fail
Extended VOC	mg/kg	<0.001	0.5	Pass
BTEX + MTBE	mg/kg	<0.001	0.1	Pass
Extended SVOC	mg/kg	<0.05-8.0	2.0	Fail

Determinant	Units	Results Range	PE Threshold	PE pass / Fail
Cresols & Chlorinated Phenols	mg/kg	<0.001	2.0	Pass
Phenols	mg/kg	<0.007	2.0	Pass
Mineral Oil (C11-C20)	mg/kg	<10-43	10	Fail
Mineral Oil (C21-C40)	mg/kg	<10-600	500	Fail
Conductivity	uS/cm	110-880	-	Pass
Redox Potential	mV	211.90-254.90	-	Pass
pH		8.2-10.2	-	Pass

This assessment has been based on a worst case scenario assuming new water pipes will be laid in the made ground soils at a typical depth of 0.90 m bgl. Under this scenario the laboratory analysis indicates that Polyethylene (PE) pipes are unlikely to be suitable and would result in a **moderate** risk to site end users.

However, the type of pipe material used for any new supply pipes should take into account the final design proposals which include supplies being suspended as part of the podium slab design.

7.6.3 Controlled Waters

Two samples from the Capita Symonds site investigation recorded marginally elevated Selenium concentrations. Additionally marginally elevated concentrations of leachable contaminants, namely Arsenic, Lead, Copper, Cyanide and limited PAHs have been recorded within the samples of made ground. However the overall risk ranking is considered to be **low** for the following reasons:

- Recorded threshold exceedances of leachable concentrations are limited in their concentrations.
- The site is to comprise hardstanding post construction, therefore the potential for leachate generation post construction will be significantly reduced through the hard-surfacing, therefore reducing the risk.
- There are no surface water abstractions within 500m of the site.
- There are no ground water abstractions within 250m of the site.
- There are no Source Protection Zones (SPZs) within 250m of the site.
- Although the River Medlock is located 162 m to the north of the site and is down gradient, it is wholly culverted breaking any potential pollutant linkage.

It should be noted that any assessment of controlled waters for a 'significant risk of significant harm' should be undertaken in the context of the Environment Agency's current stance on the definition of 'significant', which, is intended to capture only those scenarios where there are tangible, demonstrable, and plausible risks of negative affects upon either human health or the wider environment, rather than marginal exceedances of individual Tier 1 threshold values.

7.7 Refined Conceptual Site Model

A semi quantitative risk assessment (Tier 1/2) approach has been undertaken for the site, based on the available site information. This is based on source – pathway – receptor conceptual risk model in accordance with current UK guidance and establishes the likelihood and severity of potentially active pollutant linkages at the site.

The refined conceptual site model represented below is based on the site's proposed end use predominately residential (with no home grown produce). The risks identified at the site as a result of the proposed development (assuming no remedial action is implemented) are summarised in Table 13, with a graphical representation given in Drawing 1011906.DWG.GL.016.

Table 13 – Refined Conceptual Site Model

Contaminant Source	Pathway	Receptor	Consequence of Pollutant Linkage	Likelihood of Pollutant Linkage	Overall Risk
Asbestos fibres or ACMs in the near surface soils	1. Inhalation of fibres	Construction workers / future maintenance workers	Severe	High	Very High
		Site end users	Severe	Unlikely	Moderate / Low
		Adjacent site users (general public during construction)	Severe	High	Very High
Contamination within the Made Ground on site (Lead)	2. Dermal Contact	Construction workers	Severe	Likely	High
		Site end users	Severe	Unlikely	Low
	3. Inhalation of fugitive dust	Construction workers / future maintenance workers	Severe	Likely	High
		Site end users	Severe	Unlikely	Low
		Adjacent site users (general public during construction)	Severe	Low likelihood	Moderate

Contaminant Source	Pathway	Receptor	Consequence of Pollutant Linkage	Likelihood of Pollutant Linkage	Overall Risk
	4. Ingestion of soils	Construction workers / future maintenance workers	Severe	Low	Moderate
		Site end users	Severe	Unlikely	Low
Contaminants within the Made Ground on site	5. Vertical / lateral migration	Controlled waters (Secondary A and Principal Aquifers)	Minor	Likely	Low
Contaminants within the Made Ground on site	6. Permeation of buried services (new water supplies)	Site end users / Construction workers	Severe	Low	Moderate
Asphyxiant and/or explosive ground gases (CO2, CH4)	7. Accumulation of toxic / asphyxiant explosive gases	Construction workers	Severe	Unlikely	Low
		Site end users	Severe	Unlikely	Low
	8. Accumulation of explosive gases	Build environment / Structures	Severe	Unlikely	Low
Depleted oxygen	9. Asphyxiation	Construction workers	Severe	Low	Moderate

7.8 Outline Remediation Strategy

Potentially significant pollution linkages have been identified and therefore, remedial action will be required to mitigate the identified pollution linkages. Additionally, it is considered that a detailed remediation and verification strategy will be required as part of the planning process. However, in summary, the following key remedial measures are anticipated as being required:

- The Contractor must undertake a risk assessment in accordance with Control of Asbestos Regulations (2012) and prepare their own method statements with respect to how they intend to mitigate the risk. On site control measures are likely to include (note this is not exhaustive / exclusive) appropriate PPE and RPE, dust / fibre control measures, dust and fibre monitoring.
- Dust and fibre control measures must be employed at all times during earthworks including the sheeting and damping down of soil stockpiles as required, damping down of haul routes and wheel washing as required. Dust and fibre migration must be prevented at all times and environmental controls must be agreed with the Local Planning Authority.
- The Contractor must ensure that adequate provision is made for working in confined spaces / deep excavations due to the locally recorded presence of depleted oxygen within the soils beneath the site.
- Any previously unidentified contamination arising during the site development remains a possibility. In recognition of this, the Contractor has a responsibility to notify the Client / Contract Administrator should

any unusual ground conditions or previously unidentified contamination (e.g. evidence of visual or olfactory contamination) be revealed during the redevelopment of the site. If such conditions are encountered, work in the area of the contamination should stop until expert advice has been sought and appropriate action (agreed with the Local Planning Authority) taken.

- Management of waste soils will be required in accordance with WM3 and the Landfill Directive, and, where appropriate the Definition of Waste Code of Practice (DoWCoP).

8. Disposal of Soil Waste

8.1 Introduction

The Contractor must ensure that any waste soils are first adequately classified in accordance with the EA's WM3 guidance prior to applying the results of WAC (Waste Acceptance Criteria) analysis.

8.2 WAC Analysis Undertaken

Three WAC analyses were undertaken on the made ground material at the site to provide an indication of the typical waste streams in the event of off-site disposal. A summary of the WAC testing results are presented in Table 14. Copies of the results can be found in the Geotechnical Engineering Ltd factual report.

Table 14 – WAC Test Results

Exploratory Hole Reference	Sample Depth (m)	WAC Category			Remarks
		Inert	Stable Non-Reactive Hazardous Waste	Hazardous Waste	
CP/RC101A	0.30	--	Yes	--	Total Organic Carbon (3.1%) in excess of inert threshold (3.0%) Mineral Oil (580 mg/kg) in excess of inert threshold (500 mg/kg)
CP/RC101B	1.5 – 1.6	Yes	--	--	--
CP/RC104A	0.30	--	Yes	--	Total PAH (810 mg/kg) in excess of inert threshold (100 mg/kg)

Further to the above, it should be noted that:

- UK legislation requires that all waste scheduled for off-site disposal receive some form of 'pre-treatment'. Although minimum requirements for pre-treatment are not defined, this could include drying out of water-logged material, mechanical sorting, hand picking of visible asbestos fragments, removal of organic matter, etc.
- Additional WAC testing will be required prior to any off-site disposal. The minimum frequency of testing will need to be agreed with individual landfill operators and must meet the requirements of current UK legislation and guidance.

9. Geotechnical Assessment

9.1 Assumed Actions

The range of envisaged column loads for each of the four tower blocks is presented as Table 15 below. These values should be read in conjunction with Figure 7, are representative of un-factored (SLS) actions, and were derived during the course of the Stage 3 design.

Figure 7 – Illustrative View of Structural Model

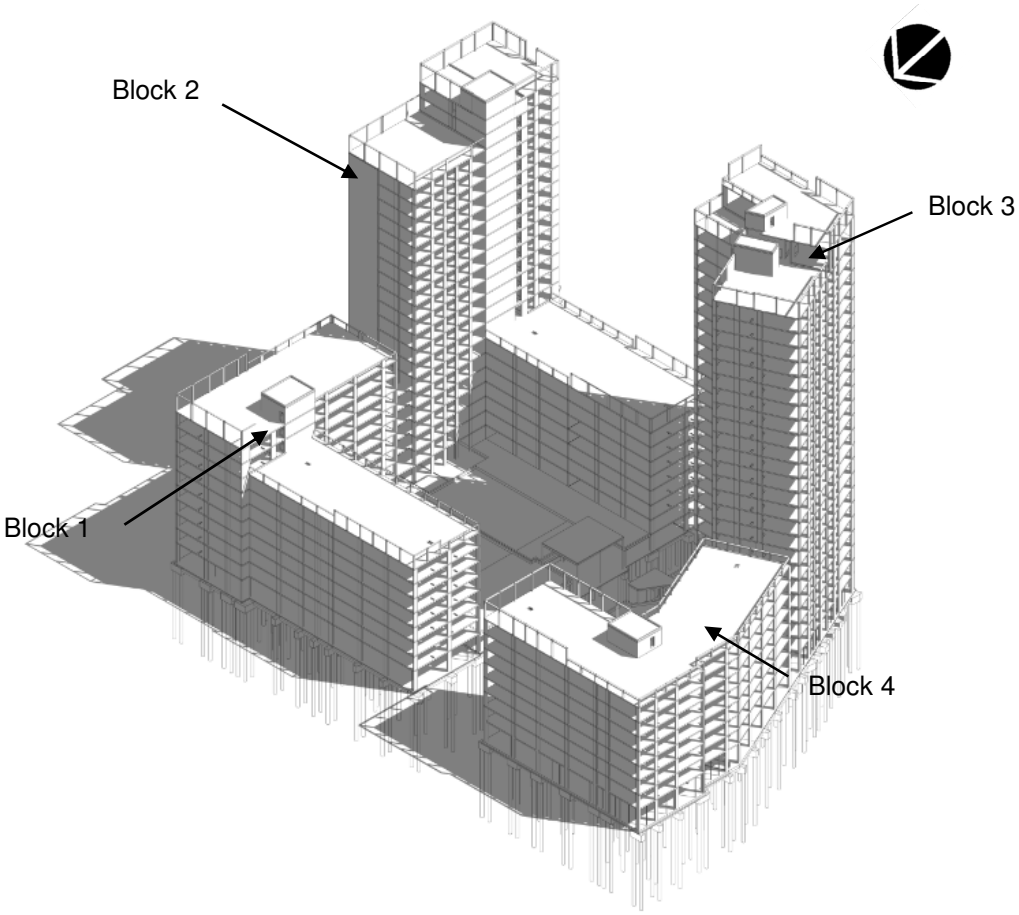


Table 15 – SLS Actions

Block	Column Loading (kN)		$\frac{\text{Core Load}}{\text{Core Area}}$ (kPa)
	Minimum	Maximum	
1	1,450	6,000	750
2	1,500	5,500	750
3	1,300	5,800	1,600
4	1,200	5,500	350

9.2 Buried Obstructions

Historical fire insurance mapping suggests the presence of two former basements and an air raid shelter at the site. The positioning of these features has been confirmed by ground investigation along with the identification of previously undocumented obstructions, with details presented within Table 16.

Table 16 – Buried Obstructions

Exploratory Hole	Depth Obstruction Encountered (mbgl)	Description of Obstruction
TP103	3.30	Exploratory hole terminated on Light greenish grey concrete obstruction – assumed to be remnant of air raid shelter
CP/RC104	0.70	Exploratory hole terminated due to concrete obstruction – assumed to be remnant of air raid shelter
TP114	2.75	Exploratory hole terminated due to manmade void, possibly a cellar, on the eastern edge of the trial pit (extent not determined)
CP/RC106A	1.10	Inspection pit terminated at 1.30 m bgl due to brick culvert

It is assumed that basement retaining walls remain fully intact. Should these features remain buried below the site, then they will pose an obstruction to future piling works and an allowance should be made for probing at individual pile positions within the affected areas.

Additional exploratory works may be required to fully quantify the exact extent and orientation of relic underground features.

9.3 Foundations

The optimal foundation solution will be dependent upon a review of: (a) cost; (b) buildability; and (c) settlement performance. A range of possible foundation solutions are presented in the following sections.

9.3.1 Raft Foundation

Raft foundations are most effective where the change of net change of vertical stress (building load minus excavation unloading) does not exceed 100kPa. As the proposed development does not incorporate any form of basement excavation, the net change of vertical stress at building core positions will be much greater than this limiting value and, for this reason, the use of a raft foundation solution is unlikely to be technically feasible.

9.3.2 Shallow Footings

Given the structural loads imposed it is considered unlikely that shallow pad foundations will be suitable or cost effective for the proposed development and are not discussed further.

9.3.3 Piled Foundations

Consideration should be given to deep (piled) foundation solutions.

Although continuous flight auger (CFA), rotary bored, and driven steel piles are all technically feasible foundation solutions, driven piles are unlikely to penetrate more than a few hundred millimetres into the Sandstone bedrock and are not likely to be acceptable due to noise levels, on this basis they have been discounted.

CFA piles are advantageous in the sense that they do not require temporary support within made ground, Glaciofluvial Deposits, or completely weathered sandstone, but installation depths will be limited to 2.5 or 3.0m in competent Sandstone bedrock. Any obstructions relating to former basement and/or air raid shelter structures would also need to be broken out / pre-bored in advance of piling.

Rotary bored piles can provide a high-capacity foundation solution, but will require temporary steel casing to the base of the Glaciofluvial Deposits and temporary fluid support within the completely weathered Sandstone. Unlike the CFA method, this pile type does not require that buried obstructions be broken out in advance of piling, although removal of shallow obstructions prior to piling may be more economical.

Design compression resistance values for CFA and bored piles are summarised as Figure 8 and

Figure 9. It should be noted that these values have been prepared in accordance with Eurocode 7 and are representative of ULS Design Approach 1 Combination 2. Although ULS Design Approach 1 Combination 1 will also need to be considered, this combination is unlikely to have any impact upon overall pile geometries. Where piles reach competent bedrock, and rely on this strata for end-bearing, a minimum embedment of 2.50 m should be achieved.

Figure 8 – Compression Resistance for CFA Piles

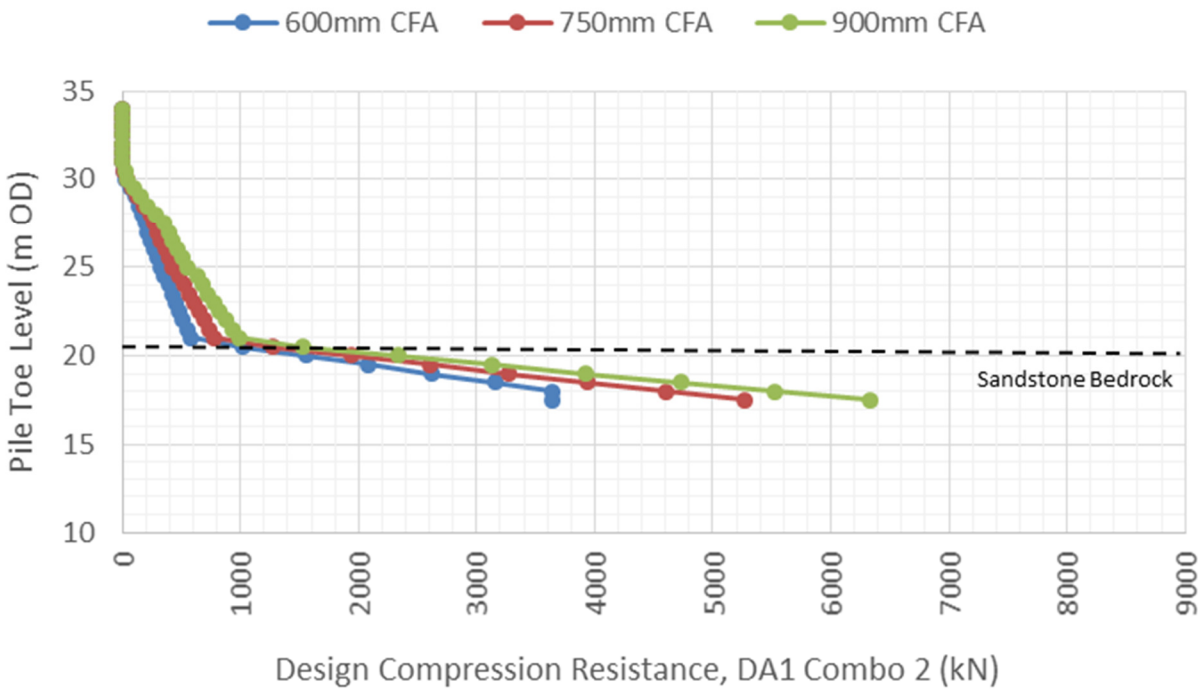
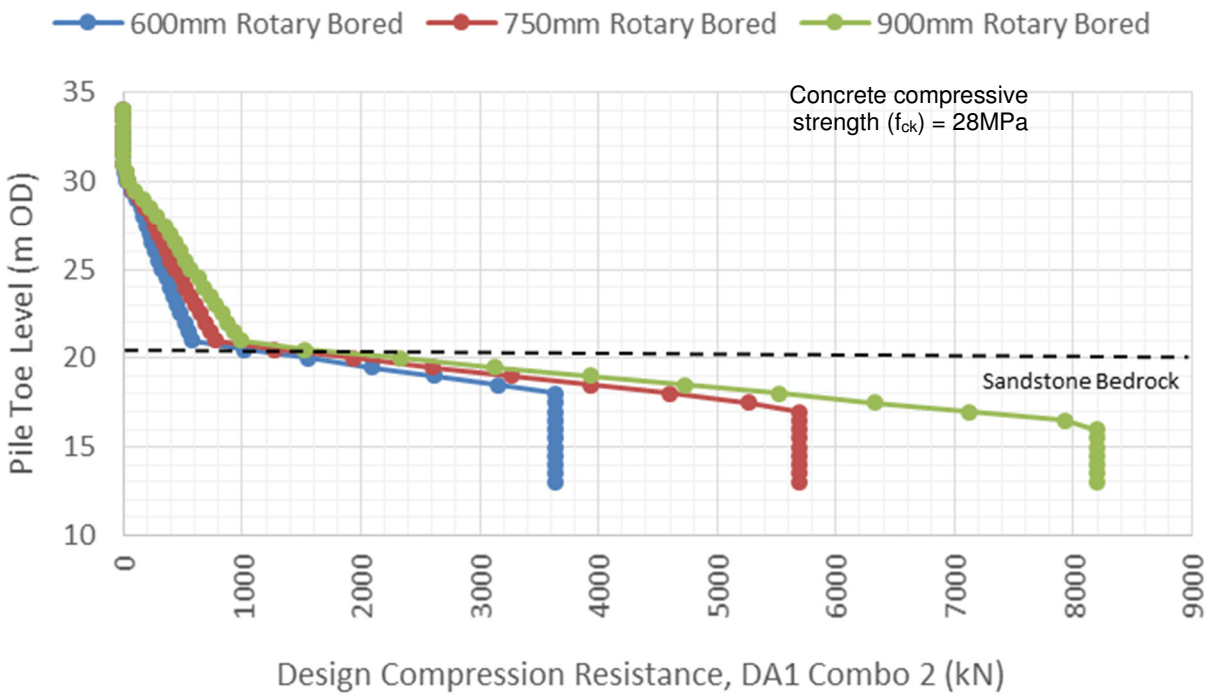


Figure 9 – Compression Resistance for Rotary Bored Piles



9.4 Floor Slabs

The previous and most recent phases of ground investigation work indicate the site to be underlain by Made Ground to an average depth of 1.5m, although it is highly variable, with depths of up to 3.8m identified at individual exploratory hole locations. On this basis, a ground bearing floor slab is not considered appropriate.

A ground bearing floor slab solution will require excavation and re-engineering of the made ground material beneath the site (as well as any soft natural deposits should they be encountered). This would also allow the removal of any below ground obstructions prior to piling. Alternatively, a piled ground floor slab could be used. Ground improvement techniques are unlikely to be viable due to the highly variable nature of the made ground and the presence of obstructions.

9.5 Groundwater Control

It is presumed that foundations shall be constructed near existing ground level, but that some localised excavation works may be required for installation of site services, formation of pile caps, and for breaking out obstructions in advance of any piling works.

The recent ground investigation works suggest shallow groundwater to be situated at 31.5m OD, or 2.5m below general surrounding ground level. On this basis, it is presumed that groundwater control measures will not be required for the excavation works described above. Although some minor seepages may be

encountered within the locally occurring Made Ground, these are likely to be controlled by sump pumping at the base of excavation.

9.6 Ground Aggressivity

Based on results presented within Section 5 of this report, the design sulphate class for concrete in contact with soils at the site is assessed to be DS-1 and the Aggressive Chemical Environment for Concrete (ACEC) is classified as AC-3z.

All buried concrete should be designed in accordance with BRE Special Digest 1:2005.

9.7 Pavement Design

Based on the significantly variable CBR results recorded to date it is recommended that new pavements a CBR value of not exceeding 3.0% is adopted for the purpose of design. In addition:

- The subgrade formation surface once exposed should be scraped clear of all wet, loose, organic, or otherwise unsuitable material, then proof-rolled and inspected by a suitably qualified person; and
- Any depressions, soft spots or voids below subgrade formation level should be removed to full depth, backfilled with suitable granular fill and compacted in accordance with Series 600 of the UK Specification for Highway Works.
- In situ CBR testing should be undertaken on the formation at regular intervals to confirm the CBR design value prior to construction.

9.8 Unexploded Ordnance

Prior to intrusive investigation being carried out at the site, a detailed unexploded ordnance (UXO) risk assessment has been undertaken for Plots 6, 7, and 8, Manchester First Street in November 2015. This assessment was undertaken by 6 Alpha and concluded that:

- There are no records of high explosive bombs having been dropped on the Plot 8 site. The nearest such incident is recorded 100m to the east of the site.
- There are no records of incendiary devices having been dropped on the Plot 8 site. The nearest such incident is recorded approximately 75m to the north, on the adjacent Plot 6/7 site.
- The potential presence of unexploded incendiary bombs poses a HIGH risk to site excavation works and a MODERATE risk to site piling works.
- The potential presence of unexploded high explosive bombs poses a MODERATE risk to site excavation and piling works.

Further to the above, 6 Alpha suggested that the following remediation measures be undertaken with respect to potential UXO at the site:

- All ground workers should be informed of potential UXO risks as part of their site induction.
- A UXO banksman be provided during all site excavation works.

Subsequently, these recommendations were carried out by 1st Line Defence, who provided a UXO banksman for the duration of the intrusive investigation.

During the investigation several exploratory holes encountered anomalies picked up by magnetometer that required the relocating of two exploratory holes (under advisement of 1st Line Defence on-site).

These boreholes were as follows:

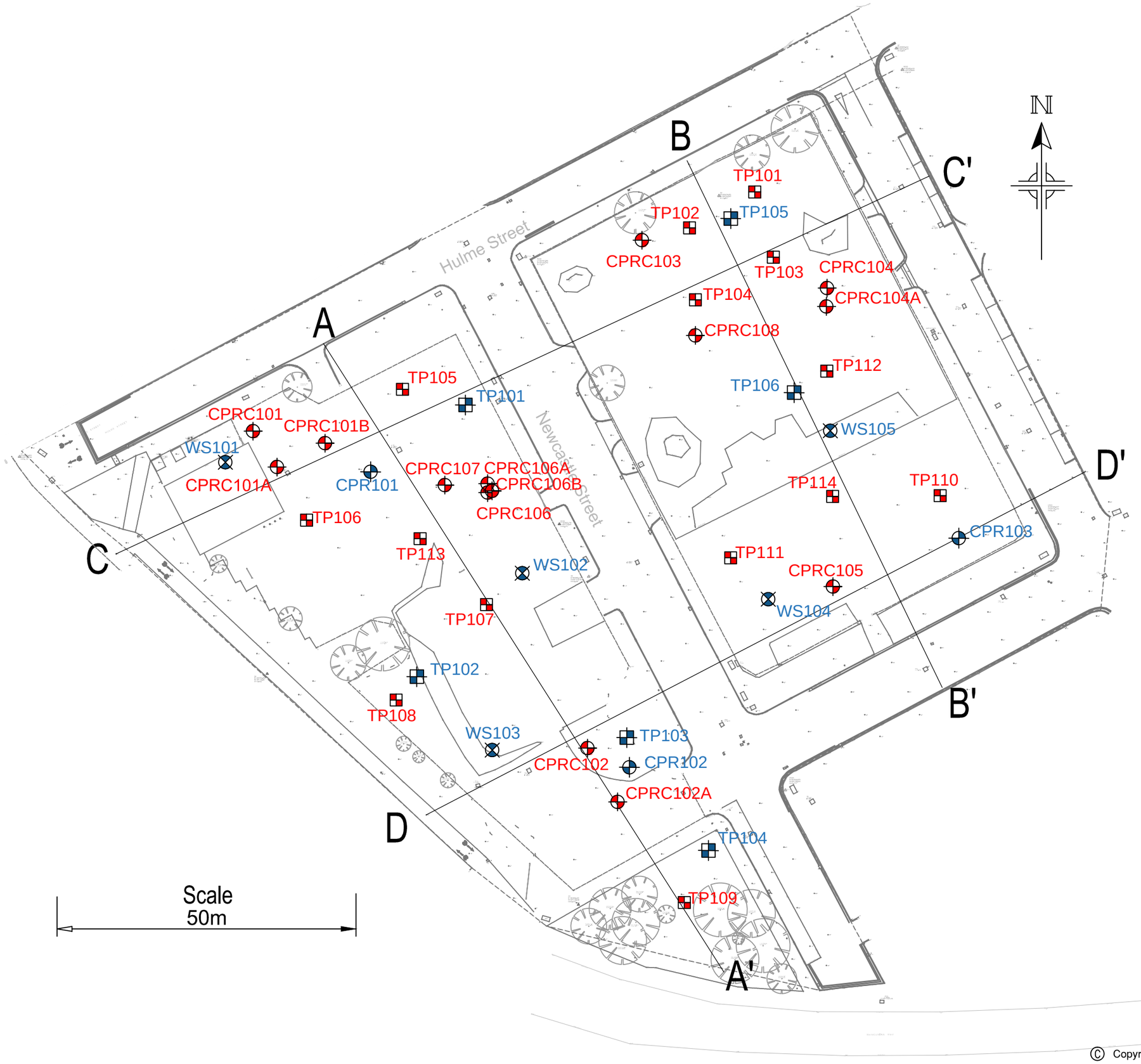
- CP/RC101A at 6.20mbgl
- CP/RC102 at 6.65mbgl

Whilst no positive identification of UXO risks were made, their presence cannot be ruled out at the site, especially in light of the documented historical 'direct hits' in the northern area of the site from WWII explosive / incendiary devices.

It should be noted that 1st Line Defence do not provide any specific remediation works for the piling phase. On this basis, it is suggested that the risk assessment be updated prior to this phase of works being tendered.

A factual report is due to be provided by 1st Line Defence that will detail anomalies detected and make recommendations with respect to the proposed piling at the site.

DRAWINGS



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1011906 | A3

DO NOT SCALE FROM THIS DRAWING

Notes

Key

Elevation (m AOD)

Geotechnical Engineering Ltd
Ground Investigation (2016)

CPRC101 — Cable Percussive borehole with Rotary Coring follow-on

TP101 — Trial Pit

Captia Symonds
Ground Investigation (2012)

TP101 — Trial Pit

WS101 — Window Sampler borehole

CPR101 — Cable Percussive borehole with Rotary Coring follow-on

Capita Symonds Borehole locations derived from Drawing Reference 001 of the Captia Symonds Report 2012

Borehole elevations have been derived from available topography data

D — D' Line of Cross Section D - D'

Issue	Date	Description	By	Chkd	Verfd
-	29/06/2016	Construction	SD	JAS	JA

Project
Plot 8 First Street, Manchester

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Exploratory Hole Location Plan

Drawing No.	Drawing Status
1011906.DWG.GL.009	Final
Job No.	**Scale**
1011906	As Shown

Originator	Checked	Verified	Issue.
SD	JAS	JA	-

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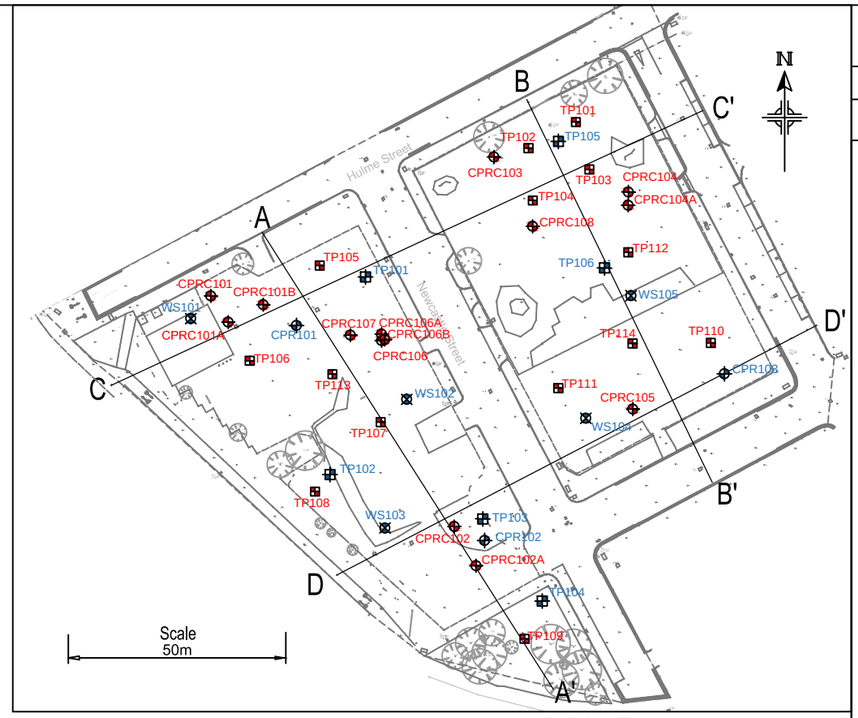

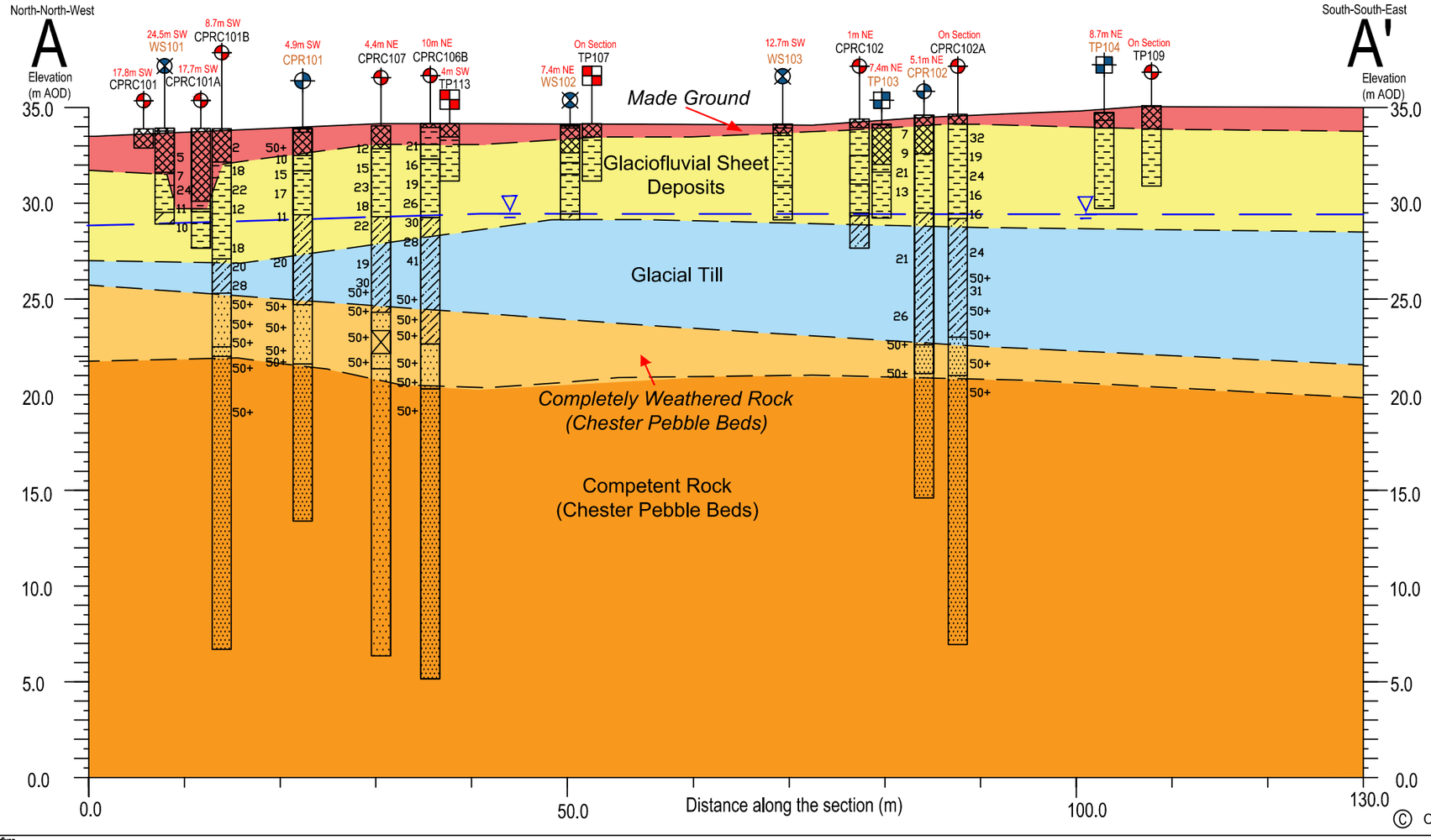

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1011906 | A3

DO NOT SCALE FROM THIS DRAWING

Notes

- Made Ground
- Glaciofluvial Sheet Deposits (Sand and Gravel)
- Glacial Till
- Completely Weathered Rock (Chester Pebble Beds)
- Competent Rock (Chester Pebble Beds)
- No Recovery
- Inferred Strata Boundary
- Inferred Groundwater Table

Map Key

- 34.32 Elevation (m AOD)
- 12m NE Distance and orientation from Section Line

Geotechnical Engineering Ltd Ground Investigation (2016)

- CPRC101 Cable Percussive borehole with Rotary Coring follow-on
- TP101 Trial Pit

Captia Symonds Ground Investigation (2012)

- TP101 Trial Pit
- WS101 Window Sampler borehole
- CPR101 Cable Percussive borehole with Rotary Coring follow-on

Capita Symonds positions derived from Drawing Reference 001

Issue	Date	Description	By	Chkd	Verfd
-	29/06/2016	Construction	SD	JAS	JA

Project
Plot 8 First Street, Manchester

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Indicative Geological Cross Section
A - A'

Drawing No.	Drawing Status
1011906.DWG.GL.010	Final
Job No.	**Scale**
1011906	As Shown

Originator	Checked	Verified	Issue.
SD	JAS	JA	-

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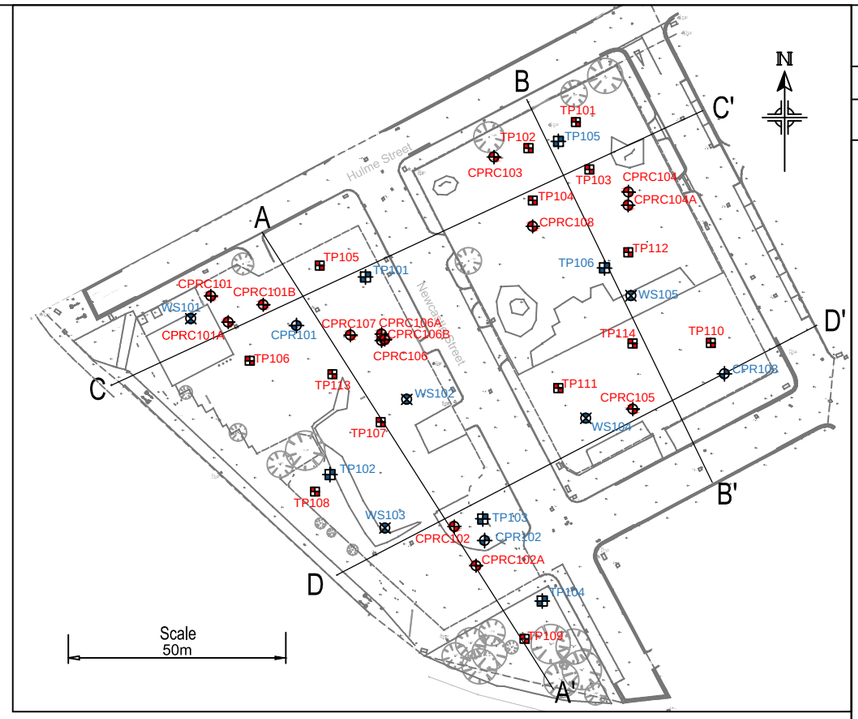

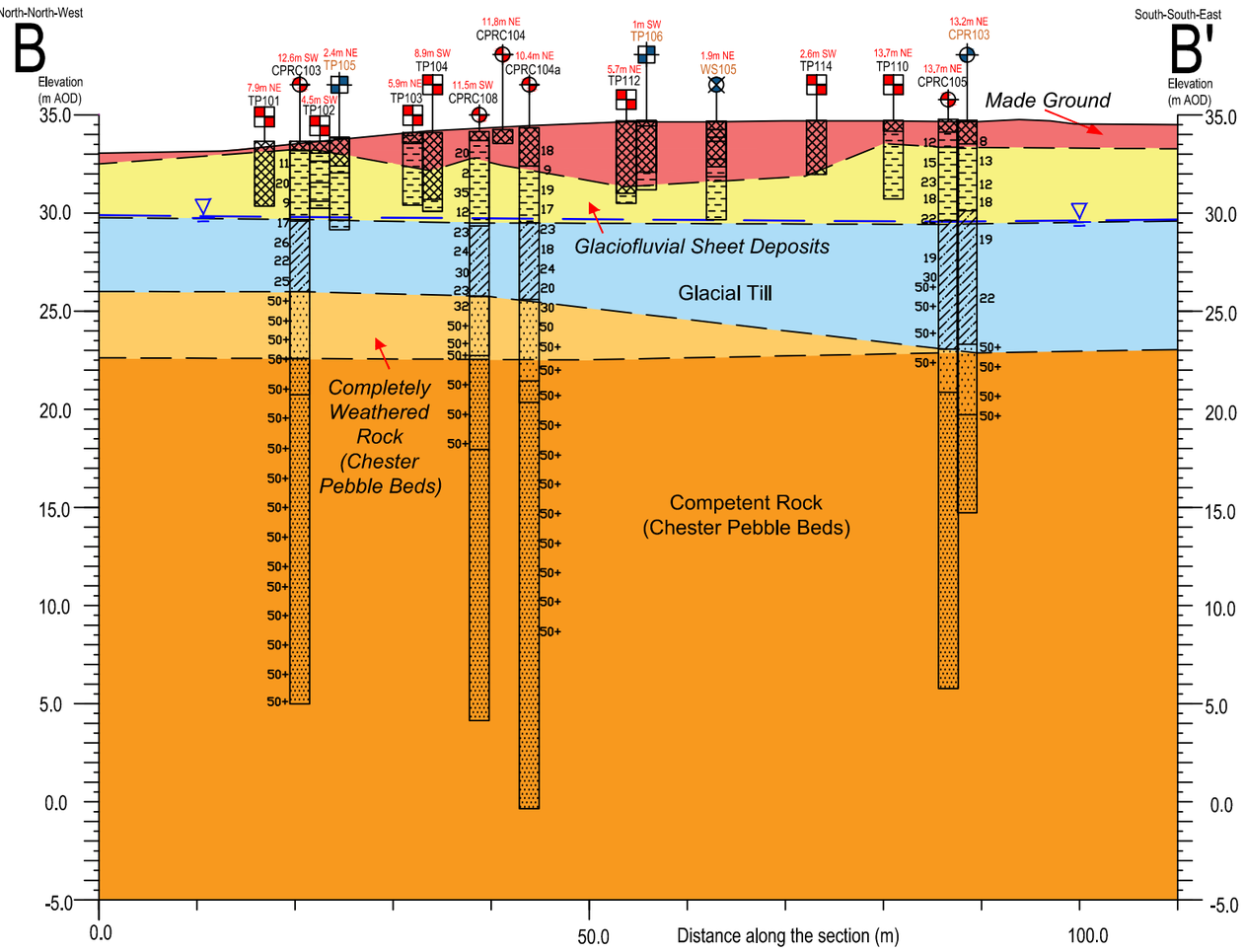

1011906 | A3

DO NOT SCALE FROM THIS DRAWING

Notes

- Made Ground
- Glaciofluvial Sheet Deposits (Sand and Gravel)
- Glacial Till
- Completely Weathered Rock (Chester Pebble Beds)
- Competent Rock (Chester Pebble Beds)
- No Recovery
- Inferred Strata Boundary
- Inferred Groundwater Table

Map Key

- 34.32 Elevation (m AOD)
- 12m NE Distance and orientation from Section Line

Geotechnical Engineering Ltd Ground Investigation (2016)

- CPRC101 Cable Percussive borehole with Rotary Coring follow-on
- TP101 Trial Pit

Captia Symonds Ground Investigation (2012)

- TP101 Trial Pit
- WS101 Window Sampler borehole
- CPR101 Cable Percussive borehole with Rotary Coring follow-on

Capita Symonds positions derived from Drawing Reference 001

Issue	Date	Description	By	Chkd	Verfd
-	29/06/2016	Construction	SD	JAS	JA

Project
Plot 8 First Street, Manchester

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Indicative Geological Cross Section B - B'

Drawing No.	Drawing Status
1011906.DWG.GL.011	Final
Job No.	**Scale**
1011906	As Shown

Originator	Checked	Verified	Issue.
SD	JAS	JA	-

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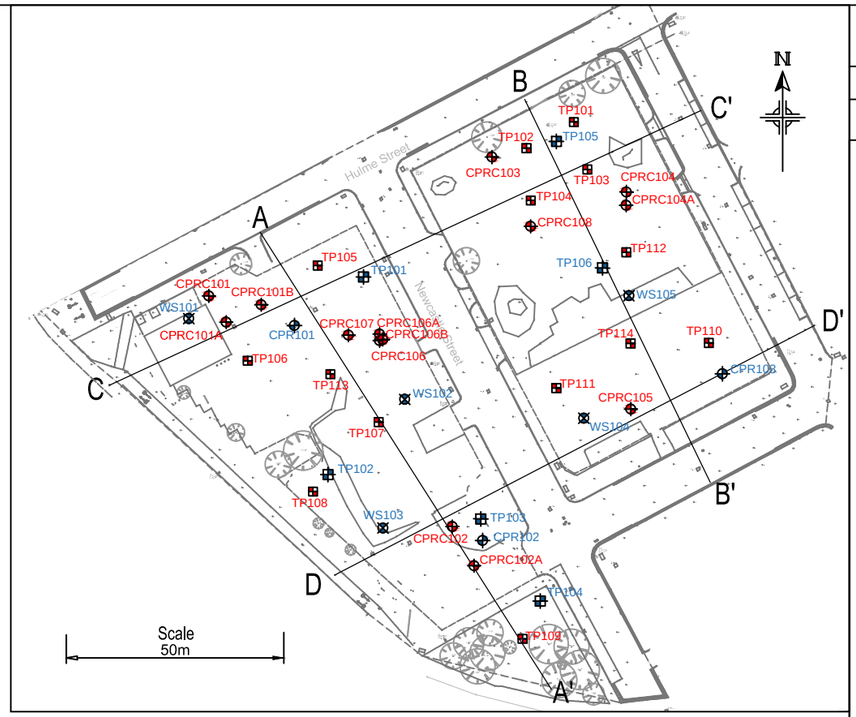

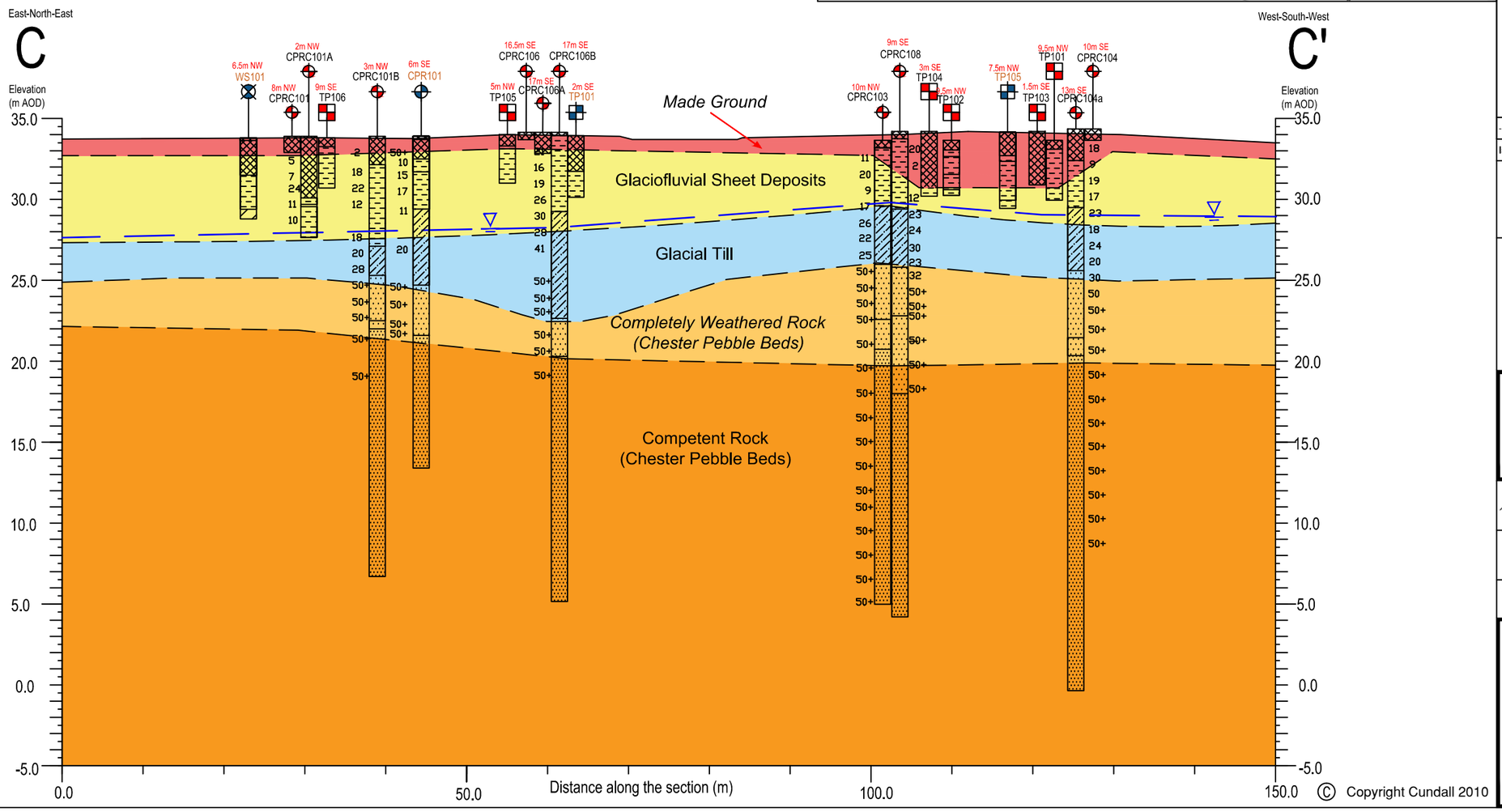

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1011906 | A3

DO NOT SCALE FROM THIS DRAWING

Notes

- Made Ground
- Glaciofluvial Sheet Deposits (Sand and Gravel)
- Glacial Till
- Completely Weathered Rock (Chester Pebble Beds)
- Competent Rock (Chester Pebble Beds)
- No Recovery
- Inferred Strata Boundary
- Inferred Groundwater Table

Map Key

- 34.32 Elevation (m AOD)
- 12m NE Distance and orientation from Section Line

Geotechnical Engineering Ltd Ground Investigation (2016)

- CPRC101 Cable Percussive borehole with Rotary Coring follow-on
- TP101 Trial Pit

Captia Symonds Ground Investigation (2012)

- TP101 Trial Pit
- WS101 Window Sampler borehole
- CPR101 Cable Percussive borehole with Rotary Coring follow-on

Capita Symonds positions derived from Drawing Reference 001

Issue	Date	Description	By	Chkd	Verfd
-	29/06/2016	Construction	SD	JAS	JA

Project
Plot 8 First Street, Manchester

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Indicative Geological Cross Section
C - C'

Drawing No.	Drawing Status
1011906.DWG.GL.012	Final
Job No. 1011906	Scale As Shown

Originator	Checked	Verified	Issue.
SD	JAS	JA	-

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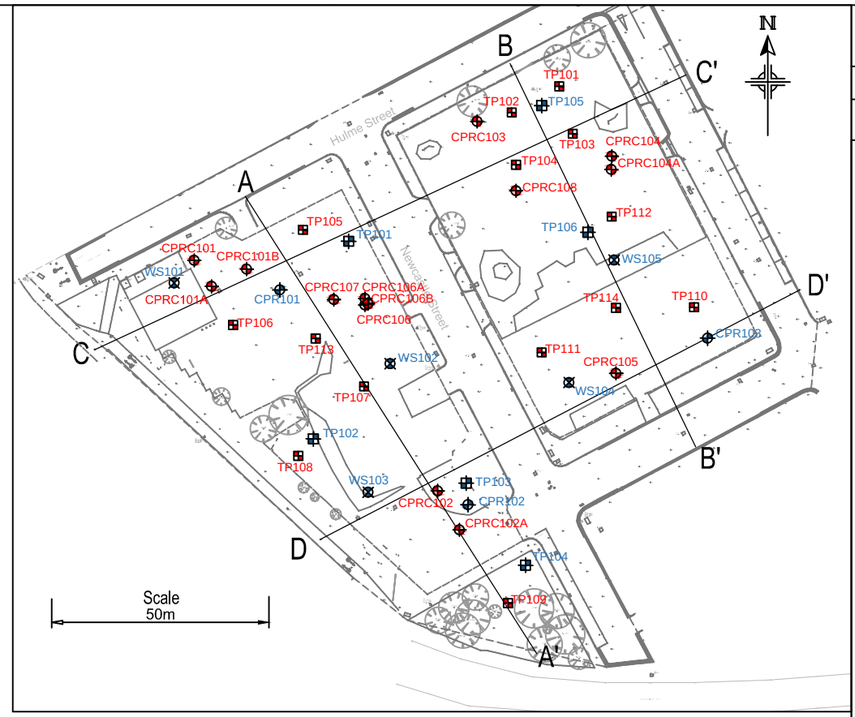

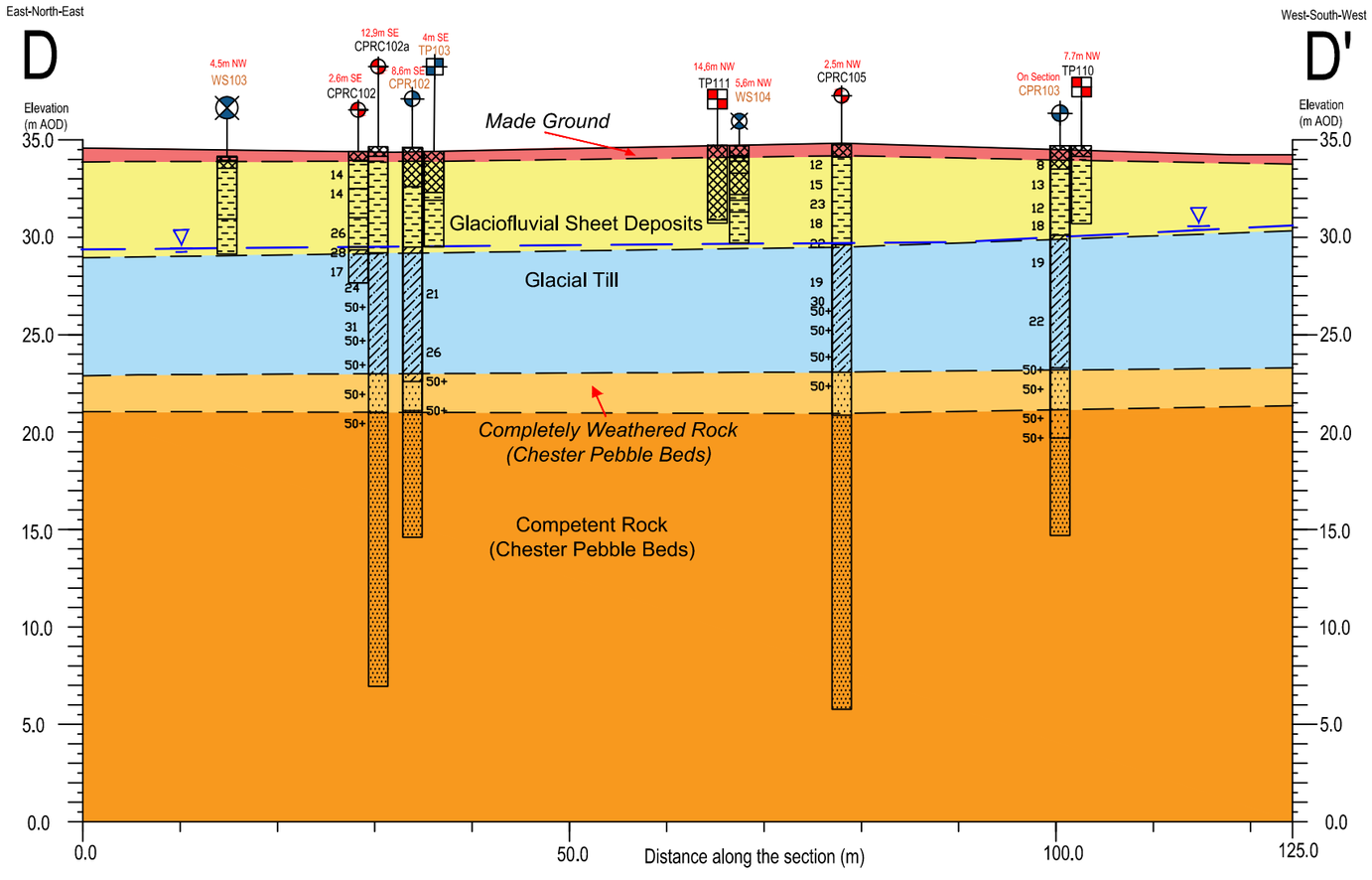

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Notes

- Made Ground
- Glaciofluvial Sheet Deposits (Sand and Gravel)
- Glacial Till
- Completely Weathered Rock (Chester Pebble Beds)
- Competent Rock (Chester Pebble Beds)
- No Recovery
- Inferred Strata Boundary
- Inferred Groundwater Table

Map Key

- 34.32 Elevation (m AOD)
- 12m NE Distance and orientation from Section Line

Geotechnical Engineering Ltd Ground Investigation (2016)

- CPRC101 Cable Percussive borehole with Rotary Coring follow-on
- TP101 Trial Pit

Captia Symonds Ground Investigation (2012)

- TP101 Trial Pit
- WS101 Window Sampler borehole
- CPR101 Cable Percussive borehole with Rotary Coring follow-on

Capita Symonds positions derived from Drawing Reference 001

Issue	Date	Description	By	Chkd	Verfd
-	29/06/2016	Construction	SD	JAS	JA

Project
Plot 8 First Street, Manchester

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Indicative Geological Cross Section
D - D'

Drawing No.	Drawing Status
1011906.DWG.GL.013	Final
Job No. 1011906	Scale As Shown

Originator	Checked	Verified	Issue.
SD	JAS	JA	-

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Notes

Legend

< 310 mg/kg

> 310 mg/kg

Results from the ground investigation performed in 2016

① TP111 at 0.3m 540 mg/kg
② CP/RC101A 0.6m 360 mg/kg
② CP/RC101A 3.3m 520 mg/kg
② CP/RC101B 0.6m 530 mg/kg
③ CP/RC106A 0.6m 370 mg/kg

Results based on Drawing Number 001 (Capita Symonds) from the ground investigation performed in 2011

④ WS101 at 0.5m 990 mg/kg
⑤ WS105 at 0.3m 10 mg/kg

Issue	Date	Description	By	Chkd	Verfd

Project
First Street: Plot 8

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Lead Concentrations Recorded in Laboratory Testing of Samples

Drawing No.	Drawing Status
1011906.DWG.GL.0014	Final
Job No. 1011906	Scale 1:1,500 (in A3)

Originator	Checked	Verified	Issue.
SD	DM	KDM	-

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Notes

Legend

- Not Detected
- Detected but < 0.001% Mass by Volume
- > 0.001% Mass by Volume

1. CP/RC101A Chrysotile at 0.6m 0.002%
2. AOP8BE5 Chrysotile at 0.5m 0.002%
3. AOP8BE5 Crocidolite at 0.5m 0.001%
4. AOP8AF7 Crocidolite at 1.0m 1.48%
5. AOP8BB5 Chrysotile at 0.7m 0.002%
6. AOP8BE5 Chrysotile at 0.5m 0.015%

Issue	Date	Description	By	Chkd	Verfd

Project
First Street: Plot 8

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Asbestos Concentrations Recorded in Laboratory Testing of Samples

Drawing No.	Drawing Status
1011906.DWG.GL.015	Final
Job No. 1011906	Scale 1:1,500 (in A3)

Originator	Checked	Verified	Issue.
SD	DM	KDM	-

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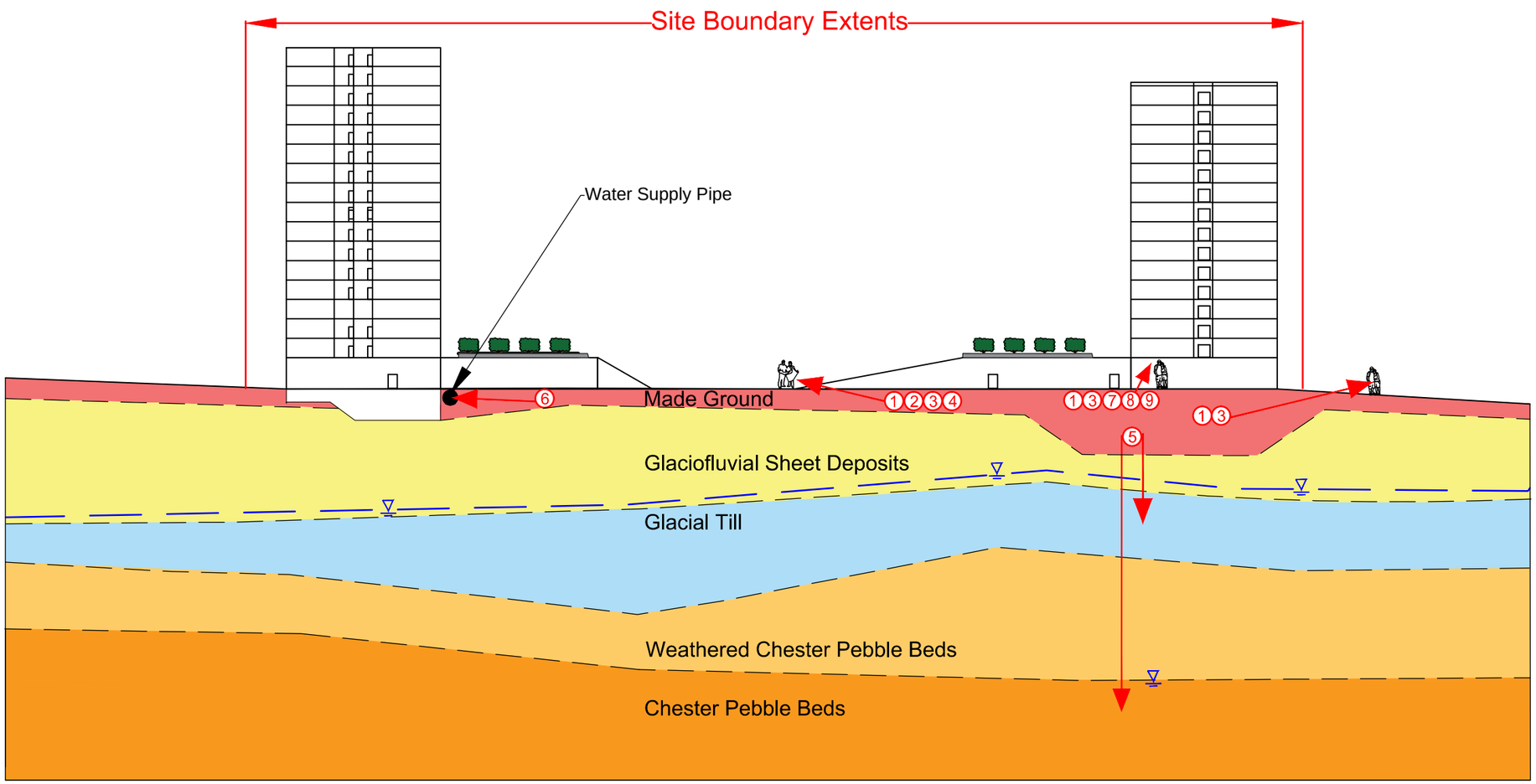

Contaminant Source	Pathway	Receptor	Consequence of Pollutant Linkage	Likelihood of Pollutant Linkage	Overall Risk
Asbestos fibres or ACMs in the near surface soils	1. Inhalation of fibres	Construction workers / future maintenance workers	Severe	High	Very High
		Site end users	Severe	Unlikely	Moderate / Low
		Adjacent site users (general public during construction)	Severe	High	Very High
Contamination within the Made Ground on site (Lead)	2. Dermal Contact	Construction workers	Severe	Likely	High
		Site end users	Severe	Unlikely	Low
	3. Inhalation of fugitive dust	Construction workers / future maintenance workers	Severe	Likely	High
		Site end users	Severe	Unlikely	Low
		Adjacent site users (general public during construction)	Severe	Low likelihood	Moderate
	4. Ingestion of soils	Construction workers / future maintenance workers	Severe	Low	Moderate
		Site end users	Severe	Unlikely	Low
Contaminants within the Made Ground on site	5. Vertical / lateral migration	Controlled waters (Secondary A and Principal Aquifers)	Minor	Likely	Low
Contaminants within the Made Ground on site	6. Permeation of buried services (new water supplies)	Site end users / Construction workers	Severe	Low	Moderate
Asphyxiant and/or explosive ground gases (CO2, CH4)	7. Accumulation of toxic / asphyxiant explosive gases	Construction workers	Severe	Unlikely	Low
		Site end users	Severe	Unlikely	Low
	8. Accumulation of explosive gases	Build environment / Structures	Severe	Unlikely	Low
Depleted oxygen	9. Asphyxiation	Construction workers	Severe	Low	Moderate

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Notes

- Made Ground
- Glaciofluvial Sheet Deposits (Sand and Gravel)
- Glacial Till
- Glacial Till (predominantly granular)
- Weathered Sandstone (Chester Pebble Beds)
- Sandstone (Chester Pebble Beds)
- Potential Contaminant Linkage
- Inferred Strata Boundary
- Inferred Groundwater Table

Issue	Date	Description	By	Chkd	Verfd

Project
First Street: Plot 8

Client
Ask Property Developments Ltd

Architect
RTKL

Title
Refined Conceptual Site Model

Drawing No.	Drawing Status
1011906.DWG.GL.016	Final
Job No.	**Scale**
1011906	Not to Scale

Originator	Checked	Verified	Issue.
SD	DM	JA	-

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APPENDIX A

Introduction

For 'contamination' to exist a valid contaminant linkage must be present. That is, there should be a source of contamination, a receptor where 'significant harm' or 'significant possibility of harm' may be caused; and a pathway which connects the two. Should any element of this contaminant linkage not be present (or severed) then the land may not be regarded as contaminated land, as defined in Part IIA of the Environmental Protection Act 1990 (amended).

Land Quality

Where contaminated land is suspected, the risk assessment should take into account site specific hazards (i.e. chemical composition of the soil and/or groundwater) and conceptual model for the site. Within the UK, DEFRA have produced a human toxicological risk assessment known as the Contaminant Land Exposure Assessment (CLEA) Model (Contaminated Land Research report series (CLR Report No's 7, 9 and 10). It should be noted that with effect from August 2008, CLR Report No's 9 and 10 were replaced by Environment Agency's Science Reports SC050021/SR2 and SC050021/SR3, respectively. Also, CLR 7 has been withdrawn and no replacement has been published to date.

The CLEA model is used to derive site specific Soil Screening Values (SSVs) based upon the current or proposed land use of the site, which are utilised as 'trigger values' within the regulatory framework. Some of the inputs of the CLEA model are the physical, chemical and toxicological properties of the contaminant. As the toxicology of contaminants can vary significantly, published guidance on toxicology has been published by the following relevant stakeholders in the derivation of SSVs:

- Environment Agency (EA).
- Land Quality Management Limited/Chartered Institute of Environmental Health (LQM/CIEH).
- Contaminated Land: Applications In Real Environments/Department for Environment and Rural Affairs (CL:AIRE/DEFRA) promoted via the Department for Communities and Local Government (DCLG).
- Atkins ATRISK^{SOIL}

The SSVs are derived using the CLEA model according to six standard land uses and are applicable to long-term human exposure to soil contaminants. It should be noted that the CL:AIRE/DEFRA modelling uses a modified version of the CLEA model to derive LLTCs or 'Low Levels of Toxicological Concern' rather than the 'minimal risk' or 'ALARP' (As Low As Reasonably Possible) approach promoted by LQM/CIEH, EA and ATRISK^{SOIL}. The six standard land uses comprise:

- Residential with home-grown produce.
- Residential without home-grown produce.
- Allotments.

- Public Open Space 1 (residential).
- Public Open Space 2 (park).
- Commercial.

Although the four key stakeholders all follow the same approach in principal (namely the use of the CLEA model) individual approaches, toxicological data used, Excess Lifetime Risks (ELRs) for cancer and exposure parameters do differ for the derivation of SSVs, and therefore, so do the SSVs themselves. For example, a practitioner is likely to see little difference in an SSV between the four major model sets for Arsenic as a wealth of toxicological data and exposure reactions are available for this contaminant, reducing uncertainty and minimising the margins for error. Conversely for Lead, UK-based toxicological data is sparse, and the models rely upon European and US data, with robust exposure modelling being only recently available. This has resulted in there being variations in SSVs, and indeed LQM/CIEH have not published an SSV for this substance.

The key consideration in determining which SSVs are the most suitable for any given site is the toxicological data and exposure modelling used in deriving an SSV, and, whether the practitioner considers a particular model to appropriate to the site. An example of this is whether an exposure model that assumes a six year old female spends four hours per day in a private garden every day for a year wearing a t-shirt is a reasonable assumption for a practitioner to apply.

Where an SGV is not available for a specific contaminant, Site-Specific Assessment Criteria (SSAC) can be derived using the current CLEA Software which follows the methodology laid out in the following reports:

- Contaminated Land Report (CLR 7) (now withdrawn and has not been replaced).
- Human health toxicological assessment of contaminants in soil (replaces CLR 9).
- Updated technical background to CLEA model (replaces CLR 10).

SSV Models

With the EA SGVs now largely redundant and only relevant in a small number of scenarios (as discussed below), the two most comprehensive models are the S4ULs and ATRISK^{SOIL}. The C4SLs, despite comprising of a limited set of threshold values, are gathering increasing prominence and importance as they currently enjoy the support of DCLG and DEFRA. Further C4SL threshold values are anticipated as further research is undertaken.

LQM/CIEH S4ULs

In January 2015 LQM/CIEH released S4ULs (Suitable 4 Use Levels) based upon the based on the current CLEA Guidance (Science Reports SC050021/SR3 (the CLEA Report) and SC050021/SR2 (the TOX report)), with updated toxicological and exposure data, but maintaining a minimal risk approach. The S4ULs provide Generic Assessment Criteria (GAC) for Human Health Risk Assessment and can be used as a conservative

approach to the risk assessment in the absence of the application of other screening values. The S4ULs are derived with the intention to replace the previously published 2nd Edition LQM/CIEH GACs.

ATRISK^{SOIL} Soil Screening Values (SSVs)

Atkins have derived ATRISK^{SOIL} SSVs based on the current CLEA Guidance (Science Reports SC050021/SR3 (the CLEA Report) and SC050021/SR2 (the TOX report)). Atkins have based the SSVs on the default assumptions provided in the current CLEA Guidance which are being used in the development of further SGVs by Defra and the Environment Agency. The Soil Screening Values (SSVs) produced by Atkins are generally applicable to the UK for common contaminants and are commercially available and have been widely promoted for use by Local Authority Officers.

Category 4 Screening Levels (C4SLs)

DEFRA have promoted the adoption of C4SLs in planning via DCLG. At this stage only six C4SLs by the CL:AIRE consortium have been published (Arsenic, Benze, Benzo[a]pyrene, Cadmium, Chromium VI and Lead) with further C4SLs proposed for derivation and publishing during 2015 and 2016. The primary purpose of C4SLs is to quickly determine whether a site is 'definitely not contaminated' in a Part IIA context using LLTCs, rather than adopting minimal risk. However, C4SLs are also a useful screening tool for Human Health Risk Assessment given that they have tended to use more up to date toxicological data, and, have applied more realistic exposure parameters. Given that they have support in planning from DCLG, it is considered appropriate to use them where the modelling is considered applicable to the site.

Environment Agency Soil Guideline Values (SGVs)

Although largely superseded by S4ULs, ATRISK^{SOILS} and C4SLs, the SGVs are retained where considered relevant, and, where more recent SSVs have not been derived. MTBE (Methyl-tert Buthyl-ether) is an example of where this may apply.

Applicability of Screening Values

The application of screening values enables auditable, consistent evaluation of land contamination problems. Screening values designed to be consistent with SSVs, provide a preliminary, generic assessment of the risks to human health arising from the presence of contamination within the soil.

The practical application of screening values is the facility to compare site data, which informs decision-making with regard to the need or otherwise for further site evaluation and/or remediation measures. Screening values, if appropriately used, can reduce the cost of risk assessment and simplify decision-making. They are easy to understand and interpret by a wide variety of stakeholders.

Non-exceedance of any of the screening values described above will indicate that the soil contaminant concentrations are such as not to compromise human health, thereby the risk is acceptable, and that land is

suitable for its proposed end use with regard to the specific contaminants assessed. However, exceedance of a screening value can indicate that further assessment or remedial action may be needed.

Note: Exceedance of any of the relevant screening values does not constitute evidence of a significant possibility of significant harm (SPOSH).

Asbestos in Soils

The human health risk from asbestos is from the inhalation of asbestos fibres which can then lead to asbestos related diseases such as mesothelioma and asbestosis. Currently in the UK there is no threshold level set for environmental exposure to asbestos fibres contained within soils, with ICRCL 64/85 guidance noting that concentrations of respirable fibres in dry soils of as little as 0.001% mass can produce airborne respirable fibres above the 'control limit' of 0.1 fibre/ml air stated by the Control of Asbestos Regulations 2012. The World Health Organisation (WHO) Air Quality Guidelines state that 'No safe level can be proposed for asbestos because a threshold is not known to exist.' It is therefore considered that the detectable presence of asbestos within site soils provides a 'source of contamination.'

The pathway for asbestos fibres is their release into the air, followed by inhalation. Where asbestos is present in soils, the ability for it to become airborne is controlled by a number of factors. Where asbestos is present as part of a bound Asbestos Containing Material (ACM - such as cement bound roofing sheets), degradation or disturbance of the material will be required in order to release fibres into the air. Where loose asbestos (such as insulation), or where ACMs have been significantly degraded though age or disturbed/broken down by processes such as demolition, then no disturbance of soils through site use is required, as the action of wind may release and transport fibres in the air.

Another factor in the potential release of asbestos fibres from soil is the composition of the soils itself. Research undertaken by Addison et al (1988), reported in CIRIA C733, suggests that soil type (sand, clay or intermediate grading) has a substantial effect of airborne fibre release, with clay soils releasing around 40% of the airborne fibres of granular (sand and gravel) soils. The same research also noted a relationship between soil moisture content and airborne fibre release, with only a small increase resulting in substantial reduction of airborne fibres. Comparing results of a completely dry soil to one with 10% (w/w) increase in moisture content reduced airborne fibre counts as much as 90%.

A further consideration of asbestos fibre pathways is 'tracking' whereby ACMs and asbestos fibres attach to items such as footwear or vehicle tyres to be later released in other locations, such as inside residential properties (i.e. when site users return home).

The following factors have been used to rank the potential consequence of a contaminant – pathway – receptor linkage and the potential significance for current and future land use.

Potential Consequence of Hazard – Receptor Linkage (in accordance with CIRIA C552)	
Severe	Short-term (acute) risk to human health likely to result in significant harm. Short-term risk of pollution of sensitive water resource. Catastrophic damage to buildings/property. A short-term risk to a particular ecosystem, or organism forming part of such ecosystem.
Medium	Long-term (chronic) damage to human health. Pollution of sensitive water resources. A significant in change in a particular ecosystem, or organism forming part of such ecosystem. Damage to sensitive buildings and structures.
Mild	Slight short term health effects to humans. Slight pollution of non-sensitive water resources. Some change to population densities but with no negative effects on the function of the ecosystem. Slight damage to sensitive buildings, structures and services.
Minor (Negligible)	Non-permanent effects to human health (easily prevented by means such as ppersonal protective clothing etc.). Easily repairable effects of damage to buildings, structures and services (e.g. discolouration of concrete).
Potential Significance: Risk Classification (in accordance with CIRIA C552)	
Very High Risk	There is a high probability that severe harm could arise to a designated receptor from an identified hazard, or, there is evidence that severe harm to a designated receptor is currently happening.
High Risk	Harm is likely to arise to a designated receptor from an identified hazard at the site. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) is required and remedial works may be necessary in the short term and are likely over the longer term.
Moderate Risk	It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not undertaken already) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the long term.
Low Risk	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Negligible Risk (Very Low)	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.