Providing Ground Solutions

Fairview Ventures Limited

Centric Close, Oval Road, Camden

Geoenvironmental and Geotechnical Interpretive Report - Revision 1

December, 2016

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EXECUTIVE SUMMARY

Card Geotechnics Limited (CGL) has been commissioned by Fairview Ventures Limited to undertake a desk study and site investigation at the site at Centric Close, Camden, London. The site is currently occupied by seven small warehouse units. The proposed redevelopment comprises the demolition of the existing buildings and the construction of a mixed residential and commercial (Class B1), four to seven story block with a landscaped courtyard and communal amenity area. A basement will be present in the west of the site, to be used for commercial floor space and storage.

The desk study indicates that on the earliest maps, the site was occupied by a Pianoforte factory before being redeveloped in the 1950's and then again in the 1980's to its current layout. A railway is located along the western boundary of the site and a potential underground storage tank (UST) or interceptor was noted on site.

CGL has undertaken a ground investigation to support the redevelopment. The investigation encountered a general Made Ground thickness of up to 3.0m of Made Ground (base not proven in this location). The Made Ground was underlain by Alluvium in the centre of the site, with London Clay below. Water strikes were not encountered during drilling, however, during monitoring, groundwater was encountered at between 2.8mbgl to 3.0mbgl. No visual evidence of contamination was encountered at the site; however, asbestos fibres were identified in four of the nine samples of the Made Ground during laboratory analysis.

To date, four ground gas monitoring visits have been undertaken at the site, with a maximum flow reading of 0.1l/hr. The maximum carbon dioxide concentration recorded was 4.2% while methane was been detected above the limits of detection of the gas meter (<0.1%). Gas screening values have been calculated based on the results to date and the site corresponds to Characteristic Situation 1, and therefore no gas protection measures are considered to be required. This will be confirmed once the two remaining monitoring visits are completed.

Chemical analysis undertaken on the Made Ground samples indicates that concentrations of lead and a number of PAHs are elevated above the assessment criteria and are considered to pose a low to medium risk to human health. Additionally, asbestos fibres were detected in a number of samples. Elevated concentrations of contaminants were also encountered in the groundwater; however, the London Clay is unproductive strata and there are no surface water features close to the site. Therefore, a negligible to low risk was considered for controlled waters.

Based on the findings of the ground investigation, a capping layer is required in soft landscaping, where the Made Ground remains at formation level. The capping layer should comprise a minimum of 450mm of imported clean subsoil and topsoil and should be subject to verification testing.

Due to the presence of elevated concentrations of organic contaminants in the Made Ground, the use of barrier pipes for water supply will be required. This should be confirmed with the local water supply company.

In order to minimise the volumes of soils being disposed to landfill facilities, it is prudent to consider material management options prior to waste disposal. However, a preliminary assessment of the Made Ground samples indicates that the majority of material would be classified as non-hazardous. Asbestos fibres were encountered in a number of locations. However, asbestos quantification indicates that the amount of asbestos fibres in these samples is below the hazardous threshold and therefore the Made Ground at these locations can be disposed to a facility that can accept non-hazardous asbestos containing material.

Geotechnical design parameters have been calculated based on the findings of the CGL site investigation. Piled foundations are recommended for the proposed high rise development, using continuous flight auger or bored pile techniques founding into the London Clay Formation. However, additional information is required to establish ground conditions and design parameters below 5mbgl.

Based on the ground conditions encountered across the site, excavations required during the development should not pose difficulties for conventional excavators and earthmoving equipment. In view of the presence of Made Ground at the surface, fully suspended ground floor slabs should be adopted for the development. A design California Bearing Ratio (CBR) value of <2.5% is recommended for pavement and roadway design where formations are to be on Made Ground.

Buried concrete should be designed to DS-2, AC-1 for both the Made Ground and Alluvium, and DS-4, AC-3 for the London Clay Formation.

Additional site investigation is recommended to provide deeper ground investigation information to facilitate foundation design, and to investigate the previously inaccessible areas. This includes additional investigation under the footprint of current site buildings, in the south of the site that was previously inaccessible and in the location of the UST/interceptor. A Remediation Strategy report will also be required for planning.

1. INTRODUCTION

Card Geotechnics Limited (CGL) has been commissioned by Fairview Ventures Limited to undertake a desk study and geotechnical and geoenvironmental ground investigation in support of the proposed redevelopment of the site at Centric Close, Oval Road, LB Camden, London, NW1 7EP.

This report provides:

- A summary of the history and environmental setting of the site;
- Details of the site works and laboratory testing undertaken as part of this investigation;
- Details of the ground and groundwater conditions encountered during this investigation;
- A source-pathway-receptor risk assessment to assess potential risks to human health and environmental receptors (including controlled waters) arising from contaminated soils and ground gas onsite, and provide outline recommendations for remediation, if required;
- Recommendations for foundations, floor slabs, concrete and pavement design.

This report describes the work completed and presents the findings of the assessment and recommendations, including recommendations for further investigation, if required.

2. SITE LOCATION AND DESCRIPTION

2.1 Site location

The site is located off Oval Road in Camden, North London, NW1 7EP. The Ordnance Survey National Grid Reference for the approximate centre of the site is 528521E, 183892N.

The site location is shown on Figure 1.

2.2 Site description

The site covers an area of approximately 0.36 Hectares (3,600m²). The site is broadly rectangular in shape and is generally flat, however, there is a slight downward gradient towards the centre of the site, possibly to allow for management of site drainage.

The site currently comprises seven industrial units along the western boundary with associated hardstanding used for parking over the eastern part of the site. A gravel access path extends around the perimeter of the buildings and the site boundary. The site is bounded by railway land and track to the west and residential and commercial properties to the east, north and south. The southern boundary of the site is embanked and the ground level of the adjacent properties are around one meter lower than the site ground level. A vent pipe from a possible tank or interceptor was noted along the entrance road into the site.

A site layout plan is presented as Figure 2.

2.3 Proposed development

The proposed development for the site is understood to involve the demolition of the existing buildings and the construction of four to seven storey block comprising residential units over commercial (Class B1) floor space. A basement will be constructed in the west of the site, comprising commercial (Class B1) units and some limited storage space. Associated soft and hard landscaping, communal amenity areas and car parking are also proposed.

The proposed development plans are included in Appendix A.

3. DESK STUDY

3.1 General

Sections 3.2 to 3.4 below provide a summary of conditions at the site in the context of the historical, geological and environmental settings.

3.2 Historical development

The historical development of the site has been traced from Ordnance Survey maps dating between 1870 and 2014 of scales 1:1,056 to 1:10,560. These maps are presented in Appendix B. Publicly available aerial imagery[1] has also been used to indicate the current site conditions. Table 1, below includes a summary of the site development.

Table 1. Summary of the development of the site and surrounding area

Year	***On Site***	***Off Site***
1870-1873	A *PianoForte Manufactory* occupied a large area in the north of the site. The southern end of the site was occupied by two structures of unknown use and soft landscaping with footpaths.	A *Potato Market* was present immediately north of the site. The *London and North Western Railway* was present immediately west of the site. A large *Goods Shed/Depot* was present 120m north of the site associated with the railway. To the east of and south of the site were residential properties and Oval Road.
1896	No discernible change.	The *Potato Mar*ket immediately north of the site is no longer indicated. The *Goods Shed/Depot* north of the site was now labelled as *Camden Goods Station*.
1951	No discernible change.	No discernible change.
1952	Previous structures on site were no longer present and a single large building of unknown use was present along the western edge of the site.	Previous *Potato Market* immediately north of site had been replaced by a *Warehouse*.
1966-1969	Site labelled as a *Good's Yard*.	No discernible change.
1982-1987	Site comprised of seven separate units along the western side of the site and labelled as *Centric Yard*.	*Warehouse* immediately north of the site was no longer labelled.
2016 (Aerial Imagery)	No discernible changes from past development. Area of hardstanding along the eastern side of the site with an access road onto Oval Road.	Residential buildings with gardens immediately to the south-east of the site.

In summary, the earliest available mapping indicates the site was occupied by a pianoforte manufactory from the 1870's. The site was redeveloped in the early 1950's comprising a single structure of unknown use along the western boundary. The site was further redeveloped in the 1980's to its current layout, to create seven units along the western

[1] https://www.google.co.uk/maps

border. Several features of potentially contaminative historical activities have been identified in the surrounding area, including a railway immediately west of the site and goods depots, predominantly to the north of the site.

3.3 Anticipated ground conditions

Groundsure GeoInsight and EnviroInsight reports have been obtained for the site and the relevant information is summarised below. Copies of the Groundsure reports are presented as Appendix C. Additionally, digital mapping on the British Geological Survey (BGS)[2] website has been used to review the published geology.

3.3.1 Published and unpublished geology

According to the British Geological Survey (BGS), the site is underlain by the London Clay Formation and there are no superficial deposits recorded to be present within 1km of the site.

The London Clay Formation comprises bioturbated or poorly laminated silty clay to clayey silt with some lenses of sandy clay. The possible thickness of the London Clay Formation, in the vicinity of the site, is indicated to be approximately 40m thick.

This is supported by the nearby borehole records, located approximately 100m north and northwest of the site, which encountered 1.1m to 1.7m of Made Ground over the London Clay Formation. A deeper borehole located approximately 60m southwest of the site encountered “clay” (likely to be the London Clay Formation) from ground level to 37m bgl, over “clay sand” (possibly the Lambeth Group) between 37m and 65.5m bgl, then Chalk to a confirmed depth of 98.5m bgl. Copies of the borehole logs and their locations are presented in Appendix D.

According to the Groundsure report, the site is reported to be at a moderate risk from the presence of shrink swell clay and a very low risk from landslides and collapsible deposits. Regarding the risk of shrink swell clay, advice should be taken from the National House Building Council (NHBC) and Building Research Establishment (BRE).

3.3.2 Hydrogeology and hydrology

The Environment Agency (EA) has produced an aquifer designation system consistent with the requirements of the Water Framework Directive. The designation have been set for superficial and bedrock geology and are based on the importance of aquifers for portable

[2] http://mapapps.bgs.ac.uk/geologyofbritain/home.html. Accessed November 2016.

water supply, and their role in supporting surface water bodies and the wetland ecosystems.

According to the Environmental Agency (EA)[3], the London Clay Formation is relatively impermeable and classified as an Unproductive Strata. These are rock layers or drift deposits with low permeability which have negligible significance for water supply or river base flow.

The site is not reported to be within 500m of a groundwater source protection zone.

The closest surface water feature is the Regent's Canal which is located approximately 80m northwest of the site at the closest point. No other surface water features are noted within 500m of the site.

There are nine records of non-potable groundwater abstraction licenses within 1000m of the site, the nearest one is located 690m southwest of the site in Regent's Park. There are also five records of potable water abstraction licenses within 1000m of the site, the nearest of which is located 810m north of the site. There are two records of surface water abstraction licenses within 1000m of the site, located 85m north and northwest of the site. The site is not within 500m a source protection zone.

There are three records of licensed discharge consents within 500m of the site, one located 115m west of the site and two located 133m northeast of the site and all for Trade Discharge – Cooling Water.

The risk of flooding from rivers and the sea is classed as very low and there are no groundwater flooding susceptibility areas within 50m of the site.

3.4 Environmental setting

The Envirosight report, obtained from GroundSure, was used to provide information on the environmental setting of the site and possible sources of ground contamination. A summary of the key points is set out below. It should be noted that a number of these entries may be duplicates based on the feature ID codes, distance and age of the record.

- There are no records of petrol filling stations within 500m of the site.

[3] http://apps.environment-agency.gov.uk/wiyby/default.aspx Accessed November 2016.

- Historical potential sources of contamination offsite include 125 records within 500m of the site; these mainly relate to the operation of a railway line in the vicinity of the site.
- There are twelve records of historical tanks located within 250m of the site, six are located between 50m and 160m north east of the site, four are located 180m to 185m north of the site and two are located 240m south of the site.
- There are no records of historical or currently operational landfills within 1000m of the site.
- There is one record of a waste disposal site within 1000m and this is located 171m to the northeast. It was licensed between 1994 and 1997 and processed household waste.
- There are 40 records of electrical substations within 250m of the site, the nearest of which is located 31m to the southwest.
- There are records of two railway tunnels within 500m of the site, located 180m south and 190m southeast of the site. However, these tunnels are not reported to be underground railway lines.
- References to BRE[4] and HPA[5] guidance documents on radon indicates that the site is not positioned within a radon affected area and less than 1% of homes are above the actions level. Therefore, no radon protection measures are considered necessary for the development at this site.
- There are 13 records of Part A (2) and Part B Activities and Enforcements within 500m of the site. Six of these relate to dry cleaning activities, five relate to the unloading of petrol and two of these relate to vehicle respray processes.
- There are no coal mining areas or brine affected areas within 75m of the site.
- There are no records of Designated Environmental Sensitive Sites within 1000m of the site.

[4] BRE. (1999). *Radon: Guidance on protective measures for new buildings. Building Research Establishment, Report BR211,* 1999.
[5] HPA. (2007). *Interactive atlas of radon in England and Wales. Health Protection Agency, HPA-RPD-033,* 2007

4. PRELIMINARY RISK ASSESSMENT

4.1 Introduction

Historical contamination of land may present harm to human health and the environment. Current UK legislation stipulates that the risk associated with any potential land contamination is assessed and remediated, if necessary. Under the Town and Country Planning Act 1990 (as amended), potential land contamination is a "material planning consideration" together with the National Planning Policy Framework (March 2012) which means that a planning authority must consider contamination when it prepares development plans or considers individual applications for planning permission. It is the responsibility of the developer to carry out the remediation where it is required and satisfy the Local Authority that the remediation has been carried out as agreed.

Additionally, Part 2A of the Environment Protection Act 1990 required that a significant source-pathway-receptor linkage exists to determine a site as contaminated land. This means that there has to be a contaminant present, a receptor that could be harmed by this contaminant, and a pathway linking the two. Part IIA deals with the contamination risk from a site in its current use, however, the planning system requires that the proposed use is considered. Where remediation is carried out under the planning system, it should be ensured that the site is in such a condition that it would still not meet the definition of contaminated land under Part 2A.

4.2 Preliminary Conceptual Site Model

A conceptual site model has been compiled for the site based on the historical, geological and environmental information obtained to identify the potential sources of contamination and the associated potential pollutant linkages.

4.2.1 Potential sources

Potential contamination sources can include current and historical activities on the site. The following potential sources have been identified at the site.

Made Ground – A layer of Made Ground is potentially present beneath the site which may contain contamination from historical site uses. There is also a potential for ground gases if appreciable organic content is present within Made Ground.

Asbestos - Potential for presence within site structures / Made Ground. (Risks from asbestos in existing buildings not assessed).

Potential underground storage tanks (UST) or petrol interceptor – There is the potential for the presence of UST's beneath the site associated with historical land use due to observations of a venting pipe at the surface.

Potential contamination associated with historical land use – Past industrial activities on the site including a pianoforte manufactory and goods storage yard, which could be a potential source of contaminants.

Off-site sources – Regarding off-site potential sources, the most pertinent include; historical tanks located between 50m and 160m northeast of the site, an electricity substation located 31m to the southwest and a historical warehouse immediately north of the site. However, the potential risk from these sources is considered to be limited due to low permeability of the London Clay Formation resulting in the limited potential for migration of groundwater, apart from through potential Made Ground.

4.2.2 Potential pathways

The potential migration pathways that may be present at the site include:

Ingestion & inhalation – Contamination within Made Ground may result in ingestion (including via ingestion of home grown produce) or inhalation of contaminated dust, including asbestos fibres and ground gases/vapours.

Direct/dermal contact – Direct/dermal contact with contaminated soils or groundwater can result in uptake of contaminants through the skin.

Ground gas/vapour migration – If there is appreciable organic content in the Made Ground and a potential UST or interceptor, there is potential for ground gases and/or vapours, which could migrate through the soil matrix into the proposed buildings.

Drainage and services – Could provide a preferable pathway for contamination and/or ground gases/vapours.

Root Uptake – Vegetation and plants can take up contaminants present within the soil/groundwater.

Lateral and vertical migration of contaminants – The migration of potential contaminants in groundwater, though this is considered to be limited by the low permeability of the London Clay Formation.

4.2.3 Potential receptors

Potential receptors at the site are likely to be:

Future site occupants – Primarily at risk from dermal contact, inhalation or ingestion and from ground gas/vapour accumulation within buildings, arising from contaminated Made Ground/groundwater.

Construction workers – Could be affected by contamination within building fabric, Made Ground and groundwater during construction works. Construction workers are likely to be in close contact with soils during excavations.

Buildings & structures – Buried concrete and services, such as plastic water supply pipes, can be at risk from chemically aggressive ground and potential contamination. Ground gases and vapours may also accumulate in buildings and structures presenting an explosive or asphyxiation risk.

Vegetation & plants – At risk from phytotoxic contaminants such as copper, zinc and nickel.

Off-site receptors – Primarily at risk from inhalation or ingestion from contaminated soils and from migration of ground gas/vapour and accumulation in buildings.

Controlled waters – At risk from the migration of dissolved or suspended contamination within the groundwater, but nearest surface water feature is the Regent's Canal 80m north of the site which is unlikely to be in continuity with local groundwater and the London Clay is unproductive strata.

4.3 Preliminary qualitative risk assessment

A qualitative risk assessment has been undertaken based on the findings of the Conceptual Site Model and the potential linkages that may exist at the site in accordance with Contaminated Land Report (CLR) 11[6]. The risks identified are in accordance with DEFRA

[6] The Environment Agency. (2004). *Model Procedures for the Management of Land Contamination.* CLR 11.

and Contaminated Land Report (CLR) 6[7], site prioritisation and categorisation rating system, which is summarised below in Table 2.

Table 2. Risk Rating Terminology

Risk Rating	Description
High Risk	Contaminants very likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Enforcement action possible, Urgent action required
Medium Risk	Contaminants likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Action required in the medium term
Low Risk	Contaminants may be present but unlikely to create unacceptable risk to identified targets Site probably suitable for proposed use Action unlikely to be needed whilst site remains in current use
Negligible Risk	If contamination sources are present they are considered to be minor in nature and extent Site suitable for proposed use No further action required

Based on the above terminology and an assessment of the risks posed by the potential pollutant linkages at the site are outlined in Table 3, below.

Table 3. Preliminary qualitative risk assessment

Source/Medium	Receptor	Potential Exposure Route	Risk Rating
Explosive / asphyxiating ground gases from underlying Made Ground, if present.	Internal building spaces, future occupants and off-site residents.	Migration of gases through the surface and via permeable soils	Low to medium
Asbestos within site structures / Made Ground, if present. (Risks from asbestos in existing buildings not assessed).	Construction workers and future site occupants.	Direct inhalation of particulates	Low to medium
Organic/inorganic contaminants (e.g. PAHs, hydrocarbons, metals etc.) within underlying Made Ground and possibly associated with underground storage tanks.	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Low to medium
	Future site occupants	Direct ingestion of soil & dust, inhalation of particulates & vapours, and dermal contact	Low to medium
	Vegetation and plants	Root uptake	Low to medium

[7] M.J. Carter Associates. (1995*). Prioritisation and Categorisation Procedure for Sites which may be Contaminated*. Department of the Environment. CLR 6.

Source/Medium	Receptor	Potential Exposure Route	Risk Rating
	Controlled Waters (Regent's Canal, groundwater)	Lateral migration of contaminated groundwater to local surface water bodies	Low
	Buildings and structures	Direct contact with water supply pipes and underground concrete structures	Low to medium
Off-site contaminants including hydrocarbons, PCBs, heavy metals, organic contaminants within groundwater	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Low
	Future site occupants	Direct ingestion of soil & dust, inhalation of particulates & vapours, and dermal contact	Low
	Vegetation	Root uptake	Low

Based on the information available, a generally low to medium risk is considered to be applicable to the site. This is based on the potential sources of contamination from historical land use on the site and the possible presence of UST or interceptor, although the potential risk from off-site sources is considered to be limited due to the low permeability of the London Clay.

5. CURRENT GROUND INVESTIGATION

5.1 Fieldwork

An intrusive investigation was undertaken by CGL on 10th May 2016 comprising four window sampler (WS) boreholes and four hand dug foundation inspection pits (FIPs). Standard Penetration Tests (SPTs) were undertaken in the boreholes at 1.0m intervals from around 1.0mbgl. The WS boreholes were undertaken in areas of hardstanding in the northeast and centre of the site and extended to a maximum depth of 5.45m bgl. The FIPs were excavated down the sides of the building to expose the existing foundations. The site investigation was broadly undertaken in accordance with the requirements of BS 5930:2015[8] and BS 10175:2011[9].

Arisings from the boreholes and FIPs were logged and representatively sampled by a suitably qualified engineer from CGL in order to obtain samples for laboratory testing and characterise the encountered strata. Three of the WS boreholes, WS01, WS02 and WS03, were installed with combined groundwater and ground gas monitoring standpipes.

An exploratory hole location plan is provided as Figure 3 and the logs for the WS boreholes and FIPs are included in Appendix E.

No works could be undertaken inside the warehouses or in the southern area of the site due to the active nature of the site. No targeted investigation could be undertaken in the location of the possible UST/interceptor as this was located near the main access road.

5.2 Monitoring

Following completion of the site works, two rounds of ground gas and groundwater monitoring were undertaken on 16th May and 1st November 2016. During the first round, groundwater was encountered in borehole WS02 while the other two boreholes (WS01 and WS03) were found to be dry. A sample of the groundwater was collected from WS02 for laboratory testing and the dissolved oxygen, redox, pH, temperature, electrical conductivity and total dissolved solids parameters of the groundwater were also tested on-site. During the second round only borehole WS03 could be accessed as vehicles were

[8] British Standards Institute, (2015). *Code of practice for ground investigations, Incorporating Amendment 2.* BS 5930:2015*2*..

[9] British Standards Institution, (2011). Investigation of potentially contaminated sites – Code of practice. BS 10175:2011.

parked over the other boreholes. Groundwater was encountered in borehole WS03 at 3.0m bgl.

The results of the monitoring to date are included in Appendix F.

An additional four rounds of ground gas and groundwater monitoring will be undertaken at the site to allow further characterisation of the gas regime present. The results from these additional monitoring rounds will be included as an addendum report upon completion.

5.3 Laboratory testing

5.3.1 Chemical

Representative samples were submitted for laboratory analysis at I2 Analytical Limited, a UKAS and MCERTS accredited laboratory for the following determinants:

- Soil organic matter (SOM) and moisture content;
- Heavy metals including; arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc;
- Speciated total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH);
- Total Monohydric Phenols and cyanide;
- Asbestos screening, identification and quantification (where encountered) in Made Ground samples; and
- Total sulfate (SO_4 equivalent) and pH.

In addition, selected soil samples were also tested for water soluble sulfate and total sulfur. Three samples of the Made Ground were tested for Waste Acceptance Criteria (WAC).

One groundwater sample was also tested for a similar suite of determinants and hardness and two soil samples were tested for leachable concentrations of the same suite.

The results of the laboratory chemical testing are presented in Appendix G.

5.3.2 Geotechnical

Selected samples of the Alluvium and London Clay were sent for geotechnical laboratory analysis at Geolabs Limited, a UKAS accredited laboratory. The analysis included:

- Moisture Content; and
- Atterberg Limits.

The results of the geotechnical laboratory testing are presented in Appendix H.

6. GROUND AND GROUNDWATER CONDITIONS

6.1 Ground conditions

The ground conditions encountered during the CGL site investigation are summarised in Table 4, below and the full logs are included in Appendix E.

Table 4. Summary of ground conditions

Stratum	Depth to top of stratum (mbgl) [mOD]	Typical thickness (m)
[MADE GROUND] Tarmac and/or concrete with rebar over Loose gravelly sand, gravel & cobbles. Gravel and cobbles were generally brick, concrete and flint with rare ceramic and slate. Sand was fine to coarse Slightly gravelly slightly sandy clay was encountered in WS02. Full thickness not proven in WS01 or the FIPs.	0.0 [32.2 to 32.6]	2.3 to >3.0
Soft low to medium strength dark grey slightly silty CLAY with occasional black specs of decomposed organic matter. *Encountered in WS02 and WS03 only* [ALLUVIUM]	2.3 to 3.0 [30.4]	0.4 to 1.3
Firm to stiff medium to high strength mottled dark grey and brown to dark brown CLAY to slightly silty CLAY. *Encountered in WS02, WS03 and WS04 only* [LONDON CLAY FORMATION]	3.0 to 3.6 [29.1 to 30.0]	Proven up to 1.6m (5.45mbgl) in WS02

A summary of the geotechnical test results is presented in Table 5, below, and plots of the SPT 'N' values and undrained shear strength (c_u) against level (mOD) are included as Figure 4 and Figure 5, respectively. The c_u plot includes direct measures from on-site Hand Shear Vane (HSV) tests and correlated values from the SPT results, using established correlations[10], and assuming f_1 = 4.5 for the Made Ground, Alluvium and London Clay Formation.

Table 5. Geotechnical test data

SPT results			
Strata	**'N' value Range**	**Equivalent $c_u{}^1$ (kPa)**	**Correlated consistency/density**
Made Ground (cohesive)	4 to 10	18 to 45	Soft to firm
Made Ground (granular)	1 to 26	NA	Loose to medium dense
Alluvium	7 to 8	31.5 to 36	Firm
London Clay Formation	11 to 21	49.5 to 94.5	Firm to stiff

[10] Stroud, M.A. (1975) The standard penetration test in insensitive clays and soft rocks *Proceedings of the European Symposium on Penetration Testing,* In Tomlinson, M.J (2001). *Foundation Design and Construction 7th Ed.* Pearson Education Ltd.

HSV test results		
Strata	**c_u result (kPa)**	**Corresponding Strength classification**
Made Ground (cohesive)	23[2]	Low
Alluvium	41 to 53	Low to medium
London Clay Formation	51 to 55	Medium

Atterberg Limits						
Strata	**Moisture content (%)**	**Liquid Limit (%)**	**Plastic Limit (%)**	**% material <425µm**	**I'_p[3]**	**Volume change potential (%)[4]**
London Clay Formation	30 to 33	59 to 73	21 to 25	100	38 to 63	Medium to very high

Notes
1. Based on f_1 = 4.5
2. Single HSV test undertaken in cohesive Made Ground
3. Modified Plasticity Index
4. Based on volume change potentials given in NHBC Standards 2016, Chapter 4.2 – Building Near Trees[11]

6.2 Ground model

6.2.1 Made Ground

Hardstanding of either tarmac and/or reinforced concrete, between 0.1m to 0.3m thick, was encountered in each exploratory hole. Reinforcement bars of ~8mm diameter were encountered in the concrete at around 0.1m to 0.15m bgl.

The underlying Made Ground was proven to depths of 2.3m to 3.0m bgl, however in WS01 the borehole was terminated upon an obstruction within the Made Ground at 3.0m so the total thickness of Made Ground was not proven at this location. Based on the material recovered in the SPT cone tip the obstruction appeared to be composed of brick.

The Made Ground was found to generally comprise loose gravelly sand, gravel and cobbles, and slightly gravelly slightly sandy clay. The gravel and cobbles were generally of brick, concrete and flint with rare ceramic and slate. Three SPTs were undertaken in the cohesive Made Ground, recording 'N' values of 4 to 10 which correspond to c_u values of 18 kPa to 45 kPa (assuming f_1 = 4.5) and a relative consistency of soft to firm. In addition, a single hand shear vane test was undertaken, which indicated a strength reading of 23kPa, corresponding to a relative strength of low. SPTs undertaken within the granular Made Ground recorded 'N' values of 1 to 26, corresponding to a density classification of loose to medium dense[8]. This excludes an SPT 'N' value of 50 from WS01 at 3.0mbgl which refused on an obstruction and is therefore not considered representative of the Made Ground.

[11] National House-Building Council (NHBC), (2016). *Standards 2016 Chapter 4.2 – Building near Trees.*

6.2.2 Alluvium

Alluvium was encountered in boreholes WS02 and WS03 (in the centre of the site). The Alluvium was encountered between 3.0m to 3.4m bgl in borehole WS02 and 2.3m to 3.6m bgl in borehole WS03, corresponding to a thickness of 0.4 to 1.3m. The Alluvium was encountered as a firm dark grey organic slightly silty clay with occasional black specs of what appeared to be decomposed organic matter.

SPTs undertaken in the Alluvium recorded 'N' values of 7 and 8, which correspond to c_u values of 31.5 kPa and 36 kPa (assuming f_1 = 4.5). Several hand shear vane measurements were also undertaken within the Alluvium which recorded readings of 41 kPa to 53 kPa. The SPT and HSV results indicate a relative consistency firm and low to medium strength.

6.2.3 London Clay Formation

The London Clay Formation was encountered in boreholes WS02, WS03 and WS04 at between 3.0 to 3.6m bgl and was proven to a maximum depth of 5.45m bgl. The London Clay generally comprised firm to stiff mottled dark brown to grey clay and was locally slightly silty. Occasional pockets of medium to coarse selenite were present throughout. Infrequent fine rootlets were noted to depths of 4.0m bgl, these were also noted to be present along fissures in the clay where grey colouration was present.

SPTs undertaken in the London Clay recorded 'N' values of between 11 and 21, which correspond to c_u values of between 49.5 kPa and 94.5 kPa (assuming f_1 = 4.5) and HSV tests recorded values of between 51 kPa to 55 kPa. This corresponds to a general consistency of firm to stiff and medium to high strength.

The results of the Atterberg tests undertaken on samples of the London Clay are summarised in Table 5. The results indicate that the shallow London Clay present is a 'high' to 'very high' plasticity clay[8] with a medium to very high volume change potential[11].

6.3 Visual and olfactory evidence of contamination

A fragment of potential Asbestos Containing Material (ACM) was encountered in FIP02 but laboratory testing found that it wasn't asbestos. However, asbestos fibres were identified by the laboratory in four of the nine Made Ground samples. No visual or olfactory evidence of contamination was noted in the Alluvium or London Clay Formation.

Samples of Made Ground were tested for the presence of volatile organic compounds (VOCs) using a photo ionisation detector (PID), the maximum recorded concentration was 1.8ppm in a sample from borehole WS03.

6.4 Groundwater

No groundwater was noted during the site works. During the subsequent monitoring visit on 16th May 2016 boreholes WS01 and WS03 were dry, while groundwater was recorded in borehole WS02 at 2.8m bgl. The groundwater purged dry during bailing and did not recharge; indicating that it was perched groundwater in the Made Ground confined above the low permeability Alluvium and underlying London Clay. During the second visit groundwater was encountered in borehole WS03 at 3.0m bgl (boreholes WS01 and WS02 could not be accessed).

An additional four rounds of groundwater monitoring will be undertaken by CGL as part of the ground gas monitoring. The groundwater level results will be included as an addendum report following the completion of the additional monitoring.

6.5 Ground gas

Four rounds of ground gas monitoring have been conducted at the site to date on 16th May, 1st November 2016, 18th November 2016 and 30th November 2016; two additional rounds will be undertaken by CGL to establish the ground gas regime present in accordance with BS 8485:2015[12]. The results of these remaining monitoring rounds will be included as an addendum report following completion of the additional monitoring. The results of the ground gas monitoring conducted to date are presented in Appendix F and summarised below:

- Atmospheric pressure conditions – 988mb to 1030mb
- Carbon dioxide maximum – 4.2%;
- Methane maximum - <0.1%;
- Oxygen minimum - 14.5%;
- Flow maximum - 0.1 l/hr; and

[12] British Standards Institute, (2015). *BS 8485:2015- Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings*.

- VOC maximum - 0.6ppm.

6.6 Sulfate and pH conditions

The results of the sulfate and pH testing conducted are included in Appendix G and summarised in Table 6, below. Testing undertaken on the London Clay Samples indicated that one of the two samples was potentially pyritic.

Table 6. Sulfate and pH conditions

Strata	Water soluble sulfate (g/l)	Acid soluble sulfate (%)	Total sulfur (%)	Total potential sulfate (%)	pH
Made Ground	0.01 to 0.82	0.05 to 0.72	NA	NA	7.8 to 11.4
Alluvium	0.12 to 0.15	0.05 to 0.07	NA	NA	7.9 to 8.0
London Clay Formation	0.31 to 3.1	0.07 to 0.82	0.03 to 0.36	0.09 to 1.08	7.7 to 8.0

* NA = not applicable

The groundwater sample from borehole WS02 had a pH of 6.9 and a sulfate (as SO_4) content of 439mg/kg.

7. CONTAMINATION ASSESSMENT

7.1 Introduction

This section evaluates risks to potential receptors at the site from identified chemical contamination. Potential receptors have been identified with reference to the Part 2A regime and associated DEFRA guidance[13]. As with the Part 2A regime, under the planning regime all receptors (humans, controlled waters, ecology, crops/livestock and buildings) have been considered if there is the potential for them to be adversely affected by exposure to contamination. CGL's approach and rationale to assessment criteria adoption is presented in Table I1 Appendix I.

7.2 Risks to human health (long-term chronic risks)

A total of 13 samples from the site have been analysed for potential contamination; nine from the Made Ground, two from the Alluvium and two from the London Clay Formation.

The results of the chemical laboratory testing are present in Table I2 (Made Ground) and Table I3 (natural soils) within Appendix I. The results have been compared against "residential without plant uptake" land use.

7.2.1 Made Ground

The results of the assessment in Table I2 of Appendix I indicates that the US_{95} concentrations of lead, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene and dibenzo(a,h)anthracene exceed their assessment criteria.

Asbestos fibres was detected during laboratory analysis in four samples of the Made Ground from boreholes WS01 (0.4m and 2.7m bgl) and WS03 (0.4m bgl) and foundation inspection pit FIP01 (0.5m bgl). Asbestos quantification of the asbestos containing samples indicated that the asbestos concentrations were between <0.001% and 0.003%.

The site is considered to pose a **low to medium** risk to future site users and construction workers due to recorded concentrations of metals, hydrocarbons and PAHs and presence of asbestos in the Made Ground. It is considered that the potential risk to future site users can be mitigated by the provision of soil capping layers in soft landscaped areas. It is anticipated that the risk posed to construction workers can be further mitigated by the use

[13] DEFRA (2012). *Environmental Protection Act 1990:Part 2A Contaminated Land Statutory Guidance.*

of appropriate health, safety and welfare provisions. These include, but are not limited to, the use of appropriate personal protective equipment (PPE) and good site hygiene.

7.2.2 Natural soils (Alluvium and London Clay Formation)

The assessment presented in Table I3 of Appendix I indicates that none of the measured concentrations for the contaminants analysed in samples of natural soil exceeded the assessment criteria. Therefore, the risk to human health from contamination within the natural soils is considered to be **low**.

7.2.3 Ground gas

The results of the gas monitoring conducted on site to date are presented in Section 6.5 and included in Appendix F. The risk from ground gas has been assessed in accordance with BS 8485:2015[14]. Gas screening values (GSVs) have been calculated for the site using the maximum recorded flow rate (0.1 l/hr), carbon dioxide concentration (4.2%) and methane concentration (<0.1%) recorded to date. The GSV for methane is 0.0001 l/hr and the GSV for carbon dioxide is 0.0042 l/hr, indicating the site conforms to Characteristic Situation (CS) 1 and therefore gas protection measures are not required.

Based on the current results the risk to future site users and structures from ground gas is considered to be **low**. This will be confirmed once the remaining four monitoring visits have been undertaken, although given the concentrations recorded to date, it is considered unlikely that this will result in an increase in the ground gas regime. It is noted that both visits to date have been undertaken at high pressure.

7.3 Risks to vegetation and plants

The risk to vegetation and plants from phytotoxic contaminations present within the Made Ground has been assessed and is presented in Table I5 of Appendix I. The assessment indicated that the maximum recorded and US_{95} concentrations were below the assessment criteria. The site is therefore considered to pose a **low** risk to vegetation and plants from phytotoxic contaminants within the Made Ground.

7.4 Controlled waters assessment

One sample of the perched water was taken from borehole WS02 for chemical analysis. In addition, two of the soil samples of the Made Ground from foundation pit FIP01, which

[14] British Standards Institute, (2015). *BS 8485:2015 - Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings*.

had the highest contaminant concentrations, and foundation pit FIP03, which was considered to be representative of the general Made Ground, were scheduled for leachate testing. The results of these were screened against the EU drinking water values (DWV) and the Freshwater Environmental Quality Standard (EQS).

The majority of contaminants were found to be below their assessment criteria, however the concentration of nickel in the water sample from WS02 exceeded the screening values for both the freshwater EQS and the DWV. In addition, leachable total cyanide, fluoranthene and lead concentrations in the sample from foundation pit FIP01 exceeded the freshwater EQS and the lead concentration exceeded the DWV.

A summary of the exceedances is presented in Table 7 below and a full summary of the analysis is presented in Table I4 in Appendix I.

It should be noted the leachate test process is generally conservative as it typically overestimates the leachable concentrations for infiltrating water (due to the nature of the leaching process). In addition, the total cyanide concentration has been compared against the free cyanide assessment criteria, assuming that all the cyanide present is free cyanide rather than any complex cyanide as a worst-case scenario for the initial assessment.

Table 7. Summary of contaminant exceedances in groundwater

Sample location	**Contaminant**	**Measured concentration (μg/l)**	**Bioavailable fraction (μg/l)**	**Freshwater EQS (μg/l)**	**EC Drinking Water Value (μg/l)**
WS02 (perched water)	Nickel	25	9.09	4	20
FIP01 (leachate)	Total cyanide	6.2	-	1	50
	Fluoranthene	2.3	-	0.1	-
	Lead	190	-	1.2	10

Given the water encountered on site is considered to be perched water within the Made Ground and that the site is located on London Clay, which is designated as Unproductive Strata, and that there are no nearby surface water features or aquifers, the potential risk to controlled waters is considered to be **negligible to low**.

7.5 Risks to buildings and structures

7.5.1 Sulfate and pH conditions

The potential risk to on-site and structures from contamination within the soils and groundwater is considered to be **low to medium**, although this can be mitigated against through appropriate concrete design. Appropriate concrete design classes are discussed in Section 9.7.

7.5.2 Water supply pipes

An assessment of the contaminant concentrations against criteria for buried services is presented in Table I6 of Appendix I. The majority of concentrations of contaminants recorded in soil samples taken at typical service run installation depths were below the assessment criteria. However, in two locations, 0.4m in WS01 and 0.5m in foundation pit FIP01, the concentration of naphthalene, used as a proxy for VOCs and SVOCs, exceeded the assessment criteria.

On this basis, and due to the pH and conductivity of the perched water encountered in WS02 it is recommended that appropriate pipe material such as wrapped steel or polythene/aluminium composite barrier pipe be used in accordance with advice provided by the UKWIR[15]. Underground service trenches should also be backfilled with clean granular fill.

7.6 Qualitative risk assessment

A qualitative risk assessment (QRA) has been undertaken for the site based on the results of the CGL site investigation and is presented in Table 8, below. Potential pollutant linkages have been identified in accordance with CLR 11[16] and their risk rating have been assessed in accordance with CLR 6[17]. A summary of the risk rating system is presented in Table 2 in Section 4.3.

A pictorial version of the conceptual site model (CSM) devised for the site is included as Figure 6.

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[15] UK Water Industry Research, (2010). Guidance for the selection of water supply pipes to be used in brownfield sites. Report No. 10/WM/03/21

[16] Environment Agency, (2004). Model Procedures for the Management of Land Contamination, CLR 11.

[17] M.J. Carter Associates, (1995). Prioritisation and Categorisation Procedures for Sites Which may be Contaminated, CLR 6. Department for the Environment.

Table 8 . Qualitative risk assessment

Source/Medium	**Receptor**	**Potential Exposure Route**	**Risk Rating**
Explosive / asphyxiating ground gases from underlying Made Ground, if present.	Internal building spaces, future occupants and off-site residents.	Migration of gases through the surface and via permeable soils	Low (subject to confirmation through further ground gas monitoring)
Asbestos within site structures / Made Ground, if present. (Risks from asbestos in existing buildings not assessed).	Construction workers, off site residents and future site occupants.	Direct inhalation of particulates	Low to medium
Organic/inorganic contaminants (e.g. PAHs, hydrocarbons, metals etc.) within underlying Made Ground	Construction workers	Direct ingestion of soil and dust, inhalation of particulates and vapours and dermal contact	Low to medium
	Future site occupants	Direct ingestion of soil & dust, inhalation of particulates & vapours, and dermal contact	Low to medium
	Vegetation and plants	Root uptake	Low
	Controlled waters (Regent's Canal, groundwater)	Lateral migration of contaminated groundwater to local surface water bodies	Negligible to low
	Buildings and structures	Direct contact with water supply pipes and underground concrete structures	Low to medium
Off-site contaminants including hydrocarbons, PCBs, heavy metals, organic contaminants within groundwater	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Low
	Future site occupants	Direct ingestion of soil & dust, inhalation of particulates & vapours, and dermal contact	Low
	Vegetation	Root uptake	Low
UST/interceptor	Construction workers	Direct ingestion of soil, inhalation of vapours and dermal contact	Low to medium
	Future site occupants	Direct ingestion of soil, inhalation of vapours and dermal contact	Low to medium
	Controlled waters (Regent's Canal, groundwater)	Lateral migration of contaminated groundwater to local surface water bodies	Low

8. GEOENVIRONMENTAL RECOMMENDATIONS

8.1 Contamination and remediation

The results of the site investigation indicated elevated concentrations of lead, several PAHs and the presence of asbestos fibres in the Made Ground, which pose a potential risk to human health where the Made Ground is exposed. It is considered that the risks presented to future occupants from the contamination and asbestos within the Made Ground can be mitigated through the provision of a barrier layer in the form of building/hardstanding and a soil capping layer in areas of soft landscaping.

Recommendations for remediation works are provided below. However, further investigation will be required to confirm the remediation strategy. This is particularly with respect to establishing the ground conditions and the potential presence of contamination beneath the footprint of the current warehouse buildings (once they have been demolished) and in the vicinity of the potential UST near the site entrance. In addition, a further four rounds of ground gas monitoring are to be undertaken to further characterise the ground gas regime.

8.1.1 Capping layers

Due to the presence of metals, hydrocarbons, PAHs and asbestos within the Made Ground, proposed areas of soft landscaping should be provided with suitable topsoil and cohesive subsoil to form a capping layer. Elsewhere on the site, the barrier layer will be formed by building footprints or hardstanding.

In areas of soft or communal landscaping, where Made Ground remains at formation level, the capping layer should comprise a minimum 450mm of imported material with a geotextile marker layer at the base and a minimum of 150mm topsoil at the surface.

In areas where soft landscaping is located on podiums and where the Made Ground is not present at formation level, only a growth medium is required. The thickness of the growth medium should be agreed with the landscape architect, but is considered likely to comprise a minimum 150mm topsoil.

The subsoil/topsoil imported to form the capping layer/growth medium should be clean soil from a known and reputable source. Chemical certification of the source material test results and details of source should be provided by the Contractor prior to capping material being brought to site. Topsoil should conform to the requirements of BS 3882[18].

Once placed, the capping layer/growth medium would be subject to validation by a qualified geoenvironmental engineer. Inspection pits should be dug to validate the capping layer/growth medium construction and the landscaped areas should be sampled at a frequency of one sample per 250m^2 for each source. The soils should not contain foreign bodies or contaminant concentrations that exceed the maximum permissible concentrations presented in Appendix J.

To certify the integrity of the capping layer, placement should commence after installation of foundations and drainage works.

8.1.2 Gas protection measures

Based on the results of the gas monitoring conducted to date the site conforms with CS1. However, should the additional monitoring rounds identify elevated flow rates or concentrations of carbon dioxide or methane, gas protection measures may be required in accordance with BS 8485[12] and CIRIA C735[19]. This will be confirmed in an addendum to this report.

8.2 Buried services

It is recommended that appropriate pipe material such as copper or composite barrier pipe be used for water supply pipes placed in the Made Ground, in accordance with UKWIR advice[20]. The final water pipe specification should be agreed with the local water supply company.

8.3 Watching brief and discovery strategy

It is recommended that during the development, a watching brief is maintained by the Main Contractor. Where unexpected gross contamination, such as oily material, material of an unusual colour or odour and potential asbestos containing material (ACM), is encountered, the following discovery strategy is recommended:

1. Work to cease in that area.

[18] British Standards (2015) BS 3882. Specification for topsoil and requirement for use.
[19] CIRIA (2014) Good practice on the testing and verification of protection systems for buildings against hazardous ground gases (C735).
[20] UK Water Industry Research (UKWIR), (2010). Guidance for the selection of Water Supply Pipes to be Used in Brownfield Sites

2. Notify geoenvironmental engineer, to attend site and sample material for appropriate analysis and risk assessment. Notify Contaminated Land Officers of the Local Authority as appropriate.
3. If required by the risk assessment, geoenvironmental engineer to supervise the excavation of contaminated material, which should be placed in a bunded area and covered to prevent rainwater infiltration.
4. Soil samples should be obtained by the geoenvironmental engineer from both the excavated material, and the soils in the sides and base of the excavation to demonstrate that the full area of contamination has been excavated. Where appropriate, in-situ testing should be undertaken on the sides and base of the excavation to assess the presence of residual contamination in the soils.
5. On receipt of chemical test results, the soils may be classified for disposal, or treatment if appropriate, and dealt with accordingly.
6. Detailed records of the stockpile sizes, source and location should be kept and regularly updated to allow materials to be easily tracked from excavation until leaving the site.
7. Records of excavated areas and the results of chemical testing should be incorporated within the final verification report for the site.

To facilitate appropriate waste disposal and potential re-use of materials all excavated soils should be segregated and stockpiled depending on their soil classification.

8.4 Material management

8.4.1 Re-use, recycling and recovery (Waste Hierarchy)

In order to minimise the volumes of soils being disposed of to landfill facilities, it is prudent to consider material management options prior to waste disposal. Screening of uncontaminated natural arisings may permit the reuse of this material on site or for other sites under the WRAP Quality Protocols[21] for uncontaminated aggregates or the CL:AIRE protocol[22].

[21] WRAP, (2016). The Quality Protocols
[22] CL:AIRE, (2011). The Definition of Waste: Development Industry Code of Practice. Version 2.

8.4.2 Waste disposal

A preliminary waste classification assessment has been undertaken in accordance with the technical guidance WM3[23]. The nine samples of Made Ground analysed were assessed to be "Not-hazardous". Three Waste Acceptance Criteria (WAC) tests were undertaken on samples of the Made Ground, two were recorded to be classed as "non-hazardous" waste and one as "inert" waste.

In addition, asbestos was detected in four samples of the Made Ground (in FIP01, WS03 and two samples from WS01) at concentrations below the hazardous waste threshold (0.1%), therefore the material would require disposal at a non-hazardous waste facility which accepts asbestos containing soils. No visible Asbestos Containing Materials (ACMs) were identified during the site works. Should ACMs be encountered in the soils the impacted material will require segregation from other arisings. The ACMS should be separated from the soil matrix, by hand picking for example, tested and disposed of hazardous waste.

Uncontaminated natural soils are automatically deemed inert for disposal.

All waste requiring disposal will require pre-treatment. This can be performed on site or carried out a licensed off-site facility and can include selective segregation or other processes. It should be noted that no pre-treatment is required for material sent for recovery processes rather than disposal. All material intended for off-site disposal or treatment should be transported and disposed of in accordance with the Environmental Protection (Duty of Care) Regulations, 1992 and the Landfill (England and Wales) Regulations, 2002 (as amended).

8.5 Health and safety

All site works should be undertaken in accordance with the guidelines prepared by the Health and Safety Executive (HSE, 1991)[24] and CIRIA Reports 132[25] and C650[26]. All work

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[23] Environment Agency, (2015). Technical Guidance WM3. Waste Classification Guidance on the Classification and Assessment of Waste. 1st Edition.
[24] Health and Safety Executive (HSE), (1991). Protection of Workers and the General Public During the Development of Contaminated Land. Guidance Note HS(G)66.
[25] Steeds J.E., Shepard E., Barry D.L., (1996). A Guide for Safe Working on Contaminated Sites. CIRIA Report 132.
[26] CIRIA, (2005). Environmental Good Practice – Site Guide, 2nd Edition. CIRIA Report C650.

should also be carried out in accordance with the Contractor's Construction Health and Safety Plan and current asbestos regulations[27] and guidance[28, 29].

During the development precautions should be taken to minimise exposure of workers and the general public to harmful substances. Attention should also be given to restricting potential off-site nuisances such as dust and odour emissions. Such precautions should include, but not be limited to:

1. Personal hygiene, washing and changing procedures.
2. Adequate personal protective equipment, including disposable overalls, gloves and particulate filter masks/vapour respirators where required.
3. Measures to avoid surface water ponding and positive collection and disposal of all on-site run-off.
4. Regular cleaning of all site roads, accesses road and public highways, also including dust suppressions methods (e.g. water spraying) if necessary.
5. All waste haulage vehicles should be covered when leaving site to minimise the release of airborne particulates.

Site staff undertaking groundworks should be advised of the potential for ACMs to be encountered, be training in basic visual recognition of ACMs and provided with suitable respiratory protective equipment (RPE).

It is noted that the contractor may be required to assess the risk of handling and removing asbestos containing soils, should they be encountered, and should implement appropriate control measures. An assessment will need to be undertaken to determine whether the works would be notifiable under the HSE's Control of Asbestos Regulations[27] and hence require a licensed contractor to undertake the works. Asbestos containing soils should be dampened down when handled to prevent fibre release, taking care that the dampening down is undertaken in the appropriate way, time and with appropriate amounts of water to suppress dust and fibre release but not saturate the soils. As far as reasonable possible, soil movements should be minimised and double handling avoided.

[27] Health and Safety Executive, (2012). The Control of Asbestos Regulations.
[28] Health and Safety Executive, (2006). Asbestos: The Licenses Contractor's Guide. Guidance Note HSG247.
[29] Health and Safety Executive, (2006). Work with Materials Containing Asbestos, Control of Asbestos Regulations 2006 Approved Code of Practice and Guidance.

9. GEOTECHNICAL RECOMMENDATIONS

9.1 General

This section presents preliminary geotechnical recommendations for the site based on the results of the ground investigation conducted to date and assuming the development will comprise a high rise structure, up to seven stories tall, with a one storey basement under part of the structure..

9.2 Geotechnical design parameters

Geotechnical design parameters have been derived for the encountered strata based on the soil descriptions, laboratory testing results, SPT 'N' values recorded during the site work and published data, where no relevant data has been obtained. A summary of the design parameters are presented in Table 9.

Table 9. Summary of geotechnical design parameters

Stratum	Design level to top of stratum (mOD)	Bulk Unit Weight γ_b (kN/m^3)	Undrained Cohesion c_u (kPa) [c']	Friction Angle ϕ' (°)	Young's Modulus E_u (MPa) [E']
Made Ground (cohesive)	32.5	18	30	24[a]	18[d] [13.5][e]
Made Ground (granular)	31.5	18	- [0]	28[b]	- [30]
Alluvium	30.5	18	30	22[a]	18[d] [13.5][e]
London Clay Formation	29.5	20	50 + 3.5z[c] [5][b]	24[a]	30 + 2.1 [d] [22.5 + 1.6][e]

Notes

a. *Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310..*

b. *Burland et. al (Eds) (2001) Building response to tunnelling, CIRIA Special Publication 200, CIRIA*

c. *z = mOD below top of London Clay*

d. *Based on 600 Cu. Burland et. al (2001), CIRIA Special Publication 200, Building response to tunnelling, Case studies from the Jubilee Line Extension, London.*

e. *Based on 0.75 Eu. Burland et. al (2001), CIRIA Special Publication 200, Building response to tunnelling, Case studies from the Jubilee Line Extension, London.*

A conservative Cu design line of *Cu = 50 + 3.5z* (where z = depth below the top of the London Clay) has been derived for the London Clay based on the results of SPT and HSV testing conducted, however it should be noted that the investigation was limited to the upper 5m bgl of the site (i.e. approximately the upper 2m of the London Clay).

9.3 Foundations

Due to the presence of around 3 to 4m of variable Made Ground and variable superficial deposits across the site, conventional shallow spread foundations are not considered to be appropriate. Piled foundations founding into the London Clay are considered likely be appropriate for apartment buildings. Shallow foundations may be suitable for lighter structures such as out buildings or bin and bike stores. To date the ground investigation has been limited to 5mbgl or the top 2m of London Clay. Therefore, additional information is required to establish parameters for the deeper ground.

A raft or piled raft solution may be considered for the proposed single basement to the north-east of the site subject to an assessment of the settlements and stresses on the underlying infrastructure. Early consultation with the Statutory bodies would be recommended in this regard to determine the tolerances of the underlying structures and hence the feasibility of a raft.

The retaining system of the basement box will be formed by either bored piles or diaphragm walls.

9.4 Excavations

Based on the ground conditions encountered across the site, excavations required during the development should not pose difficulties for conventional excavators and earthmoving equipment. Care should be taken when operating heavy plant on exposed surfaces of soft Made Ground. The installation of robust working platforms may be required to ensure stability of the operating plant where operating on this material.

Since no significant shallow groundwater was noted during to the ground investigation, a contiguous pile wall, or similar embedded retaining wall system with temporary propping at the top, is considered appropriate to laterally support the earth pressures applied towards the open basement excavation.

The Made Ground is likely to require battering back and/or temporary support for any excavations. It is considered unlikely that shallow perched groundwater will be encountered in significant quantities within the Made Ground based on the lack of significant groundwater observed within the monitoring wells. Excavations in the London Clay are anticipated to remain relatively stable in the short-term.

9.5 Floor slabs and pavement design

Due to the presence of variable Made Ground and soft Alluvium, fully suspended ground floor slabs should be adopted in the development including the single basement construction. The floor slab shall meet the requirements set out in the buried services and concrete section below.

Based on the variability of the Made Ground on which pavement will likely be laid, design CBR of less than 2.5% would apply. Therefore, the subgrade would require improvement in accordance with clauses 5.16 to 5.21 of *Interim advice note 73/06*[30]. Care should also be taken during construction of roadways during inclement weather to avoid excess softening and deterioration of exposed cohesive material. The formation level should be proof rolled and where soft spots are encountered the material should be excavated and replaced with well compacted granular material. For external works and landscaping areas the presence of alluvial deposits should be considered as may cause excess or differential settlement at particular regions on site depending on the applied loading or excavation works. Those land works should comply with NHBC[31] standards.

9.6 Drainage

Due to the presence of contaminants in the Made Ground, and the underlying Alluvium/London Clay, conventional soakaways or permeable paving are not considered appropriate for the site.

9.7 Buried concrete

The availability of total potential sulfate (TPS) in pyritic soils (i.e. London Clay) is dependent on the extent to which the soils are disturbed, and the level to which the soils may oxidise, resulting in sulfate ions that may reach the concrete. In this regard, BRE SD1 guidance[32] states that *"Concrete in pyritic ground which is initially low in soluble sulfate does not have to be designed to withstand a high potential sulfate class unless it is exposed to ground which has been disturbed to the extent that contained pyrite might oxidise and the resultant sulfate ions reach the concrete. This may prompt redesign of the structure or change to the construction process to avoid ground disturbance; for example, by using precast or cast-in-situ piles instead of constructing a spread footing within an excavation"*.

[30] Interim Advice note 73/06 Revision 1 (2009) design guidance for road pavement foundations. (DRAFT HD25)
[31] NBHC (2016) *Standards 2016: Foundations – Part 4*
[32] Building Research Establishment. (2005). *Concrete in aggressive ground*. Special Digest 1, 3rd Ed.

Several samples of the Made Ground, Alluvium and London Clay were analysed for BRE pH and sulfate. Of the two samples of London Clay tested, one sample was pyritic while the other was found to not be pyritic. On this basis it should be assumed that the London Clay present is pyritic unless further testing is undertaken over a broader range of samples from different depths. Based on the maximum total sulfate and water soluble sulfate content for each stratum, concrete within the London Clay should be designed to DC4/AC-3s, while concrete in the Made Ground or Alluvium should be designed to DS2/AC-1s. Table 10 shows the appropriate classifications for the strata present

Table 10. Design sulfate and ACEC classifications

Stratum	Water soluble sulphate (2:1 Leachate Equivalent)	
	DS class	**ACEC Class**
Made Ground	DS-2	AC-1s
Alluvium	DS-2	AC-1s
London Clay Formation	DS-4	AC-3

10. RECOMMENDATIONS FOR ADDITIONAL SITE INVESTIGATION

Additional works are considered to be required at the site based on the limited scope of investigation conducted at the site to date by CGL. The following works are considered to be required:

- Additional investigation in the area of the potential UST near the site entrance, including additional chemical testing for potential contamination.
- Additional window sampling in the west and south of the site which were inaccessible during the CGL site works, including within the footprint of existing buildings following demolition. Additional chemical testing of Made Ground and underlying natural soils to assess potential contamination.
- Cable percussion boreholes to investigate the deeper ground conditions (including the London Clay) beneath the site and to provide further geotechnical information to aid in the design of foundations.

Following completion of the supplementary site investigation, a full remediation strategy will be required to provide recommendations and guidance on the remediation requirements for the site and to include a verification plan.