A2 Dominion Developments Ltd

156 West End Lane, West Hampstead

Geotechnical and Geoenvironmental Interpretative Report – Revision 1

April, 2020

Card Geotechnics Limited
4 Godalming Business Centre
Woolsack Way, Godalming GU7 1XW
Telephone: 01483 310600
www.cgl-uk.com

Author	Jessica Whelan, Senior Engineer *BSc (Hons) MIEnvSc*	JWhelan
Checked	Richard Ball, Technical Director *MSc BSc CEng MICE FGS*	
Approved	Robin Slade, Operations Director *BSc CEnv MIEMA*	Rob Slade

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Contents

FIGURES

APPENDICES

EXECUTIVE SUMMARY

Card Geotechnics Limited (CGL) has been commissioned by Silver DCC on behalf of the applicant A2 Dominion Developments Limited, to undertake a ground investigation in accordance with the written programme of ground investigation as approved on 20th February 2020 (application reference 2020/0200/P) pursuant to Condition 26a of planning permission reference number 2015/6455/P (approved on 23rd June 2017) for the comprehensive redevelopment of 156 West End Lane, West Hampstead. The site was most recently occupied by a retail showroom and builders' merchant with associated yard, however this use ceased in January 2020. The approved development includes 164 self-contained residential dwellings across two multi-storey blocks, with ground floor flexible commercial floorspace, accessible parking spaces and areas of communal landscaping.

There is a Network Rail retaining wall along the southern boundary of the site and accordingly, the design team and main contractor will continue its liaison with Network Rail throughout the works and all necessary approvals will be obtained from Network Rail.

The site has previously been the subject of a desk study by RSA Geotechnics Limited and their findings have been reviewed as part of this report. From the earliest available mapping from 1871, the site was part of open fields with a railway cutting present encroaching on the south western corner of the site associated with the *Midland Railway* line butting the southern boundary. In the following years the site was occupied by small buildings in the western quarter of the site with the remainder of the site as tennis courts. The railway cutting extended along the southern edge of the site to facilitate railway sidings. By 1946, a *Garage* and petrol forecourt had been constructed in the western area of the site. By 1985, the site was developed into its current layout.

The ground conditions encountered during the CGL investigation generally comprised between >1.6m and 3.2m of Made Ground. In the southern section of the site, the base depth of the Made Ground increased to between greater than 2.8m and 4.0m. In borehole BH2 only, a 3.8m thick layer of possible Head Deposits was recorded. The London Clay Formation was encountered within four locations between depths of 2.2m and 6.0m bgl and was proven to a maximum depth of 30m bgl. Perched water was encountered during the works within the Made Ground in three locations only. Subsequent monitoring recorded perched water resting at depths of 0.71m and 1.2m.

Visual evidence of contamination was identified in the form of a hydrocarbon sheen on perched water adjacent to a former above ground fuel tank, an isolated pocket of black stained gravel with hydrocarbon odour in one of the boundary foundation inspection pits, and ashy material within three central exploratory locations. Elevated concentrations of arsenic, lead, and polycyclic aromatic hydrocarbons were encountered within the Made Ground, representing a moderate risk to long-term human health.

The initial ground gas monitoring visit indicated carbon dioxide <5%, no measurable concentrations of methane and no sustained flow – corresponding to Characteristic Situation 1 or low risk. Further ground gas monitoring and assessment is recommended to confirm the risks posed to future site occupiers based on the prevalent gas regime.

Based on the investigation completed to date, is it considered that the future development will require the following remediation measures:

- Provision of soil capping layers in areas of soft landscaping,
- Protective pipework for water supply pipes, and
- Implementation of a watching brief and discovery strategy during construction.

A preliminary waste characterisation indicates that the tested samples of Made Ground are not hazardous and may be re-used / recovered or disposed at suitably licensed inert or non-hazardous waste facilities, subject to Waste Acceptance Criteria (WAC) testing. A watching brief and discovery strategy is recommended during the proposed development construction, so that, in the event unexpected contamination is encountered, it can be dealt with promptly and appropriately.

Based on the ground conditions encountered and anticipated structural loads, Continuous Flight Auger (CFA) piled foundations are recommended for the development. Suspended floor slabs are recommended, and pavements formed within the Made Ground should be designed to a CBR value of <2.5%, although proof rolling and retesting may achieve a higher CBR value.

Excavations are likely to require temporary support, particularly along the southern edge of the site in the infilled cutting, and perched water control measures may be required.

Concrete should be designed to design sulfate classes DS-3 and AC-3 (concrete in Made Ground), DS-1 and AC-1s (concrete in possible Head Deposits) and AC-3s (concrete and piles in London Clay).

At the time of the investigation, it was not possible to access the western half of the site due to the presence of the existing building fronting onto West End Lane, and the requirement to maintain access and egress to the rear section of the site. Therefore, additional ground investigation is required in the western area of the site to investigate the area of the former Garage and petrol forecourt, to confirm or otherwise, the established conceptual side model. This should include further ground gas monitoring and assessment to confirm the prevalent gas regime, assess potential risks to receptors and requirements for specific ground gas protection measures. It is noted that it is not currently viable to carry out investigation in the areas of the existing buildings, therefore it is recommended that this work is carried out once the buildings have been demolished.

1. INTRODUCTION

Card Geotechnics Limited (CGL) has been instructed by Silver DCC Limited on behalf of the Client A2 Dominion Limited, to produce a Geotechnical and Geoenvironmental Interpretative Report, following completion of ground investigation, for the proposed development of 156 West End Lane, West Hampstead to assist with discharge of planning condition 26b of Planning Permission 2015/6455/P. It is understood that the approved development is for 164 self-contained residential dwellings arranged across two buildings ranging in height from three to seven storeys. The development will also include ground floor commercial units, an area of accessible parking and areas of communal soft landscaping.

The site has been the subject of a previous desk study by RSA Geotechnical[1] which has been made available to CGL for review.

The objectives of this report are to:

- Undertake a review of the previous desk study and provide commentary with respect to the environmental, historical and geological setting of the site, in conjunction with geotechnical and geoenvironmental risks based on available published data sources;
- Provide information on the ground conditions encountered on site and provide analysis and interpretation of chemical and geotechnical laboratory testing undertaken on representative soil samples;
- Present a source-pathway-receptor risk assessment based on the findings of the intrusive investigation and results of chemical testing;
- Provide geoenvironmental recommendations for soil and water contamination and ground gas;
- Provide recommendations for remediation and verification (where required); and
- Provide geotechnical recommendations for foundation design, roads/pavement design and sulfate protection for buried concrete.

[1] RSA Geotechnics Limited. (2015). *Desk Study Report – 156 West End Lane, West Hampstead, London, NW6 1UF*. Report Reference: 14151DS. Dated November 2015.

2. SITE CONTEXT

2.1 General

This report should be read in conjunction with the previous RSA Geotechnics Desk Study[1], which includes detailed information on the site context. A summary of pertinent information is presented in the following sections.

2.2 Site Location and Description

The site is located at 156 West End Lane in West Hampstead. The Ordnance Survey grid reference for the approximate centre of the site is 525600E, 184870N and the nearest postcode is NW6 1UF. A site location plan is presented as Figure 1, and a Site Layout Plan is presented as Figure 2.

The site is approximately rectangular in shape, covering an area of approximately 0.64 hectares, and can be split into two distinct areas. The western third of the site comprises a five-storey building fronting onto West End Lane. The upper floors of the building were formerly used as council offices, with the ground floor occupied with a retail showroom and builder's merchant. The remainder of the site comprises the rear yard of the former builder's merchant. An access road to the rear yard is present along the southern boundary of the existing building. It is noted that the south westernmost section of the site includes a below ground retaining wall structure with associated cantilevered structure currently utilised as car-parking spaces. The cantilever is present above the adjacent off-site Platform 1 of the West Hampstead Thameslink railway station.

During the walkover undertaken by RSA, an electrical substation was observed within the existing building, and an above ground fuel tank was identified in the rear yard abutting the eastern end of the southern boundary of the site. Evidence of hydrocarbon staining on the concrete was also noted around the tank.

The site is bounded to the south by Thameslink railway line, to the east by a Multi-Use Games Area (MUGA), and to the north by the rear gardens of housing fronting onto Lymington Road and to the west by the north to south trending West End Lane.

2.3 Approved Development

It is understood that the development will comprise 164 self-contained residential dwellings, 763sqm of flexible non-residential use, 1093sqm of employment floorspace, and 63sqm of community meeting space in buildings ranging from 3 to 7 storeys. The development will include the provision of a new vehicular access from West End Lane, and eight accessible car parking spaces. The development will also include new areas of public open space, the widening of Potteries Path and associated cycle parking, and landscaping. The approved lower ground and ground floor development plans for the site are presented within Appendix A.

2.4 Site History

Selected sources have been reviewed to assess the site's historical development and potential for historical contamination.

2.4.1 Historical Mapping

CGL has undertaken a review of a previous desk study[1], which indicates that from the earliest available maps of 1871, the site was part of a larger field, with a small road crossing the north eastern corner and a railway cutting within the south westernmost section of the site, associated with the *Midland Railway* abutting the southern boundary of the site.

From 1915, the site comprised various small buildings and a Hall in the western quarter, with tennis courts and associated pavilion building in the remainder of the eastern area of the site at this time. The cutting in the south western section of the site is indicated have been extended along the southern edge of the site to incorporate two railway sidings associated with the Midland Railway. This can be seen clearly in the 1935 mapping and the aerial map from 1946 also shows the southern edge of the site to be separate from the remainder of the site, indicating the cutting is still present. Additionally, the aerial map shows two large buildings had been constructed within the western quarter of the site. Later maps identified the larger building as a *Garage* and in 1974 a *Depot*.

By 1985, the cutting along the southern strip of the site is no longer present and is assumed to have been infilled (with unknown materials). Access to the site was revised to extend over the location of the former cutting, and there is a void beneath the south westernmost extent of the site due to a retaining wall and cantilever structure. The site layout remains unchanged on later map editions. Plate 1 and Plate 2 below presents a summary of key historical development across the site.

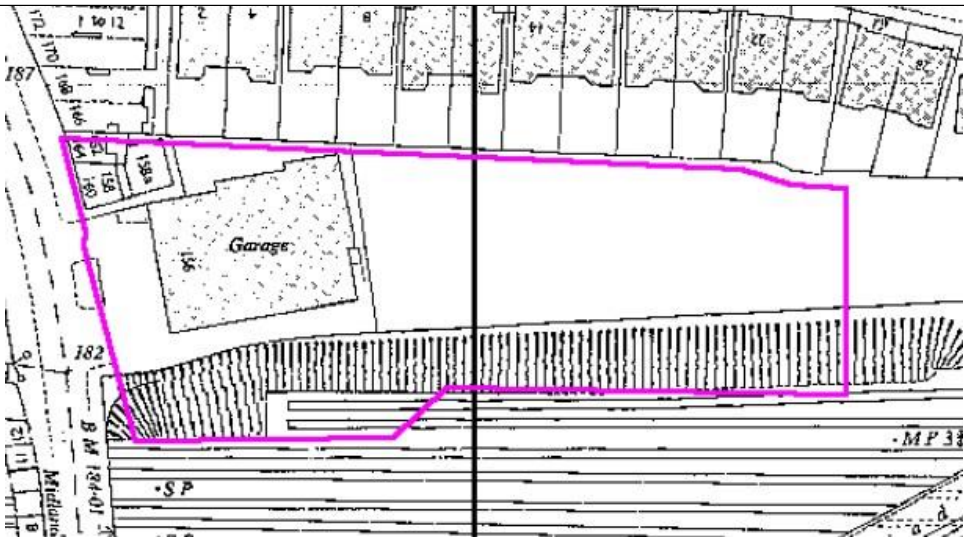

Plate 1. Extract of 1954-1960 Envirocheck Historical Map presented within RSA Desk Study Appendices.

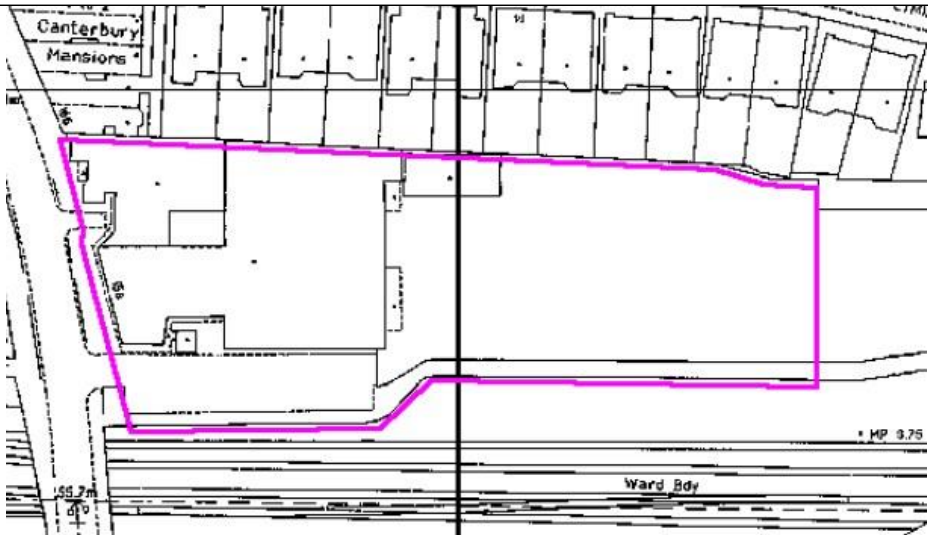

Plate 2. Extract of 1992-1995 Envirocheck Historical Map presented within RSA Desk Study Appendices.

2.4.2 Planning History

The planning history for the site indicates that the garage in the western half was historically used as a petrol station with associated fuel tanks. The site (and fuel station) were redeveloped in the 1970s to provide the current site layout, however, it is recognised that there is potential for historical contamination to remain in this area.

In 1964, an application was also made for a temporary extension to the car-parking facilities into the eastern third of the site. A plan included within the application details that the central area of the site immediately behind the *Garage* building was an existing car park with surfaced with an 'Ash Finish' and that the temporary car-park would be surfaced the same. It is unknown if this extension was granted or took place.

2.5 Unexploded Ordnance (UXO)

The RSA Desk Study reviewed the 1945 London Bombing Maps and the online WWII bomb census website which indicated that bombs were dropped within 150m of the site.

In order to assess the risk further, CGL instructed a Preliminary Unexploded Ordnance (UXO) Threat Assessment Report which confirmed the site was considered a high risk. The follow on Detailed UXO Threat Assessment recommended that during intrusive works the risks of UXO need to be considered and watching brief undertaken by component and trained persons.

Copies of the preliminary and detailed UXO threat assessment reports are included within Appendix B of this report.

2.6 Anticipated Ground Conditions

With reference to the British Geological Survey (BGS) Geological Sheet Map 256[2], the site is expected to be underlain by solid geology of the London Clay Formation. No superficial deposits are shown to be present at the site, although it is indicated that Head deposits may be present to the north of the site.

Historical BGS borehole records have been reviewed by CGL, which confirm the London Clay Formation extends to approximately 50m below ground level.

2.7 Hydrogeology and Hydrology

With reference to the RSA report and Defra's MAGIC website, the London Clay underlying the site is classified as 'Unproductive Strata'. The site is not situated within a groundwater Source Protection Zone, nor is it indicated to be at risk from flooding.

The nearest surface water feature (and controlled water) is the Regents Canal located some 2.4km south east of the site.

[2] British Geological Survey. (2006). *North London*. England and Wales Sheet 253. Bedrock and Superficial Geology. 1:50,000.

3. PRELIMINARY RISK ASSESSMENT

3.1 Introduction

Historical contamination of land may present harm to human health and the environment. Current UK legislation stipulates that the risk associated with 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 (February 2019), which means that a planning authority must consider contamination when they prepare development plans or consider 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 Environmental Protection Act 1990 requires 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 2A 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.

3.1 Preliminary Conceptual Site Model

A preliminary conceptual model (CSM) has been compiled for the site with respect to the approved development to identify the potential sources of contamination and the associated potential pollutant linkages. For the preliminary CSM, a *residential without plant uptake* land use has been assumed in terms of human health, based on the approved development. This model also informs the potential need for further investigation at the site. The preliminary CSM is presented graphically as Figure 3.

3.1.1 Potential Sources

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

- *On-site sources* – Historically a garage and petrol station were present in the western area of the site, and the remainder of the site was used as tennis courts and an assumed infilled cutting. There is potential that the central and eastern area of the site may have been developed with a temporary ash surfaced car-park, but this is unconfirmed. Although the site has since been redeveloped to the current layout, the historical on-site activities have the potential to be a source of a wide range of contaminants including metals, polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs). Additionally, Given the site was redeveloped by 1985, there is potential for asbestos containing materials to be present within the Made Ground. Furthermore, Made Ground can be a source of ground gas where an appreciable organic content is present. In addition, degradation of hydrocarbons/organic chemicals in the ground can produce organic vapours and ground gases

- *Off-site sources* – Historical and current off-site activities including a number of *unspecified Factories and Works, Cocoa Factory*, *Depots, Corporation Yards and Railway Lines/Yards.* These current and former off-site activities have the potential to be a source of a wide range of contaminants including metals, TPH, chlorinated solvents, ammonia, PAHs which could migrate onto and beneath the site.

3.1.2 Potential Pathways

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

- *Ingestion and inhalation* – contamination within the Made Ground can result in the ingestion or inhalation of contaminated soils (and asbestos fibres if present) and inhalation of ground gases/vapours.

- *Direct/dermal contact* – direct/dermal contact with contaminated soils or shallow groundwater can result in the uptake of contaminants through the skin or permeation of contaminants through structures.

- *Lateral/vertical migration* – lateral and vertical migration of ground gases/vapours or contaminants through the permeable soil matrix.*Drainage and services* – could provide a preferential pathway for dissolved phase contamination migration and/or ground gases/vapour transport.

- *Root uptake* - uptake of phytotoxic contaminants by plants and vegetation.

3.1.3 Potential Receptors

Based on the proposed end use of the site for residential purposes, the main receptors at the site are considered to be:

- *Future site occupants/users* – future residential users are primarily at risk from direct contact, inhalation or ingestion where contaminated soil is exposed at surface, inhalation of asbestos fibres, and from ground gas/vapour accumulation within buildings.

- *Construction workers* – primarily at risk from direct contact, inhalation or ingestion of contaminants, and inhalation of asbestos fibres.

- *Buildingsand structures* – buried concrete and services, such as plastic water supply pipes, can be at risk from chemically aggressive ground. Ground gases and vapours may also accumulate in buildings and structures presenting an explosive risk.

- *Vegetation and plants* – primarily at risk from phytotoxic contaminants such as copper, nickel and zinc.

- *Off-site receptors (particularly neighbouring residential areas)* – primarily at risk from inhalation or ingestion of dust and/or asbestos fibres from contaminated soils during development works, and from ground gas/vapour accumulation in buildings.

It is noted that controlled waters have been discounted as both a receptor and pathway due to no shallow groundwater being anticipated beneath the site and that the underlying London Clay Formation affords protection to the underlying hydrogeology. In addition, the nearest surface water feature is 2.4km south and comprises a lined canal. As such, controlled waters are not considered to be viable receptors or pathways for the current site development and have been discounted.

3.2 Preliminary Qualitative Risk Assessment

A preliminary qualitative risk assessment has been undertaken based on the findings of the conceptual site model and the potential pollutant linkages that may exist at the site in accordance with Contaminated Land Report (CLR) 11[3] (noting this is to be withdrawn later in 2020 and replaced with Land contamination: risk management guidance). Using criteria broadly based on those presented in CIRIA Report C552[4], the magnitude of the risk associated with potential pollutant linkages has then been assessed and is summarised below. The risk assessment methodology is presented in Appendix C.

It is noted that controlled waters have been discounted as both a pathway and receptor.

Table 1. Qualitative Risk Assessment

Potential Source/Medium	*Potential Exposure Route*	*Potential Receptor*	*Severity*	*Probability*	*Risk Rating*
Explosive/ asphyxiating gases/vapours from underlying Made Ground and	Migration of gases and vapours through the surface via permeable soils and drainage & services	Internal building spaces & future occupiers	Severe	Low Likelihood	Moderate

[3] The Environment Agency (2004) Model Procedures for the Management of Land Contamination. CLR 11.
[4] CIRIA (2001) Contaminated Land Risk Assessment. A guide to good practice. C552.

potential on and off-site sources	Inhalation of ground gases and/or vapours	Future site users	Severe	Low Likelihood	Moderate
Organic/ inorganic contaminants such as hydrocarbons, metals and asbestos within underlying soils (based on potential on and off-site sources)	Direct/indirect ingestion of soil and dust, inhalation of particle vapours and/or asbestos fibres, and dermal contact with contaminants	Construction workers	Mild	Likely	Moderate / Low
		Future site users	Mild	Low Likelihood	Low
		Off-site residents	Mild	Low Likelihood	Low
	Direct contact with underground structures and services	Buildings and structures	Mild	Likely	Moderate / Low
	Root uptake	Plants and vegetation	Minor	Likely	Low

4. GROUND INVESTIGATION

4.1 Introduction

A ground investigation was carried out by CGL based on the scope provided to the Local Authority in the letters dated 10 January 2020 and 4 March 2020. The purpose of the investigation was to assess ground contamination and to determine appropriate remedial actions where necessary. The design of the first phase of ground investigation (pre-demolition) was undertaken by Iesis Structures and the works undertaken by CGL are based on their specification document[5].

4.2 Field Work

The intrusive works were undertaken over several non-consecutive days between 19 December 2019 and 13 March 2020, and comprised:

- Five foundation inspection pits (FIPs),
- Two cable percussion (CP) boreholes,
- Four window sample (WS) boreholes (Including two abandoned due to dense soils), and
- Two machine excavated trial pits (TP).

It is noted that due to access restrictions and the presence of services, three proposed WS boreholes and a FIP located in the south western area of the site were unable to be completed. It is proposed that these will be undertaken during the second phase of ground investigation (post-demolition).

The FIPs were undertaken along the northern boundary wall of the site and excavated to the base of the retaining wall foundation which ranged in depth between 0.5m and 0.9m below ground level (bgl). The CP boreholes were drilled to 30m bgl, and the WS boreholes were drilled to depths ranging between 0.4m and 6m bgl. Due to two WS refusals at 0.4m, proposed locations WS4 and WS5 were undertaken as trial pits (ref. TP1 and TP2) excavated using a JCB 3CX. The pits were extended to depths of 2.8m and 3.4m bgl. All exploratory hole arisings were logged and representatively sampled by suitably qualified engineers from CGL.

Prior to commencing ground penetrating works, a buried services survey was undertaken by a specialist service location contractor. This survey indicated the proposed locations were clear of

[5] IESIS Structures (2020) Site Investigation Specification – West End Lane. *SE1229-ISS-XX-XX-RP-S-0001.* Dated January 2020.

potential services, however each location was further scanned by the CGL engineer with a CAT and Genny.

The ground investigation was carried out in accordance with the principles of BS5930:2015[6] and BS10175:2011[7].

An exploratory hole location plan is presented as Figure 4, and the exploratory hole logs are presented in Appendix D.

4.2.1 Sampling

Environmental samples were taken from two of the FIPs, the CP boreholes, the WS boreholes and the TPs. These comprised representative samples from each stratum retrieved in line with the CGL internal Standard Operating Procedure (SOP), which includes using the appropriate amber glass jars for the collection of samples for hydrocarbon analysis and plastic tubs to collect samples for inorganics analysis. Samples were compacted/filled into the relevant containers to minimise headspace.

Samples were stored in cool boxes with ice packs prior to dispatch to the laboratory and no nonconforming samples were reported by the laboratory.

Geotechnical samples were taken from the CP boreholes consisting of bulk, disturbed and undisturbed samples and in-situ Standard Penetration Tests (SPTs) were undertaken.

4.2.2 Installations

Standpipes were installed in the CP and WS boreholes to allow further gas and groundwater monitoring to take place. Four boreholes (BH1, BH2, WS6 and WS7) were installed with the response zone primarily running through the Made Ground. The design and construction of the monitoring well is indicated on the logs in Appendix D.

4.3 Monitoring

To date, a single ground gas and groundwater monitoring visit has been carried out at the site. The visit took place on the 10 March 2020 to record ground gas concentrations and perched water levels from the standpipes. Where perched water was encountered, samples were collected for chemical analysis. The monitoring records are included in Appendix E.

[6] British Standards Institution. (2015). *Code of practice for site investigations*. BS5930:2015
[7] British Standards Institution. (2011). *Investigation of potentially contaminated sites: Code of practice.* BS10175:2011

4.4 Laboratory testing

4.4.1 Chemical

Representative soil samples were collected from site and sent to i2 Analytical Limited (a UKAS and MCERTS accredited laboratory) for chemical testing. The analysis included testing for the following contaminants:

- Soil Organic Matter (SOM);
- Heavy metals including; arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc;
- Polycyclic Aromatic Hydrocarbons (PAH);
- Total Petroleum Hydrocarbons (TPH CWG);
- Benzene, Toluene, Ethyl benzene, and Xylenes (BTEX)
- pH determination;
- Total Monohydric Phenols; and
- Total cyanide.

The analysed samples of Made Ground were additionally screened for asbestos with laboratory microscopy.

A similar suite, including hardness, was used to analyse the perched water samples. The results of the chemical testing are presented in Appendix F.

4.4.2 Geotechnical

Representative soil samples were sent to i2 Analytical Limited for geotechnical testing, including:

- Particle size distribution testing (including sedimentation);
- Quick undrained triaxial testing;
- Atterberg Limits and moisture content; and
- Sulphate testing to BRE SD1.

The full results are present in Appendix G .

5. GROUND AND GROUNDWATER CONDITIONS

5.1 Summary

The ground conditions encountered during the investigation were generally consistent with the published geology for the site, comprising Made Ground over London Clay Formation. Possible Head Deposits were encountered in one exploratory location between the Made Ground and London Clay Formation. A summary of the ground conditions encountered is presented in Table 2 below and discussed in the following sections.

Table 2. Summary of Ground Conditions

Stratum	*Depth to Top of Stratum (m bgl)*	*Thickness (m)*
CONCRETE hardstanding *Over…*	0	0.1 to 0.3
Loose to dense dark brown, dark grey, brown, and orange brown clayey sandy gravel / clayey gravelly sand. Sand is fine to coarse. Gravel is fine to coarse, angular to subrounded flint, brick, concrete, sandstone. Ash was encountered within WS6, and clinker fragments were recorded within TP1 and TP2. *Over…*	0.1 and 0.3	0.3 to 2.5
Firm brown mottled grey sandy clay / gravelly sandy clay. Gravel is fine to coarse, angular to subrounded flint and occasional brick and sandstone. *FIP4 only – Strong hydrocarbon odour within isolated pocket of concrete gravel at 0.75m bgl in south east corner of the pit.* [MADE GROUND]	0.4 to 2.6	0.45 to 1.8
FIP2 and FIP3 only Firm dark grey mottled black slightly sandy organic clay. Rootlets and organic matter. Occasional brick fragments in FIP3. [MADE GROUND]	1.1 and 1.2	>0.5
WS7, TP1 and TP2 only Dense orange brown and brown clayey gravelly fine to coarse sand. Gravel is angular to subrounded fine to coarse flint and sandstone. Occasional flint cobbles. [MADE GROUND]	1.1 to 1.2	>1.7 to 2.80
BH2 only Firm becoming stiff light brown and orange brown gravelly silty CLAY. Gravel is fine to coarse, rounded to subrounded flint. [Possible HEAD DEPOSITS]	2.2	3.8
Firm becoming stiff brown and orange brown silty CLAY *Over…* Stiff brown mottled blue grey and blue grey silty CLAY with very fine selenite crystals. Claystone gravel encountered within BH1 [LONDON CLAY FORMATION]	2.2 to 6.0	>26.8 Base not proven

Plots of SPT ‘N’ and c_u versus depth are presented as Figure 5 and Figure 6 respectively.

5.2 Made Ground

Made Ground was encountered in each exploratory hole. The Made Ground comprised concrete hardstanding over dark brown / dark grey / brown / orange brown, clayey sandy gravel or clayey gravelly sand. The gravel comprised fine to coarse, angular to subrounded flint, brick, concrete, sandstone. Ashy material was encountered between 0.9m and 1.75m within WS6, and clinker fragments were recorded within TP1 and TP2 between 0.2m to 0.8m.

In seven of the exploratory locations, underlying the granular Made Ground was a cohesive layer generally comprising firm, brown, slightly gravelly clay. Gravel of fine to coarse, angular to rounded flint with occasional brick and sandstone.

Within FIP3 and FIP4, a layer of firm dark grey sandy organic clay with brick fragments was encountered between 1.1m and 1.6m bgl.

Along the southern edge of the site was historically a cutting down to the adjacent railway line. From historical maps, this feature appears to have been infilled in the mid-1980s and a retaining wall incorporated to facilitate the current site layout. Exploratory locations WS7, TP1 and TP2 encountered a thick layer of granular material described as 'orange brown sand and gravel' from 1.1m to 1.2m bgl with a thickness ranging between >1.7m and 2.80m. It is likely that this is the material used to infill the cutting. It is noted that due to instability of the sands and gravel within open excavations, the two trial pits were terminated within the sands and gravels.

A total of eight SPTs were undertaken within the Made Ground (boreholes BH1, BH2, WS6 and WS7) which recorded 'N' values of ranging between 6 and 36 corresponding to a relative density of loose to dense for the granular soils and a firm consistency for the cohesive sample[6].

Particle size distribution (PSD) testing confirmed that in BH1 the Made Ground was a clayey sand and gravel before becoming a very gravelly, very sandy clay at 2.6m bgl. In BH2, the PSD testing indicated the Made Ground comprised gravelly, sandy clay.

5.3 Possible Head Deposits

Possible Head Deposits were encountered within borehole BH2 only, in the eastern area of the site. The soils were encountered from 2.2m bgl and comprised firm becoming stiff light brown and orange brown gravelly silty clay. The gravel was fine to coarse, rounded to subrounded flint. The base of the deposit was proven at 6.0m bgl.

Three SPTs were undertaken which recorded SPT 'N' values of 4, 14 and 16 respectively, increasing with depth, correlating to values of undrained shear strength (c_u) between 18kPa and 72kPa (where f_1 = 4.5), or a relative consistency of firm to stiff[6].

A single PSD undertaken confirmed the soils to comprise a slightly gravelly, sandy clay.

5.4 London Clay Formation

The London Clay Formation was encountered within boreholes BH1, BH2, WS6 and WS7 only (the other exploratory locations were terminated within the Made Ground) at depths between 2.2m to 6.0m bgl and was proven to a maximum depth of 30m bgl. Although the base of the London Clay Formation was not proven during the site works, based the geological records the London Clay is anticipated to be approximately 50m thick.

The London Clay was described as firm becoming stiff brown and orange brown silty clay. At depths of 10.1m in BH1 and 8.5m in BH2, the London Clay was described as stiff brown mottled blue grey and blue grey silty clay, with very fine selenite crystals and partings of pale grey silt with depth. Claystone gravel was encountered within BH1 between 10.1m and 10.4m bgl.

SPT 'N' values recorded within the London Clay Formation were typically between 10 and >50, generally increasing with depth, correlating to values of undrained shear strength (c_u) between 45kPa and >225kPa (where $f_1 = 4.5$), or a relative consistency of firm to very stiff. However, lower 'N' values of 4 and 8 were recorded at depths of 4m and 5m within borehole WS7, which may have been influenced by the infilling of the cutting and is not considered to be representative of the London Clay.

A summary of the geotechnical laboratory testing is presented in Table 3.

Table 3. Summary of geotechnical laboratory test data for London Clay

London Clay	MC (%)	PL (%)	LL (%)	PI (%)	material <425µm (%)	I'_p (%)
BH1	28 to 41	28 to 32	67 to 111	39 to 79	100	n/a
BH2	27 to 33	29 to 32	71 to 78	42 to 46	100	n/a

Based on the above results, the London Clay Formation may be classified as clay with high to extremely high plasticity[6] with a high volume change potential[8].

5.5 Perched water

Perched water was encountered at shallow depths, either within or at the base of the granular Made Ground, at depths of 0.7m, 0.75m and 0.4m within FIP4, FIP6, and WS7 respectively. No other groundwater was encountered during the intrusive works.

During the subsequent monitoring visit, resting groundwater was recorded at depths of 0.71m and 1.2m within boreholes BH2 and WS7 respectively, which corresponds to the Made Ground. No

[8] NHBC Standards. (2017). *Chapter 4.2 Building near trees*.

groundwater was recorded within borehole WS7. It is noted that the rubber bung to borehole BH1 was unable to be removed during the monitoring and therefore a water level was not recorded.

5.6 Visual/Olfactory Evidence of Contamination

A slight hydrocarbon sheen was noted on the perched water encountered at 0.4m within the hand dug inspection pit at window sample WS7. No free product was identified within the water and no further hydrocarbon impact was noted with the surrounding or below soils.

An isolated pocket of black stained concrete gravel was encountered at 0.75m bgl in the corner of FIP4, which had a strong hydrocarbon odour.

Ashy material was encountered between 0.9m and 1.75m within WS6, and clinker fragments were recorded within TP1 and TP2 between 0.2m to 0.8m.

No other visual or olfactory evidence of contamination was noted during the site investigation.

5.7 Ground Gas

A single ground gas monitoring visit has been completed at the site, the results of which are summarised in Table 4 below. The full monitoring records are included in Appendix E. The visit was undertaken following a period of falling pressure and is therefore considered to be during worst case conditions for ground gas generation.

Table 4. Ground Gas Monitoring Summary

Borehole	Response zone	Peak Flow (l/hr)	Sustained flow (l/hr)	Min O_2 (% vol)	Max CO_2 (% vol)	Max CH_4 (% vol)	Max PID (ppm)
BH1	1.0m to 4.0m (Made Ground / London Clay)	<0.1	<0.1	14.8	3.1	<0.1	0.3
BH2	1.0m to 4.0m (Made Ground / Possible Head Deposits)	<0.1	<0.1	20.2	<0.1	<0.1	<0.1
WS6	0.5m to 2.0m (Made Ground)	<0.1	<0.1	18.4	0.4	<0.1	0.4
WS7	2.0m to 4.0m (Made Ground)	<0.1	<0.1	12.1	2.3	<0.1	1.6

Notes: NR = Not recorded, O_2 = Oxygen, CO_2 = Carbon Dioxide, CH_4 = Methane, PID = Photoionising Detector for volatile organic compounds.

With reference to Table 4, it is noted that, no sustained flow was recorded with flow rates below the monitoring equipment's limit of detection (<0.1l/hr). Carbon dioxide was generally recorded between <0.1% and 3.1%, no measurable concentrations of methane were recorded, and oxygen was normal, or depressed where measurable concentrations of carbon dioxide were recorded.

The risks associated with ground gases are discussed in Section 6.3 below.

5.8 Sulfate and pH Conditions

Sulfate and pH testing in accordance with BRE SD1[9] was undertaken on a total of 12 representative samples of the Made Ground, Possible Head Deposits and the London Clay underlying the site. A summary of this testing is given in Table 5 below. The test results are included in Appendix G.

Table 5. Summary of pH and sulfate test results

Strata	No. samples	pH	Water soluble sulfate (mg/l)
Made Ground	2	8.0 to 10.8	1,000 to 1,700
Possible Head Deposits	2	8.0 to 9.1	140 to 310
London Clay Formation	8	7.5 to 9.2	280 to 3,600

The implications for the development are discussed in Section 8.7 below.

[9] Building Research Establishment Construction Division. (2005). *Concrete in aggressive ground*. Special Digest 1, 3rd Edition.

6. CONTAMINATION ASSESSMENT

6.1 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[10]. As with the Part 2A regime, under the planning regime all receptors (humans, controlled waters, ecology, vegetation 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 H1 in Appendix H.

6.2 Risks to Human Health (Long-Term Chronic Risks)

A total of 15 samples from the site have been analysed for potential contamination; 13 from the Made Ground and two from the London Clay Formation.

The laboratory test results have been compared against Generic Assessment Criteria (GAC) that have been derived in-house by CGL for the *"Residential without plant uptake"* land use category to assess the risk to human health from contamination in soils and the summary tables are presented in Appendix H.

6.2.1 Made Ground

The results for the Made Ground are summarised in Table H2 in Appendix H and the calculated US_{95} concentrations of arsenic, lead, and PAHs; Benzo(a)Anthracene, Benzo(b)Fluoranthene, Benzo(a)Pyrene, and Dibenzo(a,h)anthracene are above their respective GACs. Asbestos was not recorded in any of the Made Ground samples from across the site.

It is noted that the exceedances of arsenic were recorded in borehole WS7 only located in the south eastern area of the site. Lead was recorded in four separate exploratory locations across the site (FIP2, FIP4, TP2 and WS6), and the exceedances of PAHs were recorded within three locations across the site (FIP4, TP1, and TP2).

It is noted that further investigation is required beneath the existing building in the western area of the site, which could not be accessed at the time of the current investigation. There is the potential for additional soil contamination to be encountered, and therefore based on the above, the risks to long-

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

term human health due to contaminant concentrations in the Made Ground are considered to be **Moderate**.

6.2.2 Natural Soils

The results for the Natural soils are summarised in Table H3 in Appendix H. Contaminant concentrations were compared directly against the GACs and indicated that concentrations are less than the GACs.

On this basis, the risks to long-term human health due to contaminant concentrations in the natural soils are considered to be **very low**.

6.3 Ground Gas Risk

Based on the single monitoring visit undertaken to date, a preliminary Gas Screening Value (GSV) has been calculated in general accordance with CIRIA 665[11]. The calculations are based on the maximum flow rate of <0.1l/hr, the maximum value of carbon dioxide (3.1%) and methane (<0.1%) recorded across the site.

The calculated GSVs are presented in Table 6 below.

Table 6. Gas Screening Value Calculation Table

Ground gas	*Maximum site concentration (%)*	*Peak flow rate (l/hr)*	*Worst case calculated GSV (l/hr)*
Methane	<0.1	<0.1	0.0001
Carbon dioxide	3.1		0.0031

Notes: GSV Calculation = max recorded value/100 x max flow rate = GSV

In accordance with CIRIA 665[11], the calculated interim GSVs in Table 6 correlate to Characteristic Situation 1 (CS1), whereby no ground gas protection measures are anticipated to be required for future development within the eastern half of the site.

Notwithstanding the above, it is noted that further investigation is required beneath the existing building in the western area of the site, which could not be accessed at the time of the current investigation. Further ground gas monitoring and assessment is recommended to confirm the risks posed to future site occupiers based on the prevalent gas regime. On this basis, the risks associated with ground gas are conservatively considered to be **low**.

[11] CIRIA. (2007). *Assessing risks posed by hazardous ground gases to buildings*, CIRIA Report C665, London

6.4 Risks to Vegetation and Plants

The risk to vegetation and plants from phytotoxic contaminants present within the Made Ground has been assessed and is presented within Table H4 of Appendix H. The US_{95} concentrations of zinc copper, nickel and boron are all below the assessment criteria.

On this basis the risk to vegetation and plants is considered to be **low**.

6.5 Perched Water Samples

A total of two samples of perched water were obtained and scheduled for chemical laboratory analysis.

The London Clay Formation is designated unproductive strata and the nearest water course is over 2km to the south, therefore there is considered to be no risk to controlled waters and the results have not been assessed.

6.6 Risks to Buildings and Structures

6.6.1 Buried concrete

There is considered to be a **low to moderate** risk to concrete due to the concentrations of sulfate identified within the London Clay during the intrusive investigation, although the risks may be mitigated with appropriate concrete mix design (see Section 8.7 below).

6.6.2 Water Supply Pipes

The available chemical test data from the soils has been compared against the UKWIR[12] values for water supply pipe assessment. With reference to Table H5 in Appendix H, the concentrations of contaminants recorded at typical water pipe depths exceed (15mg/kg of TPH C10 – C16 against threshold of 10mg/kg) the threshold for standard plastic water pipes indicating that protective water pipes may be required for the development.

The risk is considered **low**, however, the exact water pipe specification should be confirmed with the local water supply company prior to the commencement of the development. Barrier pipe may be required for the development; however, given the marginal exceedance, it may be possible to negotiate for less onerous requirements with the local water supply company.

[12] UK Water Industry Research. (2010). *Guidance for the selection of water pipes to be used in brownfield sites.* Ref 10/WM/03/21.

6.7 Revised Conceptual Site Model

The preliminary conceptual site model has revised based on the findings of the intrusive investigation, the potential pollutant linkages identified at the site and the quantitative risk assessment, in accordance with Contaminated Land Report (CLR) 11[13]. The revised CSM is presented in Table 7 and diagrammatically in Figure 7.

Table 7. Revised Conceptual Site Model.

Source/Medium	*Receptor*	*Potential Exposure Route*	*Risk Rating*	*Comments*
Explosive/ asphyxiating gases/vapours from underlying Made Ground and potential on and off-site sources	Internal building spaces & future occupiers	Migration of gases and vapours through the surface via permeable soils and drainage & services	Low	Ground conditions and interim ground gas monitoring to date indicates the site may be classified as CS1 where protection measures are unlikely to be required. The western half has not been assessed at this time.
	Future site users	Inhalation of ground gases and/or vapours	Low	
Organic/ inorganic contaminants such as hydrocarbons, metals and asbestos within underlying soils (based on potential on and off-site sources)	Construction workers	Direct/indirect ingestion of soil and dust, inhalation of particle vapours and/or asbestos fibres, and dermal contact with contaminants	Moderate / Low	Risks can be mitigated with the correct use of PPE and site procedures.
	Future site users		Moderate	Risks are likely to be mitigated by either hardstanding or the provision of capping layers within landscaping areas.
	Off-site residents		Very Low	
	Buildings and structures	Direct contact with underground structures	Moderate / Low	Concrete will require appropriate design based on sulphate class. Barrier water supply pipes may be required for the development but should be confirmed by local water supply company.
		Direct contact with underground services	Low	
	Root uptake	Plants and vegetation	Low	Contaminant conditions recorded to date do not present a risk to plants, however, a capping layer is required for the development which will mitigate against residual risks.

Note: Controlled waters discounted for both pathway and receptor.

Notwithstanding the above, it is noted that further investigation is required in the western area of the site, which could not be accessed at the time of the first phase of investigation due to the presence of the existing building, and this assessment should be reviewed upon completion of these works.

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

7. GEOENVIRONMENTAL RECOMMENDATIONS

7.1 Introduction

The investigation undertaken to date indicates that contaminant concentrations within the Made Ground across the site present a low to moderate risk to long-term human health and plant growth. The single ground gas monitoring visit undertaken to date has not identified elevated concentrations of carbon dioxide or methane.

Notwithstanding the above, the following further works are recommended:

A. Investigation in previously inaccessible areas of the site to confirm or otherwise the established CSM; and

B. Ground gas monitoring and assessment to confirm the prevalent gas regime and refine potential risks to sensitive receptors.

Geoenvironmental recommendations are presented below based on the current CSM and risk assessment. It is considered that the recommendations are suitably protective to mitigate potential risks notwithstanding the need for confirmatory investigation and further assessment.

1. Provision of capping layers in areas of soft landscaping;
2. Protection of underground services by specification of suitable materials;
3. Watching brief and discovery strategy during construction; and
4. Implementation of environmental controls and health and safety procedures to protect construction workers and adjacent site users from potential risks associated with dust, vapours and nuisance odours.

Further details for the outline remediation strategy are provided in the following sections of this report.

7.2 Capping Layers

Soil capping layers should be placed in areas of soft landscaping where Made Ground remains at formation level to prevent contact and to break-up potential pathways (for both human health and vegetation) with potential contaminants within the underlying Made Ground.

In areas of communal soft landscaping, a capping layer of clean imported topsoil should be a minimum of 450mm thick, including a minimum of 150mm imported topsoil (or 100mm of topsoil and 50mm sod/turf), with a geotextile separator at the base.

Where the Made Ground is removed and natural uncontaminated soils are confirmed at formation level by a suitably qualified geoenvironmental engineer and chemical analysis, a growth medium including a minimum of 150mm of topsoil (or greater subject to the requirements of the landscape architect) over 300mm of suitably loosened subsoil should be placed.

All imported subsoil and topsoil materials will be clean soil, from a known and reputable source. Chemical certification of the source material and details of the source should be provided by the Contractor prior to capping material being brought to site. The results should be inspected by a suitably qualified geoenvironmental engineer to confirm that the material can be accepted at the site. Topsoil should conform to the requirements of BS 3882[14].

Once imported to site, representative samples should be taken by the geoenvironmental engineer for chemical laboratory analysis, for each type/source of material imported, at a minimum frequency of one test per 150m^3 of imported material, or a minimum of three tests per source.

Once placed, the capping layer or growth medium construction should be verified by the geoenvironmental engineer at a minimum frequency of 1 pit per 50m^2 area of placed soil.

7.3 Buried Services

Based on the contaminant concentrations encountered during the investigation to date, barrier pipework is anticipated to be required for water supply pipes. The final specification for water supply pipework at the site should be agreed with the relevant water company.

7.4 Material Management and Waste Disposal

It should be noted that the management of construction waste should be carried out in accordance with the Waste (England and Wales) Regulations 2011. This places an emphasis on the Waste Hierarchy, which requires an avoidance of waste in the first instance followed by reducing the volume that requires disposal after it has been generated.

7.4.1 Re-use, Recycling and Recovery

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. Screening of shallow uncontaminated natural arisings may permit recycling/reuse of the material on site or for other sites under the WRAP[15] protocol

[14] British Standards. (2015). BS 3882. *Specification for topsoil and requirements for use*.
[15] WRAP. (n.d.) The Quality Protocol.

(uncontaminated granular soils only) or the CL:AIRE[16] protocol and could lead to a reduction in disposal requirements.

7.4.2 Waste Disposal

A preliminary assessment of the soil at the site for waste classification purposes has been undertaken in accordance with the guidance in Technical Guidance WM3[17] based on the results of the analyses undertaken.

The samples tested of Made Ground may be classified as 'not-hazardous' for off-site waste disposal purposes and may be disposed of to suitably licensed inert or non-hazardous waste facilities subject to Waste Acceptance Criteria Testing. Uncontaminated natural soils can be disposed of as inert waste.

Under the Landfill (England and Wales) Regulations 2002 (as amended), there are three types of landfill: 'inert', 'non-hazardous' and 'hazardous'.

It should be noted that all waste will require pre-treatment, where possible, before disposal to a licensed landfill. Pre-treatment can be undertaken either at the site of origin or may be carried out at a licensed off-site facility and can include selective segregation of soils conducted on site. However, there is no pre-treatment requirement if waste is sent for recovery instead of disposal.

Uncontaminated natural soils may be disposed to an inert landfill as listed inert waste. The chemical testing results and exploratory hole logs should be provided to the chosen landfill to confirm if they can accept the material based on requirements of their licence.

It may also be possible to dispose of the Made Ground to a soil hospital/ recycling facility, where disposal does not incur landfill tax. This should be discussed with a suitable facility.

All material intended for off-site disposal should be transported and disposed in accordance with the Environmental Protection (Duty of Care) Regulations, 1991 and the Landfill (England and Wales) Regulations, 2002 (as amended).

7.5 Watching Brief and Discovery Strategy

It is recommended that a watching brief is maintained, during redevelopment, by the Main Contractor. Where unexpected gross contamination, such as fibrous material, oily material or material of an unusual colour or odour, is encountered, a qualified geoenvironmental engineer should be informed and the risk associated with the contamination assessed. The regulators should also be informed of

[16] CL:AIRE (2011). The Definition of Waste: Development Industry Code of Practice. Version 2.
[17] Environment Agency. 2015. Technical Guidance WM3. Waste Classification: Guidance on the Classification and Assessment of waste. (1st Edition, May2015)

unexpected contamination observations and should be provided with the risk assessment and the verification records of remediation works to be completed if required.

The following strategy is recommended:

1. Work to cease in that area.
2. Notify geoenvironmental engineer to attend site and sample material for appropriate analysis. Notify Contaminated Land Officers of the Local Authority as appropriate.
3. Geoenvironmental engineer to supervise the excavation of contaminated material, which should be placed in a bunded area and covered to prevent rainwater infiltration/spread by wind.
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. In-situ testing should be undertaken, if appropriate, 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 appropriately 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.

If no observations of unexpected conditions are made, this should be recorded as a statement from the contractor undertaking the watching brief for inclusion in the site Health and Safety file or remediation verification report, as appropriate.

7.6 Health and Safety

All site works should be undertaken in accordance with the guidelines prepared by the Health and Safety Executive (HSE,1991)[18] and CIRIA Reports 132[19] and C650[20]. Where necessary, asbestos containing material should be handled/removed in accordance with current regulations and guidance[21,22,23]. Works should also be carried out in accordance with the Contractor's Construction Health and Safety Plan.

During redevelopment, precautions should be taken to minimise exposure of workers and the general public to potentially harmful substances. Attention should also be paid to restricting possible off-site nuisance such as dust and odour emissions. Such precautions should include, but not be limited to:

- Personal hygiene, washing and changing procedures.
- Adequate personal protective equipment.
- Dust and vapour suppression methods, including damping down, minimising the
- working face exposed and covering stockpiles, where required.
- Regular cleaning of all site roads, access roads and the public highway.
- Safe storage of fuel and other potentially polluting liquids and the provision of spill
- control and clean up facilities.
- Positive collection and disposal of on-site run-off.

The risks to construction workers can be controlled through the implementation of site safety procedures and the use of suitable personal protective equipment (PPE). Attention should also be paid to restricting possible off-site nuisance such as dust and odour emissions.

Excavations should be planned and inspected regularly by a competent person. No operatives should be permitted to enter unshored or otherwise protected excavations identified as unstable by a competent person, however shallow they are.

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[18] HSE (1991). Protection of Workers and the General Public during the development of contaminated land. Guidance Note HS(G)66, Health and Safety Executive, HMSO, 1991.
[19] CIRIA (1996). A guide for safe working on contaminated sites. Steeds JE, Shepherd E & Barry DL. CIRIA Report 132.
[20] CIRIA (2005) Environmental good practice – Site guide, 2nd Edition. CIRIA Report C650.
[21] Control of Asbestos Regulations 2012
[22] HSE (2012). Managing and Working with Asbestos - Control of Asbestos Regulations 2012, HSE 2013.
[23] CIRIA (2017) Asbestos in soil and made ground good practice site guide (C765)

8. GEOTECHNICAL RECOMMENDATIONS

8.1 General

This section presents geotechnical recommendations for the site based on the results of the first phase of ground investigation (Pre-demolition) and assuming the development will comprise residential dwellings arranged across two buildings ranging in height from three to seven storeys. The development will also include ground floor commercial units, an area of accessible parking and areas of communal soft landscaping.

8.2 Geotechnical Design Parameters

Geotechnical design parameters have been derived for the encountered strata based on the soil descriptions, laboratory testing results and SPT 'N' values, supplemented with published data. A summary of the design parameters is presented in Table 8 below.

Table 8. Summary of Geotechnical Design Parameters

Stratum	Bulk Unit Weight γ_b (kN/m³)	Undrained Cohesion c_u (kPa) [c']	Friction Angle ϕ' (°)
Made Ground	18	-	33[a]
Possible Head Deposits	19	18 + 18z[c] [0]	21[b]
London Clay Formation	20	58.5 + 5.8z[c] [5]	21[b]

Notes
- a. *Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310.*
- b. *BS 8002:2015 Code of practice for Earth retaining structures, British Standards institution.*
- c. *z = m below 8m bgl*

8.3 Foundations

The details of the proposed foundations for the development are currently unknown, however, based on the ground conditions encountered and the approved development layout it is considered that shallow foundations will not be appropriate for the development due to the thickness of the Made Ground encountered across the site. Therefore, piled foundations are recommended for the approved development, with Continuous Flight Auger (CFA) methodology considered to be appropriate.

Indicative preliminary pile working loads (kN) are presented in Figure 8 for pile diameters of0.6m, 0.75m and 0.9m, which have been calculated for a maximum pile depth of 25 m bgl. The preliminary pile working loads have been calculated using average strata levels across the site to create a general profile. The pile cut off has been assumed at approximately 1m below existing lowest ground level and any capacity contributed from the Made Ground has been ignored. For engineering purposes, it is considered that the possible Head Deposits will behave in a similar way to the London Clay Formation and therefore have been grouped together.

The following design assumptions should be considered by the piling contractor and are assumed for the preliminary pile design:

- Piles in the London Clay should adopt an adhesion value (α) of 0.5 as recommended in current LDSA guidance[24];
- Average ($\alpha\ c_u$) in the London Clay should not exceed 110kN/m^2 except where a higher limiting value is proven by a pile load test;
- c_u design lines in the London Clay should fall within the range presented by Patel[25]. Design lines falling outside this range should be used with caution;
- A Factor of safety (FoS) of 1.6 has been used for the skin friction FoS and 2 for the base capacity, with a model factor of 1.4. These values have been selected based on Eurocode 7 Design Approach 1 Combination 2 (GEO) factoring, as this is the critical case for predicting pile toe level, and assuming no pile testing will be undertaken. This is a conservative assumption.

These calculations are based on the geotechnical design parameters presented in (Section 8.2 above). It is noted that the site investigation was undertaken to a maximum depth of 30.0m bgl, and that although borehole records in the surrounding area indicate that the London Clay extends to depth the assessment has been limited to 25m bgl.

Final detailed pile design and installation method should be undertaken and specified by the specialist piling contractor awarded the work. The piling contractor may show different pile toe levels and greater load capacity based on their design approach, interpretation of the ground model and design parameters, and also their experience with piling in similar ground conditions.

8.4 Thameslink Infrastructure

There is a Network Rail retaining wall along the southern boundary of the site and accordingly, the design team and main contractor will continue its liaison with Network Rail throughout the works and all necessary approvals will be obtained from Network Rail.

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[24] London District Surveyor's Association. (2009). *Foundations, No.1 Guidance Notes for the Design of Straight Shafted Bored Piles in London Clay*. LDSA publications.
[25] Patel, D. (1992). Interpretation of results of pile tests in London Clay. *Proc. Conf. Piling in Europe, ICE.*

8.5 Excavations

The ground conditions encountered across the site during the ground investigation are not anticipated to present difficulties for conventional earth moving plant.

Based on the findings of the current ground investigation, excavations within the Made Ground, particularly within the southern extent of the site are likely to become unstable and temporary support or battering back will be required to maintain stability. Excavations in the Made Ground may encounter perched water, and control measures, such as a sump and pump system, may be required.

All excavation works should be suitably shored or otherwise supported and be regularly inspected by a suitably competent person. Under no circumstances should operatives enter unsupported or otherwise unprotected excavations or excavations identified as unstable by a competent person, this is in accordance with the guidelines presented in the CIRIA Report 97[26].

8.6 Floor Slabs and Pavement Design

Based on the ground conditions encountered, suspended floor slabs are recommended for the development. A design CBR of <2.5% should be adopted for pavements in the Made Ground. It is noted that this can be improved by proof rolling the Made Ground and re-testing.

8.7 Buried Concrete

The design sulfate (DS) and Aggressive Chemical Environmental for Concrete (ACEC) classes for the different strata onsite are presented below in Table 9. The information is based on the results of the geotechnical sulfate and pH testing.

The London Clay Formation is potentially pyritic, and on this basis, the percentage of oxidisable sulfate has been calculated for the London Clay. The results indicate oxidisable sulfate above 0.3% in each sample of the London Clay and the total potential sulfate (TPS) has therefore been considered in the selection of design sulfate class.

Table 9. Summary of DS and ACEC classes.

Stratum	Water Soluble Sulfate (WSS)		Total Potential Sulfate (TPS)	
	DS class	ACEC Class	DS class	ACEC Class
Made Ground	DS-3	AC-3	N/A	
Possible Head Deposits	DS-1	AC-1s	N/A	
London Clay Formation	DS-4	AC-3s	DS-4	AC-3s

[26] CIRIA (1992) Report 97. Trenching Practice. 2nd Edition

The availability of total potential sulfate (TPS) in pyritic soils (i.e. London Clay Formation) is dependent on the extent to which 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[27] 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".*

On this basis, the appropriate DS and ACEC class for the pyritic soils, i.e. based on water soluble sulfate or total potential sulfate, should be adopted dependent on the extent to which the soils will be disturbed during construction.

[27] BRE (2005) *Concrete in Aggressive Ground.* BRE Special Digest 1:2005.

9. CONCLUSION

In accordance with Condition 26b of planning application 2015/6455/P (approved on 23 June 2017), the first phase of site investigation (pre-demolition) has been carried out in accordance with the approved written programme (application reference 2020/0200/P).

The findings of the investigation and the laboratory results have been assessed and discussed within this report. In summary, elevated concentrations of arsenic, lead, and polycyclic aromatic hydrocarbons were encountered within the Made Ground, representing a moderate risk to long-term human health and buried water supply pipes.

The following remediation measures are recommended on the basis of the current investigation and are considered appropriate to mitigate the identified risks regarding contamination:

- Provision of soil capping layers in areas of soft landscaping,
- Protective pipework for water supply pipes, and
- Implementation of a watching brief and discovery strategy during construction.

Additional ground investigation is required in the western area of the site to investigate the area of the former Garage and petrol forecourt, to confirm or otherwise, the established conceptual side model. This should include further ground gas monitoring and assessment to confirm the prevalent gas regime, assess potential risks to receptors and requirements for specific ground gas protection measures. It is noted that it is not currently viable to carry out investigation in the areas of the existing buildings, therefore it is recommended that this work is carried out once the buildings have been demolished.