# Phase 2 Ground Investigation Report

## Abellio Bus Garage, North Hyde Gardens, Hayes, UB3 4QQ

A REPORT PREPARED FOR AND ON BEHALF OF:
Ark Data Centres Limited

**Issue Date: 05 November 2021**
**Revision No: B**
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Business

**Abellio Bus Garage, North Hyde Gardens, Hayes, UB3 4QQ**


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| | For and on behalf of<br>Paragon Building Consultancy Limited |

# DASHBOARD SUMMARY

## KEY INVESTIGATION FINDINGS

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| | **Rationale for the Investigation** |
| 1. | The development site is situated at Abellio Bus Garage, North Hyde Gardens, Hayes, UB3 4QQ (Figure 1, Appendix 1). Ark Data Centres Limited (HPF) has appointed Paragon to complete a Phase 2 Ground Investigation as a part of a wider development comprising Bulls Bridge Industrial Estate in Hayes, for which Ark Data Centres Limited are the current freeholder. HPF has been appointed as the structural engineer for the development, which comprises a MV Energy Centre on the former Abellio plot. This investigation, by Paragon, is intended to facilitate the design process and to be submitted in support of a planning application for the development. |
| 2. | The wider development site comprises five main parcels of land that are referred to as: Vodafone, Abellio, British Airways, Addison Lee and FM Conway (Maintenance Yard). This report only summarises the works completed at the Abellio Bus Garage which is hereafter referred to as 'the site'. The site has previously been un-investigated due to tenant activities at the site. The British Airways, Vodafone and Addison Lee plots have previously been investigated by Paragon. The site is relatively flat with reduced elevations in the eastern part of the site where a small area of soft landscaping is present. This area slopes down towards the Vodafone plot which is present to the east of the site. In addition, the Grand Union Canal is offsite and located within 5m of the southern boundary of the site. The former British Airways plot is situated beyond North Hyde Gardens to the north of the site and the North Hyde Gardens bridge is present to the west of the site. |
| 3. | Paragon completed a previous Phase 1 Environmental Audit on behalf of Ark Data Centres Limited in 2020 for due diligence purposes. It is understood that the client has full reliance on the data collected in this investigation and relevant information is used and referred to herein. This document has been prepared to support a planning application which will be submitted at a later stage. |
| 4. | The Phase 1 investigation identified the site has a history of being used as part of a creosote works, an oil fired power station and a former railway which extended into the land to the north. It is also understood from British Geological Survey (BGS) mapping that the site comprises artificial ground which is presumed to be from informal landfilling at the site. |
| 5. | This report details the ground investigation completed by Paragon in 2021 on the Abellio plot which comprised 1 no. cable percussive borehole drilled to 35.00m below ground level (bgl), 8 no. windowless sample boreholes drilled to a maximum depth of 5.00mbgl and 2 no. hand excavated trial pits. In addition, chemical testing was undertaken on soils and groundwater, in-situ geotechnical testing including Standard Penetration Tests (SPTs) was completed in the boreholes, ex-situ geotechnical laboratory analysis was undertaken, and three indicative rounds of gas monitoring have been completed. |

**Ground Conditions**

6. The site is mapped by the British Geological Survey as being underlain by Infilled Ground, the Lynch Hill Gravel or the Langley Silt over the London Clay. The boreholes drilled onsite encountered hardstanding over Made Ground (cohesive and granular lenses) to a maximum depth of 4.50-5.00mbgl over reworked Alluvium (cohesive and granular lenses) to 4.80-5.00mbgl over weathered London Clay Formation to 7.50mbgl, over London Clay Formation to a maximum drilled depth of 35.00mbgl.

7. Groundwater was encountered in the reworked Alluvium at around 2.30–3.00mbgl (28.31- 29.51mAOD).

8. An anomaly was recorded during the borehole clearance for Unexploded Ordnance (UXO) using the Magnetometer. This was identified within WS04 at a depth of 1.00mbgl. Due to the detection, the borehole was terminated. Recommendations for further assessment were made and this was subsequently completed under a sperate instruction. The assessment found no UXO and the anomaly was a metal rope.

**Environmental Findings**

9. A Geoenvironmental Risk Assessment was carried out on the chemical laboratory test data and a revised Conceptual Site Model was presented. Chemical test data found that the concentrations of contaminants testing within the Made Ground and natural soil were below the Generic Assessment Criteria (GAC) for a commercial land use. However, asbestos was encountered in two locations. The asbestos was quantified at <0.001% and as the site is to be almost entirely surfaced with hardstanding, the risks to future site users is considered to be low.

10. The results of the groundwater analysis found marginal exceedances of the Environmental Quality Standards for PAH and Heavy Metals. Nevertheless, the exceedances were marginal and no gross contamination was encountered. Therefore, the risk to Controlled Waters is considered to be low.

11. Three rounds of gas monitoring were completed as part of this investigation and the results identified that the elevated levels of carbon dioxide and methane. Based on a preliminary assessment using BS 8485:2015+A1:2019 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*', the site falls within Characteristic Situation (CS) 2, whereby gas protection measures are required.

**Geotechnical Findings**

12. Geotechnical design parameters for the strata encountered have been provided. The parameters have been derived based on in-situ and ex-situ tests and published empirical relations. Geotechnical testing has included standard classification testing including plasticity index, moisture content, strength testing including SPTs, and undrained unconsolidated triaxial testing. A design groundwater level has also been derived based on groundwater strikes encountered and monitoring results from the current site investigation. DS and ACEC classifications are also provided for the Made Ground and Lynch Hill Gravel Member.

13. The recorded groundwater strikes and monitoring results appear to show that groundwater flows towards the Grand Union canal and River Crane/Yeading Brook. A design groundwater level of 29.50mOD is recommended.

14. Geotechnical recommendations are summarised below.

## RECOMMENDATIONS

**Environmental**

1. The concentrations of contaminants within soil and groundwater are considered to be suitable for the proposed end use of the development, and no further investigation, monitoring or remediation is required. Therefore, a remediation strategy is not considered to be necessary. Instead, the following recommendations should be followed:
   - Capping layers (150mm topsoil and 450mm subsoil over a geotextile) are to be used in areas of soft landscaping;
   - Gas (methane and carbon dioxide) and vapour resistant membranes are to be used within future enclosed structures;
   - Asbestos control measures are to be used by the main contractor;
   - An audit trail for materials management and offsite waste disposal is to be maintained by the main contractor;
   - Whilst it is unlikely, in the event that previously unidentified contamination is uncovered during construction, works should cease until inspection and testing has been undertaken by an appropriately qualified person. Therefore, a watching brief and discovery strategy should be adopted on site during development; and
   - The main contractor will need to provide completion statements that will feed into the main verification report for the wider site.

**Regulatory**

2. This report should be submitted to the Local Planning Authority in support of a planning application for the development.

**Geotechnical**

3. Geotechnical design parameters for the strata encountered have been provided. The parameters have been derived based on in-situ and ex-situ tests and published empirical relations.

4. Given the thickness and variability of the Made Ground and existing obstructions, shallow foundations are not recommended. It is recommended that floor slabs should be suspended.

5. It is recommended that all excavations are supported. Mitigation measures should also be provided to control the ingress of groundwater.

6. A preliminary pile design has been provided based on three pile diameters. Based on the site investigations carried out to date, the ground conditions below the site have been proven to a maximum depth of 35m bgl and therefore the pile length has been limited to 30m. The pile capacities are dependent on the London Clay Formation, this stratum has been encountered in one location only and depth to surface may vary.

7. The proposed development is in close proximity to the River Crane, and ground conditions appear to have been influenced by this with alluvium locally encountered.

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| 8. | A design CBR value of less than 2.5% is recommended for pavements and roads. If site levels are increased consideration should be given to potential long-term settlement and consolidation of organic/peat layers that may be present within the alluvium. |
| 9. | Based on the results of the pH and sulphate testing carried out on samples from the Made Ground and Lynch Hill Gravel Member, the DS and ACEC classification for these strata is DS-2 and AC-2. The DS and ACEC for the London Clay Formation is DS-2 and AC-1s, assuming that all concrete placed in contact with the stratum will be due to placing of pile foundations. |
| | **Unexploded Ordnance** |
| 10. | Due to the presence of an anomaly recorded during the UXO clearance of WS04, further assessment was recommended. At this stage, it is recommended that this area is excavated under the supervision of a UXO Engineer. |
| 11. | The assessment was subsequently completed under a separate instruction and found no UXO and the anomaly was a metal rope. |

# CONTENTS

# PHASE 2 GROUND INVESTIGATION REPORT

CLIENT NAME: Ark Data Centres Limited

PROPERTY ADDRESS: Abellio Bus Garage,
North Hyde Gardens,
Hayes,
UB3 4QQ

INSPECTION DATE: 22 June 2021

## 1.0 INSTRUCTIONS

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| **1.1** | Paragon Building Consultancy Limited (Paragon) was instructed by Ark Data Centres Limited to complete a Phase 2 Ground Investigation on a site referred to as Abellio Bus Garage, North Hyde Gardens, Hayes, UB3 4QQ. The investigation included an intrusive investigation, laboratory analysis and risk assessment. These works have been completed in connection with redevelopment of the site as a MV energy centre. This redevelopment forms a part of larger redevelopment scheme for development of a data centre with MV energy centre and substation. |

## 2.0 AIMS AND OBJECTIVES

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| **2.1** | This document has been prepared to support a planning application. The aims of this report are:<br>• To provide information on the geotechnical and environmental quality of the ground present onsite to highlight potential risks and abnormal development constraints associated with potential redevelopment of the site.<br>• To assess the potential health and environmental risks to the potential development and other significant receptors from onsite sources.<br>• To assess the potential offsite sources of contamination and their impact on the potential development.<br>• To complete a gas risk assessment.<br>• Provide provisional geotechnical recommendations in relation to the potential development. |

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| **2.2** | The objectives of this report are:<br>• To provide ground conditions information and recommendations in relation to the potential future redevelopment of the site.<br>• Characterise the contamination onsite by completing an intrusive site investigation to characterise the site.<br>• To suggest a potential remediation strategy should contamination be identified.<br>• Determine the quality of the ground for geotechnical design by completing a ground investigation. |

## 3.0 SCOPE OF WORKS

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| **3.1** | The ground investigation was undertaken in general accordance with the Code of Practice for Site Investigation British Standard BS5930:2015+A1:2020, Code of Practice for the Investigation of Potentially Contaminated Sites BS10175:2011+A2:2017, Land Contamination: Risk Management (LCRM) 2020. Due regard is made to the Environmental Protection Act (EPA) 1990 Part 2A in connection with the contamination risk assessment and requirements of the National Planning Policy Framework (NPPF). |
| **3.2** | Three previous phases of work have been completed by Paragon for the wider development: A Phase 1 Desk Study for the wider site, a Phase 1 Desk Study for the Abellio Plot and a Phase 2 Site Investigation on the neighbouring plots.<br>• An earlier Phase 1 Environmental Risk Assessment was previously prepared by Paragon for the larger development (19.0633/CB/NW, 21 August 2019 – Revised for planning, Rev D – November 2021). It has outlined the potential health and environmental risks identified from desk-based searches including online searches of the historical maps, geological maps, planning records and review of data on the Environment Agency website. A site walkover was completed and an initial Conceptual Site Model (CSM) was presented.<br>• A Phase I Environmental Audit was undertaken by Paragon at the Abellio site (200054, 27 February 2020 for acquisition purposes). The report outlined the potential health and environmental risks identified from the review of online searches, historical maps, geological maps, planning records, Environment Agency information and based on findings from a site walkover.<br>• A Phase 2 Site Investigation Report was undertaken by Paragon (19.0633/CB/AW, 21 August 2019– Revised for planning, Rev D – November 2021) on the wider development plot, except for Abellio due to tenant activities that prevented access. This report documents the findings of an intrusive investigation (drilling boreholes and trial pitting), laboratory testing of soils, groundwater and gas, onsite monitoring and environmental and geotechnical risk assessment. |

## 4.0 INTRODUCTION

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| **4.1** | **Site Location** |
| 4.1.1 | The following information has been obtained from the existing Phase 1 report completed in 2020 for acquisition purposes. The Phase 1 should be read in conjunction with this report; the following is a summary. |
| 4.1.2 | The site is centred approximately at National Grid Reference: 510435, 179211, and extends to 0.47Ha. The approximate elevation of the site is 31m Above Ordnance Datum (mAOD). Site information gathered during the preliminary report is summarised below and a location plan is as Figure 1, in Appendix 1. |
| 4.1.3 | The site is surrounded by the former British Airways (BA) plot and North Hyde Gardens to the north, the former Vodafone plot to the east, the Grand Union Canal to the south and the North Hyde Gardens bridge to the west. |
| **4.2** | **General Description and Current Site Use** |
| 4.2.1 | This subject site comprises of a warehouse used as a bus garage with associated two-storey office area operated by Abellio. The warehouse has an internal car wash and repair garage. The site has a small Petrol Filling Station at the site entrance and this was fed by an above ground diesel storage tank (AST). The pipework was observed to run above ground. In addition, an Ad-Blue tank and pump was situated at the entrance to the site. |
| 4.2.2 | The site has multiple parking areas for the site staff and buses in the central and eastern part of the site. The hardstanding at the site comprises of concrete and tarmac. There was some residual staining on the ground surface which has been assumed to be from leaks from parked buses. |
| 4.2.3 | There is a small service yard to the rear of the building in the western part of the site. Two small waste oil tanks (both ASTs) were observed to be present within this area. During drilling, a spill had occurred in this area and spill kits were placed on the ground surface to contain the oil. |
| **4.3** | **Proposed Development** |
| 4.3.1 | It is our understanding that a Phase 2 Ground Investigation Report is required to provide additional preliminary data on existing contamination, ground gas and geotechnical conditions at the site to facilitate the development of an MV energy centreon the former Abellio plot. The proposed layout is presented as Figure 2, in Appendix 1. |
| **4.4** | **Planning** |
| 4.4.1 | The wider site is being developed under planning application: 75111/APP/2020/1955. A proposed development layout is presented in Appendix 1. The plot is to be redeveloped into an Energy Centre. |

**4.5 Site History**

4.5.1 The site formed open land from as early as 1868 until around 1935, where the site was part of a creosoting works, which extended offsite into the land to the north and east. By 1963, the site was shown as a pond, with embankments which were considered to be likely to be due to infilling activities. By 1982, the site was shown as being levelled but undeveloped. The current layout was shown by 2010.

4.5.2 The surrounding area has supported various industrial (potentially contaminative) land uses, including factories, brick fields, mills, railway, electricity substation, creosoting works, and rubber works.

4.5.3 Historical landfilling has been identified on site and east of the River Crane/Yeading Brook since 1936 and records indicate the landfill accepted commercial waste. In addition, the British Geological Survey (BGS) artificial ground mapping covers the entire site.

**4.6 Geology**

4.6.1 From a review of BGS mapping (269 and 270), the geology of the subject site is reported to comprise mostly of the Lynch Hill Gravel underlain by the London Clay Formation. The Langley Silt superficial deposits reportedly cover the south-western part of the site (yard at the rear of the building). The mapping also shows Artificial Ground and Alluvium within 75m of the site.

4.6.2 The surrounding area is known for being historically mined to extract the gravel. As such, there are many landfills and reservoirs in this area. It is therefore possible that the gravel deposits were largely extracted which allowed the landfilling to occur.

4.6.3 Paragon completed a Ground Investigation on the plot adjacent immediately to the north. A summary of the ground conditions are presented in Table 1 below.

**Table 1. Ground Conditions**

| Depth From (min/max) (m) | Depth To (min/max) (m) | Soil Type | Description |
|---|---|---|---|
| 0.0 | 0.1 / 0.05 | Concrete / Tarmacadam | Concrete / Tarmacadam hardstanding. |
| 0.05 / 0.1 | 1.5 / 5.8 | Made Ground | Variable Made Ground comprising soft to firm, dark brown, gravelly clay. Gravel is brick, suspected slag, clinker, timber fragment, concrete and mixed lithologies. |
| 1.5 / 5.8 | 5.7 / 10.2 | Gravel | Yellowish orange brown sandy GRAVEL. Gravel is sub-rounded to well-rounded fine to coarse mixed lithologies. Lynch Hill Gravel. |
| 5.7 / 10.2 | Unproven | Clay | Firm to stiff silty CLAY. London Clay. |

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| 4.6.4 | Groundwater was encountered in the Lynch Hill Gravel at around 29mAOD in the centre of the site and closest to the river at between 26.76 and 26.57mAOD. In comparison, the base of the River Crane channel to the east of the site is around 25.00mAOD based on Environment Agency LiDAR data. Perched groundwater was also encountered in the Made Ground and London Clay. |
| **4.7** | **Hydrogeology** |
| 4.7.1 | The Lynch Hill Gravel is classified as a Principal Aquifer of high permeability, while the Langley Silt Member is classified as a Secondary (A) Aquifer, and the London Clay Formation is classified as Unproductive Stratum. |
| 4.7.2 | The site is not located within Groundwater Source Protection Zone (SPZ). |
| 4.7.3 | There is one groundwater abstraction within a 1km radius which is approximately 530m southeast of the site and is used for evaporative cooling. |
| **4.8** | **Hydrology** |
| 4.8.1 | Grand Union Canal is located directly south of the site, and the River Crane is located approximately 75m to the east of the site. No surface water abstractions have been identified within 1km of the site. |
| 4.8.2 | There are three discharge consents within 250m of the site. These relate to records approximately 10m north for miscellaneous discharge to land, 85m south and 95m south of the site from trade discharges to the River Crane/Yeading Brook. |
| **4.9** | **Flooding** |
| 4.9.1 | Environment Agency data indicates that that the site is within Flood Zone 1, meaning the risk of flooding at the site is low. |
| **4.10** | **Regulatory Enquiries** |
| 4.10.1 | The Local Authority has not been contacted by Paragon at this time. However, it is considered unlikely that the site is currently designated as contaminated land under the provisions of the EPA 1990 Part 2A. |
| 4.10.2 | The Environment Agency has not been contacted by Paragon as part of this assessment at this stage. |
| **4.11** | **Environmental Database Information** |
| 4.11.1 | No Areas of Outstanding Natural Beauty, Environmentally Sensitive Areas, Sites of Special Scientific Interest or Special Protection Areas have been identified within a 1km radius of the site. |
| **4.12** | **Ground Stability Hazards** |
| 4.12.1 | Records indicate that the area in general has a moderate risk of subsidence hazards as a result of shrinking/swelling of underlying clay. |
| 4.12.2 | The site is not located within an area affected by coal mining activities. |

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| **4.13** | **Unexploded Ordnance (UXO)** |
| 4.13.1 | Online information indicates that there were several bomb strikes recorded around the site located adjacent to the north during World War II. As such, a specialist assessment was undertaken by Brimstone Site Investigation Limited and comprised a Stage 2 Detailed UXO Risk Assessment (Dated: 3 July 2019, Ref DRA-19-1105) to identify constraints on the proposal. This has been reported separately and a summary is provided below. |
| 4.13.2 | The report reviewed the original London bomb plot maps covering the entire German bombing campaign. The data confirmed the wider study area was bombed on at least eight separate occasions, resulting in 29 large 'iron' bombs and one parachute mine within 500m of the site. No bomb strikes were recorded within the site boundary. In addition, no records were made for the first month of the 1940 Blitz and areas of soft landscaping would disguise entry points and be unobserved. As such, there is the potential for more unidentified bombs to be present. |
| 4.13.3 | The report concluded there was a low to moderate risk from UXO and recommended mitigation measures. The risk mitigation measures included UXO safety awareness briefings, onsite supervision during excavations and a magnetometer probe survey if piling is to be implemented. |
| **4.14** | **Radon** |
| 4.14.1 | The site is not located within a radon affected area. Less than 1% of homes are above the radon action levels, as such, no radon protection measures are considered necessary. |
| **4.15** | **Previous Reports** |
| 4.15.1 | Paragon prepared a Phase I Environmental Audit at the Abellio plot for pre-acquisition purposes on 27 February 2020. The report states that the site operates as active bus depot with parking for buses, an internal car wash, repair garage and petrol filling station. The key findings included historical uses of the site as part of a creosote works and landfill which were reported as a potential source of contamination and risk to groundwater and nearby River Crane. |
| 4.15.2 | Additionally, during the inspection, oil staining was observed in discrete areas on the surface of the site. It was considered likely to be due to minor leaks from parked buses and ongoing refuelling activities. Oil staining was also identified within some drains and along the eastern and southern boundaries of the site within areas of soft landscaping. |
| 4.15.3 | Furthermore, the potential for presence of Japanese Knotweed could not be discounted. |
| 4.15.4 | As such, the risk rating for continued commercial use was reported to be moderate, and further action was recommended associated with CCTV Drainage Survey and Japanese Knotweed Survey. |
| **4.16** | **Constraints** |
| 4.16.1 | The previous due diligence report was constrained by active works and parked buses across the site. |

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| **4.17** | **Potential Contaminants of Concern** |
| 4.17.1 | Based on the foregoing, the potential contaminants of concern that require further investigation are associated with potential spills of diesel/oils as well as onsite landfill which has a potential for contamination and ground gas generation. Contaminants of concern include:<br>• Made Ground including asbestos from historical site uses and landfilling activities;<br>• Total Petroleum Hydrocarbons from current vehicle use on site and historical site uses ;<br>• Biodegradable materials and other contaminants (heavy metals and Polycyclic Aromatic Hydrocarbons) within the infilled ground; and<br>• UXO and historical ammunition. |
| **4.18** | **Potential Active Pathways** |
| 4.18.1 | Small areas of soft-landscaping are present on the eastern and southern boundaries of the site and could promote current and future pathways. |
| 4.18.2 | In addition, the underlying Lynch Hill Gravels would allow migration of contamination and ground gas (if present) due to its high permeability. The Langley Silt may also allow the migration of contamination (if present) albeit the permeability is likely to be significantly lower than the Lynch Hill Gravels. |
| **4.19** | **Potential Receptors** |
| 4.19.1 | Potential receptors identified include:<br>• Future Site Users;<br>• Construction Workers;<br>• Offsite Users;<br>• Controlled Waters (the River Crane, The Grand Union Canal and the Principal and Secondary Aquifers beneath the site); and<br>• Proposed buildings and infrastructure. |

## 5.0 PRELIMINARY CONCEPTUAL SITE MODEL

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| **5.1** | **Conceptual Site Model (CSM)** |
| 5.1.1 | Based on the risks identified within the Phase 1 Investigation a Preliminary Conceptual Site Model has been produced based on redeveloping the site. The model is based upon the source-pathway-contaminant linkage concept set out in the Environmental Protection Act 1990 and accompanying statutory guidance. For a site to be designated under Part 2A of the EPA 1990 as contaminated land, there must be at least one plausible contaminant linkage and a significant risk to the receptor must exist as a result. |

5.1.2

**Table 2. Preliminary Conceptual Site Model**

| Receptor | Potential sources | Pathways | Risk | Justification |
|---|---|---|---|---|
| **Human Health** | | | | |
| Construction and maintenance workers / Users of the site | Organic and metal contamination | Direct contact, ingestion, and inhalation via outdoor soils or translocated soil and dust indoors. | M | **Moderate risk:** Ingestion, inhalation and dermal contact with contaminated soils in excavations or stockpiles cannot be discounted. Personal Protective Equipment (PPE) and Risk Assessments and Method Statements are required. |
| | Ground gas and vapours | Inhalation, Migration through granular and fractured soils into confined spaces. | M | **Moderate risk:** Inhalation of vapours from contaminated soils or groundwater below the site cannot be discounted due to the historical use of the site. |
| Future site users | Organic and metal contamination in soils and groundwater | Direct contact, ingestion, and inhalation of outdoor soils or translocated soil and dust indoors. | M | **Moderate risk:** Inhalation of vapours from contaminated soils or groundwater below the site cannot be discounted. |
| | Ground gas and vapour | Inhalation, migration through granular and fractured soils into confined spaces. | M | **Moderate risk:** Inhalation of vapours from contaminated soils or groundwater below the site cannot be discounted due to the historical use of the site. |
| Offsite Residents (270m southwest) | Organic and metal contamination in soils, groundwater and gas | Direct contact, ingestion, and inhalation of outdoor soils or translocated soil and dust indoors. | L | **Low risk:** Residents located approximately 270m southwest are unlikely to be at risk form contaminants arising from the site as they will be cut off by the Grand Union canal. The likelihood for migration to properties a similar distance to the northwest is minimal given the considerable distance to the properties and several other areas of industrial land in between. |
| **Property** | | | | |
| Site structures and services | TPH in site soils | Direct contact between soil and structures or services. | M | **Moderate risk:** The risk from direct contact of building materials including foundations and buried services with contaminated soils and groundwater cannot be discounted at this stage. |
| | Ground gas and vapour | Migration through granular and fractured soils into confined spaces. | M | **Moderate risk:** The potential for migration of gases through soil pore space to the surface from underlying Made Ground and historical ground workings cannot be discounted at this stage. |
| **Groundwater** | | | | |
| Principal Aquifer | Metals and organic contamination in soils | Soil leaching and migration of potential soil contamination. | M | **Moderate risk:** The potential for contamination associated with the historical use of the site to impact the Principal Aquifer cannot be discounted at this stage. |
| Secondary (A) Aquifer | Metals and organic contamination in soils | Soil leaching and migration of potential soil contamination. | M | **Moderate risk:** The potential for contamination associated with the historical use of the site to impact the Secondary (A) Aquifer cannot be discounted at this stage. |

5.1.3 **Table 2. Preliminary Conceptual Site Model (Continued)**

| Receptor | Potential sources | Pathways | Risk | Justification |
|---|---|---|---|---|
| **Surface Water** | | | | |
| Grand Union Canal (directly south)<br>River Crane/Yeading Brook (70m east) | Leachable metals and organic contamination | Soil leaching and migration into drains and sewers which discharge into the ditch. | M | **Moderate risk:** The potential for contamination associated with the historical use of the site to impact the nearby surface water features cannot be discounted at this stage. |

**5.2 Key Risks Requiring Further Investigation**

5.2.1 Based on the above, the potential for some degree of ground contamination to exist as part of the historical site use cannot be discounted. In addition, in order to redevelop the site, the risk associated with land contamination will need to be quantified to determine the risk to human health and Controlled Waters.

## 6.0 GEOTECHNICAL RISK ASSESSMENT

**6.1 Risk Assessment**

6.1.1 The Preliminary Geotechnical Risk Assessment completed within the Phase 1 investigation has been expanded. The results of the assessment are provided in Table 3.

6.1.2 **Table 3. Geotechnical Risk Assessment**

| Hazard | Risk | Rationale |
|---|---|---|
| Made Ground | M | **Moderate risk:** Made Ground has been mapped onsite and is considered to be due to historical landfilling that occurred at the site. Due to the highly variable nature of the Made Ground identified, foundations of the proposed development are likely to require deepening to ensure that a suitable bearing stratum is identified. |
| Collapsible / Unstable Excavations | M | **Moderate risk:** Due to the presence of Made Ground, there is the potential for excavations to be unstable and prone to collapse. An allowance for shoring should be considered during groundworks. |
| Shallow Groundwater | M | **Moderate risk:** Groundwater is likely to be present within the superficial deposits (as identified during previous investigations within the surrounding area). As such, there is the potential for shallow groundwater to impact the stability of excavations and as such dewatering may be required. |
| Compressible strata | M | **Moderate risk:** Made Ground, Alluvium and clay have been mapped as being onsite which indicate foundations will require deepening to a competent bearing stratum. |

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| Aggressive ground conditions for concrete | M | **Moderate risk:** There is the potential for naturally occurring sulphate within the natural soils or Made Ground to produce ground that is aggressive to concrete. Formal analysis is required for concrete design. |
| Dissolution | L | **Low risk:** The site is unlikely to be affected by dissolution. |
| Landslide | L | **Low risk:** The topography of the site is relatively flat and the risk of landslides is low. |
| Mining | L | **Low risk:** The site has not been identified as being at risk of historical mining. |

**6.2 Summary of Desk Based Risk Assessment**

6.2.1 Due to the variation in the geology and presence of Made Ground mapped by the British Geological Survey, further assessment is required to understand the ground conditions on site. This should also involve a deep borehole to determine the depth of Made Ground and potential for piled foundations.

6.2.2 Due to the potential for aggressive ground conditions for concrete to exist, sulphate testing and an assessment with reference to BRE Special Digest 1 should be undertaken to determine the concrete design.

## 7.0 GROUND INVESTIGATION

**7.1 Investigation Rationale**

7.1.1 The objectives for the investigation were to identify and characterise the ground conditions, the sources, pathways and receptors (in general accordance with the Environmental Protection 1990 Part 2A), to reduce uncertainties and to provide an overview of site conditions. Details of the site methods are presented in Appendix 3.

7.1.2 The ground investigation was undertaken in general accordance and with reference, where relevant to the following documents:

- Specification for Ground Investigation, Site Investigation Steering Group, Thomas Telford, 1994;
- British Standard BS10175:2011 (A2) Investigation of potentially contaminated sites – code of practice, as amended;
- Environment Agency (2000) Secondary model procedures for the development of appropriate soil sampling strategies for land contamination. Technical Report P5-066/TR; and
- BS ISO 5667-22:2010 Water quality. Sampling. Guidance on the design and installation of groundwater monitoring points.

7.1.3 The intrusive investigation was completed between 22 June and 30 June and comprised a total of eleven exploratory holes. This included:

- 1 no. Cable Percussive Borehole drilled to 35mbgl;
- 8 no. Windowless Sample Boreholes drilled to a maximum depth of 5.0mbgl;
- 2 no. Hand Excavated Trial Pits;
- Geotechnical laboratory testing (in situ Standard Penetration testing and ex situ sampling for laboratory testing);
- Geoenvironmental laboratory testing for soil and water commensurate with the findings of the CSM; and
- 3 no. groundwater and ground gas monitoring visits.

7.1.4 A site plan showing the locations of each exploratory hole is provided in Figure 3, Appendix 1.

**7.2 Intrusive Locations**

7.2.1 The scope for each exploratory location is presented below.

7.2.2 **Table 4. Intrusive Locations**

| ID | Notes |
|---|---|
| BH01 | Drilled to 35.00mbgl |
| WS01 | Refused on concrete at 0.50mbgl |
| WS01a | Refused on concrete at 0.40mbgl |
| WS01b | Refused on concrete at 0.30mbgl |
| WS02 | Drilled to 5.00mbgl |
| WS03 | Refused on concrete at 0.40mbgl |
| WS04 | Terminated at 1.00mbgl due to an anomaly with the magnetometer |
| WS04a | Refused on concrete at 0.30mbgl |
| WS05 | Drilled to 5.00mbgl |
| HP101 | Hand excavated pit within the soft landscaped area. |
| HP102 | Hand excavated pit within the soft landscaped area. |

7.2.3 Combined ground gas and groundwater wells were installed in the boreholes as outlined below. Full details of the installations are also provided on the borehole logs presented in Appendix 4.

**Table 5. Monitoring Well Installation Details**

| ID | Drilling Depth mbgl | Slotted Well Section mbgl [AOD] |
|---|---|---|
| BH01 Deep | 35.00 | 6.00 – 15.00 |
| BH01 Shallow | 35.00 | 1.00 – 4.50 |
| WS02 | 5.00 | 1.00 – 5.00 |
| WS05 | 5.00 | 1.00 – 3.50 |

**7.3 Sampling and Testing Strategy**

7.3.1 Soil samples were collected throughout the investigation for geotechnical and environmental analysis. Samples were submitted for geotechnical testing in accordance with relevant versions of BSEN ISO 17892-6:2017, BSEN ISO 14688-1:2002, and BSEN 1997-2:2007. Environmental samples were submitted under controlled conditions with a Chain of Custody to i2 Analytical a UKAS and MCerts accredited facility.

7.3.2 Environmental soil samples were tested for a suite of contaminants to assess the risks identified in the Phase 1 report:

- Heavy metals including; arsenic, cadmium, chromium (total and VI), copper, lead, mercury, nickel, selenium, and zinc;
- Cyanide and Phenols;
- Petroleum Hydrocarbons (PHC) – Total Petroleum Hydrocarbons Criteria Working Group (TPH-CWG);
- Benzene, Toluene, Ethylbenzene and Xylene (BTEX);
- Polyaromatic Hydrocarbons (PAH) – Speciated 16;
- Asbestos screen and identification;
- Total Organic Carbon (TOC), Sulphates and pH; and
- Volatile and Semi-Volatile Organic Compounds.

7.3.3 In addition, two Waste Acceptance Criteria (WAC) tests were undertaken on the Made Ground soils.

7.3.4 The results of the soil analysis is presented in Appendix 5.

| | |
|---|---|
| 7.3.5 | Groundwater was encountered in during subsequent rounds of monitoring. Groundwater sampling was undertaken from three occasions. The samples were submitted to i2 Analytical for the following analysis:<br>• Heavy metals including; arsenic, cadmium, chromium (total and VI), copper, lead, mercury, nickel, selenium, and zinc;<br>• Cyanide and Phenols;<br>• Petroleum Hydrocarbons (PHC) – Total Petroleum Hydrocarbons Criteria Working Group (TPH-CWG);<br>• Benzene, Toluene, Ethylbenzene and Xylene (BTEX); and<br>• Polyaromatic Hydrocarbons (PAH) – Speciated 16;<br>• Total Organic Carbon (TOC), Sulphates and pH; and<br>• Volatile and Semi-Volatile Organic Compounds. |
| 7.3.6 | The results of the groundwater analysis is provided in Appendix 5. |
| 7.3.7 | Gas and groundwater monitoring was undertaken using a multi-probe gas analyser and dip meter. The results are presented in Appendix 6. |
| 7.3.8 | Soil samples were also recovered for geotechnical testing, which included:<br>• Atterberg testing with natural moisture content;<br>• Undrained Triaxial testing; and<br>• Sulphates and pH. |
| 7.3.9 | The results of the geotechnical testing are presented in Appendix 7. |

## 8.0 GROUND CONDITIONS

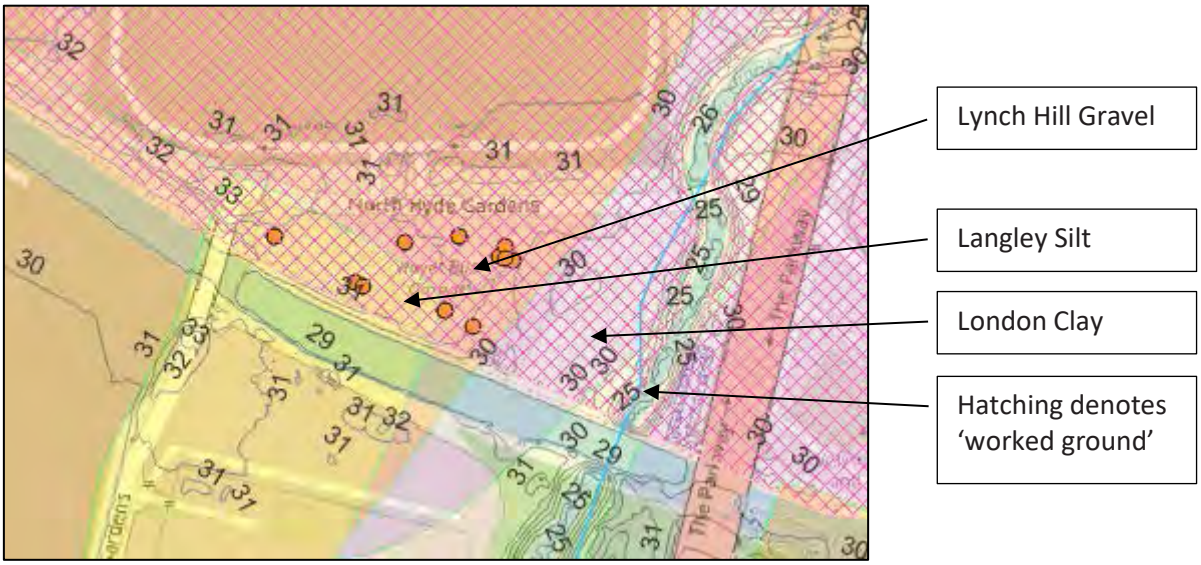
| | |
|---|---|
| **8.1** | **General** |
| 8.1.1 | Published mapping from the British Geological Survey (BGS) shows the site to in an area of 'Worked Ground' with superficial Langley Silt in the western area of the site, over the Lynch Hill Gravel and London Clay Formation. The site is directly to the west of the River Crane, and to the north of the Grand Union Canal, historical alluvial deposits/construction fill associated with these watercourses may be present on site. |
| 8.1.2 | The ground conditions are described in detail in the logs that are presented within Appendix 4. A summary of the ground conditions is also presented in Table 6. |

**Table 6. Summary of Ground Conditions**

| Depth From (min/max) (m) | Depth To (min/max) (m) | Soil Type | Description | Notes |
|---|---|---|---|---|
| 0.0 | 0.05 / 0.20 | Tarmacadam / Topsoil | Tarmacadam hardstanding / topsoil | |
| 0.05 / 0.20 | 3.50 / >5m | Made Ground | Variable Made Ground comprising very loose to medium dense brown and black sandy gravel. Gravel is concrete, brick, flint, glass, clinker, tile and mixed lithologies. | Concrete obstructions were encountered in WS01, WS01a-b and WS03 from depths between 0.20mbgl and 0.45mbgl. |
| 3.50 / 4.50 | 4.80 / 5.00 | Clay | Soft grey and black gravelly peaty clay. Gravel is mixed lithologies.<br>Alluvium | Encountered in BH01 and WS05. |
| 4.80 | >5 | Gravel | Medium dense, orange and brown sandy gravel. Gravel is flint.<br>Lynch Hill Gravel Member | Only encountered in WS05. |
| 5.00 | 7.50 | Clay | Soft to firm brown, blue and grey clay.<br>Weathered London Clay | Only encountered in BH01. |
| 7.50 | >35 | Clay | Firm to stiff brown, blue and grey clay with selenite crystals.<br>Weathered London Clay | Only encountered in BH01. |

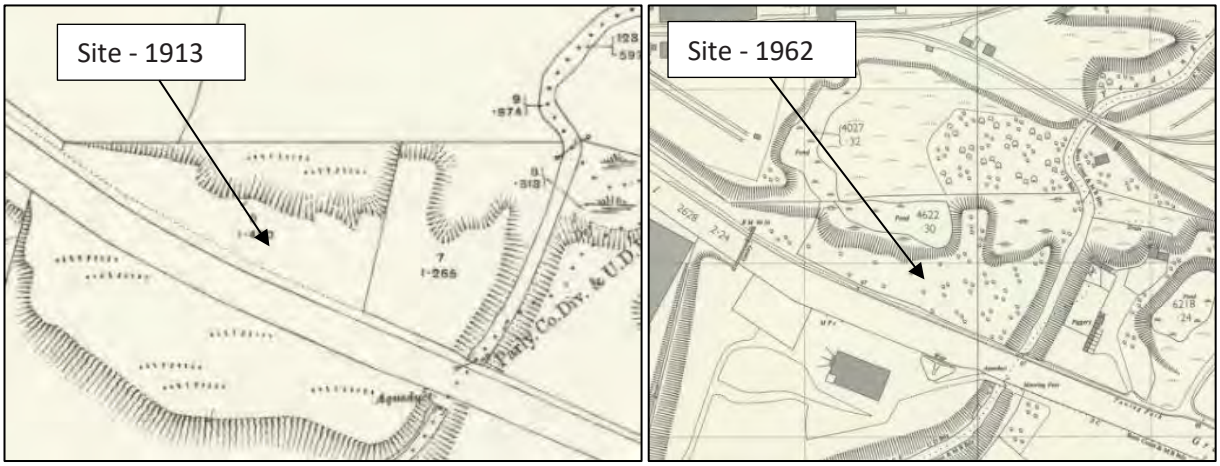
8.1.3 The geological mapping for the site is presented in Plate 1 below.

8.1.4 **Plate 1: Site Geology (BGS)**




8.1.5 In addition, historical mapping dated 1913 indicates the site to have been raised at this time, remaining in this condition until at least 1962, with marshland present at a lower level to the north of the site. This is presented in Plate 2 below.

8.1.6 **Plate 2. Historical Mapping**




**8.2 Olfactory and Visible Evidence of Contamination**

8.2.1 The olfactory and visible evidence of contamination is outlined in Table 7. Photo Ionisation Detector (PID) results greater than 10.0ppm from insitu soil screening are included in Table 8.

8.2.2 **Table 7. Summary of Olfactory and Visual Evidence of Contamination**

| ID | Depth (m bgl) | Comments |
|---|---|---|
| BH01 | 4.50 to 5.00 | Strong hydrocarbon odour |
| | 0.20 to 4.50 | Clinker |
| WS02 | 0.30 | Geotextile |
| | 0.90 to 5.00 | Clinker |
| WS05 | 0.05 to 3.50 | Slight hydrocarbon odour and clinker |

8.2.3 **Table 8. PID Screening Results (above 10ppm)**

| ID | Depth | Result (parts per million – ppm) |
|---|---|---|
| BH01 | 2.50m | 13.4 |

## 8.3 Obstructions

8.3.1 Obstructions occurred during drilling of the following windowless samples: WS01, WS03, and WS04. All samples were dry and terminated at shallow depths. Paragon attempted to drill new holes nearby WS01 and WS04, however, all of these were also met with refusal (WS01a, WS01b and WS04a). A potential bomb was identified within the area of WS04 due to an anomaly with the magnetometer. As such this position was abandoned. These obstructions are summarised in Table 9.

8.3.2 **Table 9. Summary of Obstructions**

| ID | Base Depth | Reason |
|---|---|---|
| WS01 | 0.50mbgl | Refusal on concrete at 0.50mbgl |
| WS01a | 0.40mbgl | Refusal on concrete at 0.40mbgl |
| WS01b | 0.30mbgl | Refusal on concrete at 0.30mbgl |
| WS03 | 0.40mbgl | Refusal on concrete at 0.40mbgl |
| WS04 | 1.00mbgl | Terminated at 1.00mbgl due to an anomaly with the magnetometer |
| WS04a | 0.30mbgl | Refusal on Made Ground at 0.30mbgl |

## 8.4 Groundwater

8.4.1 No groundwater strikes were recorded during drilling.

8.4.2 Groundwater was dipped on three occasions and the water levels are presented in Table 10.

8.4.3 During the third monitoring visit it was noted that the BH01 could not be located due to parked cars within the borehole area. As such, the gas readings and groundwater depth could not be taken on that day. The site was re-inspected for groundwater level monitoring on 3 August 2021.

8.4.4 **Table 10. Groundwater Monitoring Results**

| ID | Elevation (mAOD) | Groundwater Level (mbgl) [mAOD] | | | |
|---|---|---|---|---|---|
| | | 8.7.2021 | 15.7.2021 | 23.7.2021 | 3.8.2021 |
| BH01 Deep | 30.86 | 2.62 [28.24] | 2.51 [28.35] | N/A | 2.50 [28.36] |
| BH01 Shallow | 30.86 | 2.52 [28.34] | 2.51 [28.35] | N/A | 2.55 [28.31] |
| WS02 | 31.34 | 2.97 [28.37] | 2.98 [28.36] | 2.99 [28.35] | 3.00 [28.34] |
| WS05 | 31.78 | 2.27 [29.51] | 2.30 [29.48] | 2.35 [29.43] | 2.32 [29.46] |

## 8.5 Gas Monitoring

8.5.1 Gas monitoring was undertaken on three occasions on 8 July 2021, 15 July 2021 and 23 July 2021.

8.5.2 The atmospheric pressure over the three visits ranged between 1017 and 1021mbar.

8.5.3 The results are presented in Section 10.

## 8.6 Constraints

8.6.1 The main constraints during the site investigations included pedestrian movements as well as parked and moving buses across the area. Due to active operations onsite, the positions of boreholes had to be previously agreed with the Abellio management and no boreholes were allowed to be drilled in the centre of the site.

## 8.7 UXO

8.7.1 An anomaly was recorded during the borehole clearance for Unexploded Ordnance (UXO) using the Magnetometer. This was identified within WS04 at a depth of 1.00mbgl. Due to the detection, the borehole was terminated. Recommendations for further assessment under the supervision of a UXO engineer were made.

8.7.2 It should be noted that the UXO anomaly was subsequently inspected under a separate instruction and it was found to be a metal rope.

# 9.0 GEOTECHNICAL RESULTS

**9.1 Ground Conditions Discussion**

9.1.1 The geotechnical laboratory and in-situ test results are summarised in Table 11 and Table 12. The geotechnical results can be found in Appendix 7.

9.1.2 **Table 11. Summary of Geotechnical Classification Testing Results.**

| Stratum | Moisture Content (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) |
|---|---|---|---|---|
| Made Ground | - | - | - | - |
| Alluvium | - | - | - | - |
| Lynch Hill Gravel Member | - | - | - | - |
| Weathered London Clay | 30 | 58 | 32 | 26 |
| London Clay | 23 to 28 | 52 to 57 | 27 to 30 | 25 to 28 |

9.1.3 **Table 12. Summary of In-situ and Laboratory Strength Testing**

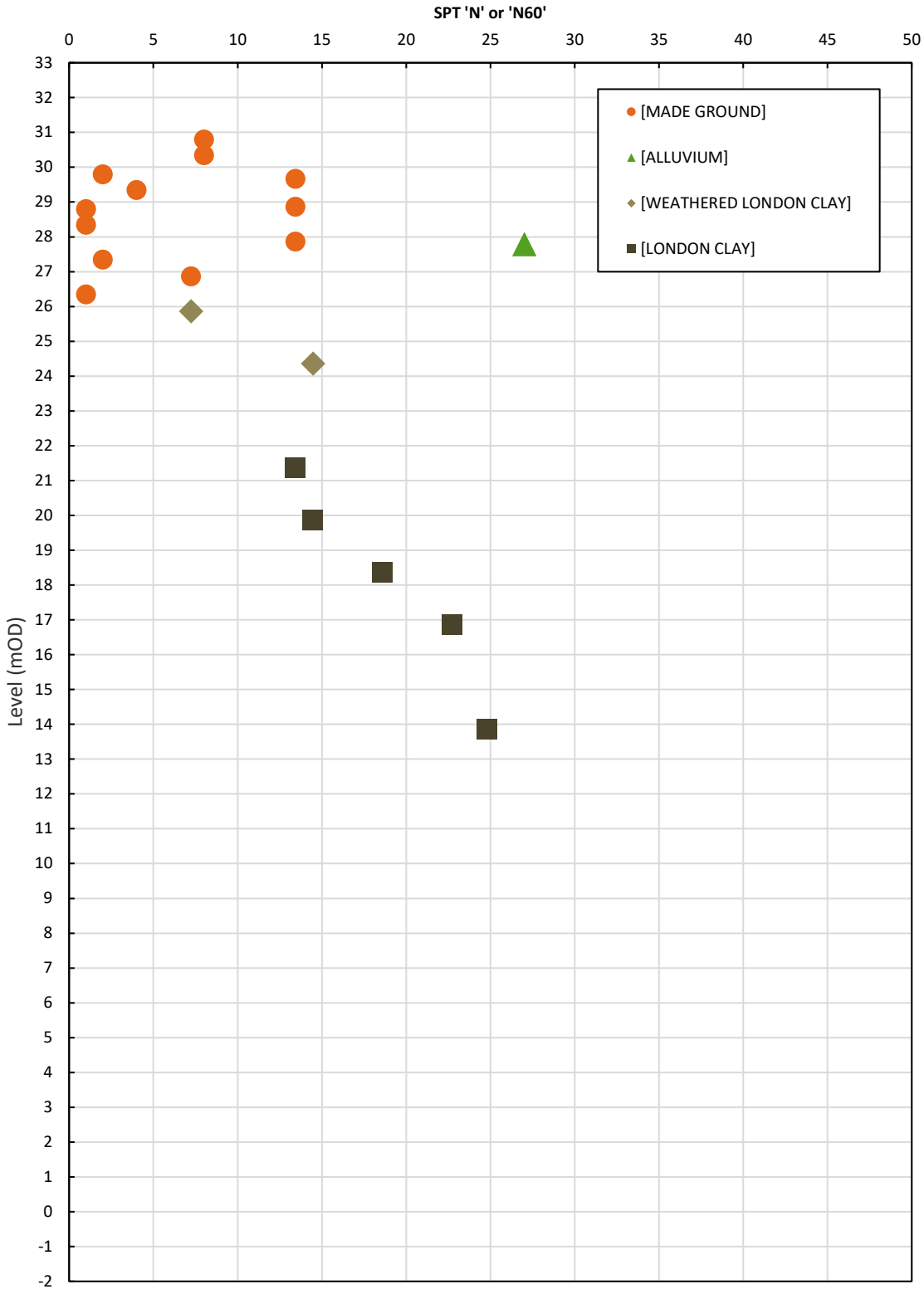
| Stratum | SPT N or N60 Values | Undrained Unconsolidated Triaxial Results (kPa) |
|---|---|---|
| Made Ground - Cohesive | 1 to 2 | - |
| Made Ground - Granular | 1 to 13 | - |
| Alluvium | 27 | - |
| Lynch Hill Gravel Member - Granular | - | - |
| Weathered London Clay | 7 to 14 | - |
| London Clay | 13 to 25 | 86 to 250 |

9.1.4 A plot of SPT 'N' or 'N60' values against elevation level is presented in Plate 3. The SPT 'N60' values were obtained by converting the 'N' values based on the SPT hammer energy report, which can be found in Appendix 7, which states the hammer has a 62% energy efficiency for BH01 and 93.29% for the Windowless Sample Boreholes.

9.1.5 A plot of undrained shear strength (cu) values against level is presented in Plate 4.

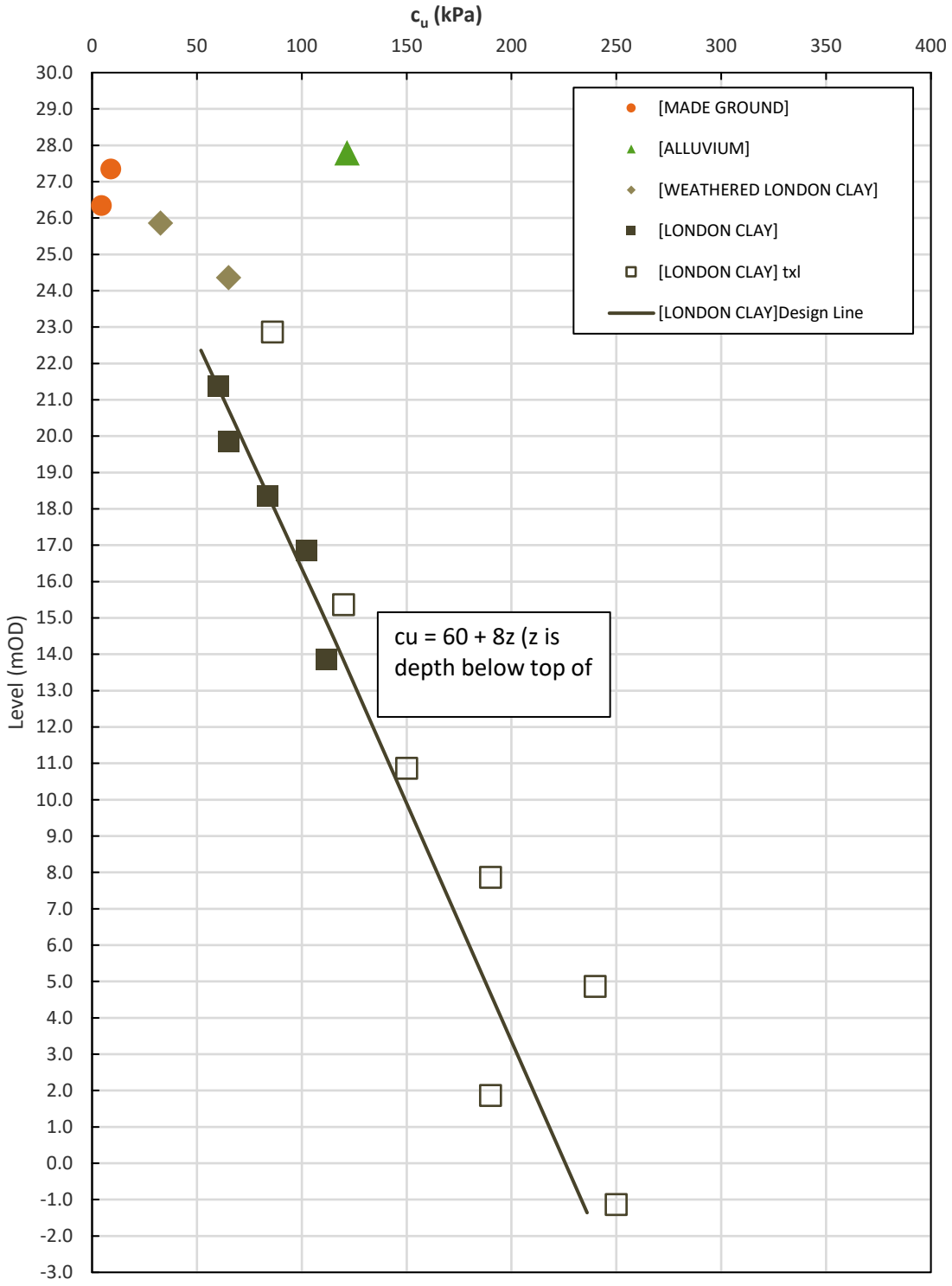
9.1.6

**Plate 3. SPT 'N60' value against level**



9.1.7

**Plate 4. Undrained shear strength plotted against level.**



## 10.0 GEOENVIRONMENTAL RESULTS

**10.1 Analytical Test Results**

10.1.1 Chemical testing was completed on soil and water samples from the investigation to determine the concentration of potential contaminants arising from existing and historical site uses, in line with the Conceptual Site Model. The results of the soil and groundwater analysis have been compared to a screening value to assess the degree of risk. The results are presented in a screening table in Appendix 5 and summarised below. The laboratory test certificates are also provided in Appendix 5.

10.1.2 The GACs used in this assessment are based on a Soil Organic Matter (SOM) content of 2.5% for the Made Ground and 1% for the natural soil, which is considered to reflect the conditions present onsite and provides the basis for a conservative assessment.

**10.2 Analytical Test Results – Made Ground Soils**

10.2.1 The results from the Made Ground have been compared to industry accepted screening values known as Generic Assessment Criteria (GAC) to determine the risks to human health. The GAC used in this investigation includes Category 4 Screening Levels and Suitable 4 Use Levels (C4SLs and S4ULs). The GAC selected is based on a commercial land use in line with the proposed development. The screening assessment is presented in Appendix 5. A detailed methodology for the assessment is presented in Appendix 8.

10.2.2 The results have identified Chrysotile Asbestos in the form of loose fibres in WS04 and BH01. The asbestos quantification results detected the asbestos to be below the limit of detection as shown in Table 13. Currently, there is no GAC for asbestos in soil. Industry guidance produced by CIRIA C7335 (2014) '*Asbestos in soil and made ground: a guide to understanding and managing risks*' states that "in the case of asbestos in soil, there is no published Soil Guideline Value (SGV) or C4SL.

10.2.3 **Table 13. Summary of Asbestos Quantifications**

| ID | Stratum | Depth (mbgl) | Asbestos Identification | Quantification Result (%) |
|---|---|---|---|---|
| BH01 | Made Ground | 2.00 – 2.50 | Chrysotile (loose fibres) | < 0.001 |
| WS04 | Made Ground | 0.80 | Chrysotile (loose fibres) | < 0.001 |

10.2.4 Agreement has yet to be reached in the UK on an appropriate toxicological criterion on which such a GAC could be based". However, asbestos is not considered to be mobile and based on the extensive hardstanding across the site, the risk to site users in its current layout is minimal. In the event of redevelopment, material management will be required when the ground is broken out. Furthermore, the risks to human health will need careful consideration.

10.2.5 No other exceedances, above acceptable thresholds for a commercial land use GAC, were identified of the contaminants tested from the Made Ground.

| | |
|---|---|
| **10.3** | **Analytical Test Results – Natural Soils** |
| 10.3.1 | The results of the chemical analysis on the natural soil samples are presented in Appendix 5. The results were compared to the GAC for a commercial use in the same way as the Made Ground. |
| 10.3.2 | No exceedances, above acceptable thresholds for a commercial land use, were identified of the contaminants tested from natural soils. |
| **10.4** | **Analytical Test Results - Groundwater** |
| 10.4.1 | The results from the groundwater analysis have been compared with Tier 1 screening values, as for the soils. This has included Environmental Quality Standards (EQS) for freshwater, due to the presence of the Grand Union Canal directly south of the site, and River Crane/Yeading Brook approximately 70m east of the site, which would be considered the most sensitive surface water receptors. There is potential for dissolved phase contaminants in groundwater to migrate to the river if they are in continuity. |
| 10.4.2 | No assessment has been completed against the Drinking Water Standards (DWS) as there are no sensitive potable abstractions within a 1km radius and the site is not within an SPZ. |
| 10.4.3 | Groundwater was recovered from BH01, WS02 and WS05 on 8 July 2021. The results were directly compared to the EQS. The laboratory test certificates are presented in Appendix 5. |
| 10.4.4 | Marginal exceedances of the PAH compound Fluoranthene have been identified in BH01 (shallow and marginal exceedances for heavy metals have been found in all samples tested (Chromium, Copper, Nickel and Zinc. |
| **10.5** | **Gas Monitoring Results** |
| 10.5.1 | Pollutant linkages associated with risks from ground gas to the property and to human health have been assed using BS 8485:2015+A1:2019 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*. |
| 10.5.2 | Three gas monitoring visits were undertaken on 8 July 2021, 15 July 2021 and 23 July 2021. During the third monitoring visit it was noted that the BH01 could not be located due to parked cars within the borehole area. As such, the gas readings could not be taken on that day. The gas monitoring records are presented in Table 14 and the monitoring records are presented in Appendix 6. |

10.5.3 **Table 14. Gas Monitoring Results**

| ID | Steady Flow (l/hr) | Steady Methane (%) | Steady Carbon Dioxide (%) | Minimum Oxygen (%) | Steady Hydrogen Sulphide (ppm) | Steady Carbon Monoxide (ppm) | VOC (ppm) |
|---|---|---|---|---|---|---|---|
| BH01 Deep | <0.1 – 0.1 | <0.1 – 6.7 | 0.9 – 2.9 | 10.6 – 10.7 | <1.0 – 1.0 | 2.0 | <0.1 – 1.1 |
| BH01 Shallow | <0.1 – 0.2 | 0.5 – 14.2 | 0.4 – 1.4 | 6.0 – 7.9 | <1.0 | 1.0 | <0.1 – 1.6 |
| WS02 | <0.1 – 0.2 | 0.1 – 0.6 | 10.3 – 11.8 | 0.4 – 1.6 | <1.0 – 1.0 | <1.0 – 2.0 | <0.1 – 4.9 |
| WS05 | <0.1 – 0.2 | <0.1 – 0.6 | 2.8 – 13.2 | 0.8 – 18.5 | <1.0 | 1.0 | <0.1 – 0.3 |

10.5.4 The results for the gas monitoring identified elevated levels of methane within BH01 and elevated levels of carbon dioxide in WS02 and WS05. Flow readings were low and ranged between the limit of detection <0.01 l/hr and 0.2 l/hr.

10.5.5 The ground gas monitoring was undertaken over periods of high atmospheric pressure ranging between 1017mb and 1021mb. No monitoring during atmospheric pressure events below 1000mb were undertaken due to the time available for the investigation and due to the investigation being completed throughout a period of dry weather.

**10.6 Domestic Drinking Water Supply Pipework Assessment**

10.6.1 The assessment for whether barrier pipework is likely to be required as part of the development has been undertaken by directly comparing the results from the soil testing with the Polyethylene (PE), metal and barrier pipe thresholds.

10.6.2 The results have shown that as the concentrations of contaminants are minor, it is considered that standard pipework could be used as part of the development. This should be agreed with the water services provider.

## 11.0 DISCUSSION

**11.1 Environmental Findings**

11.1.1 This section evaluates the risks to potential receptors at the site from identified chemical contamination. Potential receptors have been identified in line with the CSM presented in Table 2 and reference to environmental guidance, whereby all receptors have been considered. Additional information on the assessment is presented in Appendix 8.

| | |
|---|---|
| **11.2** | **Risks to Human Health from Soil Derived Contaminants** |
| 11.2.1 | Due to the low levels of contaminants identified, the risk to human health is considered to be minimal. Nevertheless, the risk from asbestos should be managed during construction through the implementation of Risk Assessments and Method Statements which should describe Personal Protective Equipment (PPE) to be used and any mitigation measures when working with the Made Ground i.e. dust suppression. |
| 11.2.2 | In addition, the risks to offsite receptors from the soil derived contaminants is considered to be minimal. |
| 11.2.3 | As such, the risk to human health is considered to be **low to medium** and soils are to be managed in line with the works on the main site i.e. implementation of a discovery strategy for previously unidentified contamination, segregation of soils and hardstanding etc., and the disposal of hazardous material (if encountered). |
| **11.3** | **Risks to Human Health from Ground Gas** |
| 11.3.1 | The Gas Risk Assessment has been carried out in general accordance with BS8485:2015+A1:2019 whereby the Characteristic Situation (CS) of the site has been identified. The Characteristic Situation ranges are between 1 and 6 and determine the gas risk to the property and the level of protection required. The process calculates a Gas Screening Value (GSV) based on gas monitoring which was undertaken based on boreholes within the Made Ground and natural geology. |
| 11.3.2 | The GSV for the site has been calculated based on the maximum concentration of methane or carbon dioxide monitored and the maximum flow rate recorded in the boreholes using the equation:<br>$$GSV = q\left(\frac{Chg}{100}\right)$$<br>Where:<br>• Chg = Concentration of a specific hazardous gas expressed as a percentage of total gas volume (%v/v)<br>• q = Total gas flow from a borehole in litres per hour (l/hr)<br>• Qhg = Calculated flow rate of a specific hazardous gas from a borehole reading<br>The results are then compared to tables set out in the guidance for assessment. |
| 11.3.3 | Based on the above calculation, the worst case GSV has been calculated as 0.028 which puts the site within CS1. However, due to the elevated levels of methane and carbon dioxide, the site has been moved into CS2 where gas protection would be necessary. |
| 11.3.4 | As such, the risk from ground gas impacting on or offsite receptors is considered to be **low to medium** as the concentrations identified on site are not considered to present a significant risk. Nevertheless, basic gas protection measures would be necessary. At this stage, a multi-gas and vapour membrane is considered to be required. |

| | |
|---|---|
| **11.4** | **Risks to Controlled Waters from Groundwater** |
| 11.4.1 | Groundwater samples were collected from BH01, WS02 and WS05 on one occasion. The results found marginal exceedances of the Environmental Quality Standards for freshwater as an assessment of the most sensitive receptor, which in this case is the River Crane. |
| 11.4.2 | The exceedances were found for the PAH compound (Fluoranthene) and heavy metals (Chromium, Copper, Nickel and Zinc). |
| 11.4.3 | Nevertheless, the concentrations were not considered to be significant, and as the site is situated 75m from the River Crane, the likelihood of significant contamination occurring is minimal therefore, the risk to Controlled Waters is considered to be **low** and a Detailed Quantitative Risk Assessment (DQRA) is not considered to be necessary. |
| **11.5** | **Property and Infrastructure** |
| 11.5.1 | Plant growth can be affected due to the presence of phytotoxic contaminants such as copper and zinc. However, due to the concentrations of contamination being low, the risk to plants and vegetation from phytotoxic contaminants is deemed to be **low**. Nevertheless, in areas of proposed soft landscaping, a clean capping of imported topsoil should be used. |
| 11.5.2 | From a preliminary risk assessment of the results to thresholds set in the UK Water Industry Research (2010) '*Guidance for the selection of water supply pipes to be used in brownfield sites*', it is possible that standard water pipes may be required for drinking water supply pipework. This is based on the low levels of contamination identified within the groundwater. As such, the risk rating is considered to be **low**. |
| **11.6** | **Risk Evaluation** |
| 11.6.1 | Following the implementation of the Phase 2 site investigation, the pollutant linkages identified in the CSM have been re-evaluated and re-classified in relation to the additional information obtained. The risk assessment has been completed for a continued use and for a potential redevelopment scenario. |
| 11.6.2 | The overall rating for the site based on a continued use is **low to medium**. The risk assessment is summarised in Table 15 below. |

11.6.3

**Table 15. *Revised Conceptual Site Model***

| Receptor | Potential sources | Pathways | Risk | Justification |
|---|---|---|---|---|
| **Human Health** | | | | |
| Construction and maintenance workers / Users of the site | Organic and metal contamination | Direct contact, ingestion, and inhalation via outdoor soils or translocated soil and dust indoors. | L M | **Low to medium risk:** Asbestos has been identified within two locations. As such, Personal Protective Equipment (PPE) and Risk Assessments and Method Statements are required for construction work. |
| | Ground gas and vapours | Inhalation, Migration through granular and fractured soils into confined spaces. | L M | **Low to medium risk:** The site has been classified as CS2 whereby gas protection measures will be required in new buildings. The risk to construction workers will be managed through PPE and Risk Assessments and Method Statements. |
| Future site users | Organic and metal contamination in soils and groundwater | Direct contact, ingestion, and inhalation of outdoor soils or translocated soil and dust indoors. | L M | **Low to medium risk:** Despite the presence of asbestos, the risk to future site users is considered to be minimal as the site is to be surfaced with hardstanding. |
| | Ground gas and vapour | Inhalation, migration through granular and fractured soils into confined spaces. | L M | **Low to medium risk:** The site has been classified as CS2 whereby gas protection measures will be required in new buildings. This will mitigate the risk to future site users. |
| Offsite Residents (270m southwest) | Organic and metal contamination in soils, groundwater and gas | Direct contact, ingestion, and inhalation of outdoor soils or translocated soil and dust indoors. | L | **Low risk:** The risk to offsite residents is considered to be minimal. |
| **Property** | | | | |
| Site structures and services | TPH in site soils | Direct contact between soil and structures or services. | L | **Low risk:** No gross contamination has been identified and as such, standard pipework should be considered. This should be confirmed with the incoming water supplier. |
| | Ground gas and vapour | Migration through granular and fractured soils into confined spaces. | L M | **Low to medium risk:** The site has been classified as CS2 whereby gas protection measures will be required in new buildings. This will mitigate the risk to future site users. |
| **Groundwater** | | | | |
| Principal Aquifer | Metals and organic contamination in soils | Soil leaching and migration of potential soil contamination. | L | **Low risk:** Despite the marginal PAH and heavy metals, the potential for a significant impact to the Principal Aquifer is considered to be minimal. |
| Secondary (A) Aquifer | Metals and organic contamination in soils | Soil leaching and migration of potential soil contamination. | L | **Low risk:** Despite the marginal PAH and heavy metals, the potential for a significant impact to the Secondary (A) Aquifer is considered to be minimal. |

11.6.4

**Table 15.** ***Revised Conceptual Site Model (Continued)***

| Receptor | Potential sources | Pathways | Risk | Justification |
|---|---|---|---|---|
| **Surface Water** | | | | |
| Grand Union Canal (directly south)<br>River Crane/Yeading Brook (70m east) | Leachable metals and organic contamination | Soil leaching and migration into drains and sewers which discharge into the ditch. | L | **Low risk:** Despite the marginal exceedances of PAH and heavy metals above the EQS, the potential for a significant impact to the River Crane and Grand Union Canal is considered to be minimal. |

## 12.0 CONCLUSIONS

**12.1** **Contamination and Remediation**

12.1.1 Overall, it is considered that there is a **Low to Moderate Risk** associated with the site in respect of land contamination. However, such risks are commensurate with a brownfield site of this nature and it is anticipated that many of the risks would be addressed / mitigated as part of the development process. Following inclusion of such measures (gas protection measures, PPE and material movement tracking) to the new development, it is anticipated that the risks identified would be reduced to low.

**12.2** **Geotechnical**

12.2.1 Geotechnical design parameters have been derived based on the results from ex-situ and in-situ testing and published empirical relations. A design groundwater level has also been derived based on groundwater strikes encountered and monitoring results from the current site investigation. DS and ACEC classifications are also provided for the Made Ground and Lynch Hill Gravel Member.

12.2.2 Given the existing ground conditions and obstructions, shallow foundations are not recommended. A preliminary pile design has been provided based on the derived geotechnical parameters.

12.2.3 Depending on the proposed pile length, it may be necessary to carry out an additional site investigation to prove the ground conditions to sufficient depth. Guidance on the required investigation depth is provided.

## 13.0 GEOENVIRONMENTAL RECOMMENDATIONS

**13.1 Contamination and Remediation**

13.1.1 Whilst no formal remediation is required, the following recommendations have been made.

13.1.2 Where landscaped areas are proposed, a capping layer will be required to prevent contact with underlying contaminants (asbestos). At this stage, the following is deemed appropriate.

13.1.3 **Table 16. Composition of Capping Layer.**

| Layer | Minimum Thickness |
|---|---|
| Topsoil | 150 |
| Subsoil | 450 |
| Geotextile | Terram 1,000 or similar |

13.1.4 In addition, the Topsoil and Subsoil are to meet the requirements of BS3882, Specification for Topsoil. The supplier should provide a test certificate prior to purchase. It is then recommended to test the soils once they arrive onsite to ensure they meet the requirements for a commercial land use based on S4ULs and C4SLs.

13.1.5 Thickness and composition of the topsoil should be subject to inspection and validation by chemical analysis. The quality of the geotextile should also be undertaken through visual inspection.

**13.2 Gas Protection Measures**

13.2.1 Based on the proposed development which is understood to be an MV energy centre, the site use is considered to be less sensitive than if the site was used for residential purposes. The monitoring undertaken to date has analysed boreholes from across the site. The results have shown the Characteristic Situation (as outlined in BS8485:2015+A1:2019) for the site is CS2.

13.2.2 As such, gas protection measures should be implemented as part of the design. For a Type D development with a Characteristic Situation of CS2, a score of 1.5 will be needed. This could be reached by installing a high performance gas and VOC resistant membrane.

13.2.3 Based on the results of the gas risk assessments, it is possible additional monitoring in the footprint of the new building could reduce the risk rating.

**13.3 Piling Works Risk Assessment**

13.3.1 There may be an increased risk to Controlled Waters from the piling required for the scheme from vertical migration of groundwater from the Made Ground to the underlying aquifers mobilised during piling. This is of particular importance if the final loading of the building increases significantly than the loads used in this investigation, as this would mean deeper piles would be required which may penetrate the London Clay and terminate in the underlying Chalk, which is classified as a Principal Aquifer and drinking water resource.

| | |
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| 13.3.2 | During the investigation, minor concentrations of contaminants have been recorded, and as such the risk to Controlled Waters is considered to be low. As such, a Piling Works Risk Assessment is unlikely to be required. However, this may still be stipulated by the Local Authority as a requirement for the development. Reference should be made to the Environment Agency document relating to 'Piling into Contaminated Sites' (EA, 2002). |
| **13.4** | **Asbestos in Soil** |
| 13.4.1 | Based on the presence of asbestos fibres within the shallow soils onsite, it is likely that some degree of asbestos management will be required. The protection of workers from exposure to asbestos is regulated by the Control of Asbestos Regulations (HSE, 2012). As such, appropriate Risk Assessments and Method Statements should be put in place to ensure the risks are minimised. This should be not be limited to Personal Protective Equipment (PPE) and Respiratory Protective Equipment (RPE), segregation of stockpiles, dust suppression by damping down stockpiles, and / or covering stockpiles with sheeting. |
| **13.5** | **Buried Services** |
| 13.5.1 | In accordance with the UK Water Research Guidance (2010) and due to the low concentrations of contaminant identified, standard pipework is considered suitable for the development. However, this report and appendices would be submitted to the local water authority to gain approval for the use of such pipes. |
| **13.6** | **Material Management and Waste** |
| 13.6.1 | Due to the presence of asbestos, some degree of segregation may be required. Whilst no formal waste assessment has been carried out, the soils are likely to be classified as non-hazardous waste. In addition, the quantification results for asbestos have been identified at concentrations below the threshold for hazardous waste. |
| 13.6.2 | During groundworks, asbestos fibres will require careful management through dampening down stockpiles / sheeting before disposal. In addition, a watching brief should be undertaken as part of the groundworks as there are areas of the site that were not investigated. A discovery strategy should also be put in place so that Paragon are contacted in the event that previously unidentified contamination is encountered. For the avoidance of doubt, this means any oil, malodourous or discoloured material. |
| 13.6.3 | The laboratory certificates and drilling logs, provided in the appendices, should be provided to the waste receivers to confirm their ability to accept waste arisings from the site. It is the waste producer's responsibility to classify and appropriately manage waste under duty of care (section 34 of the Environmental Protection Act 1990). Further asbestos qualification and WAC testing may be required as part of the future development. |
| **13.7** | **UXO** |
| 13.7.1 | An anomaly was recorded during the borehole clearance for Unexploded Ordnance (UXO) using the Magnetometer. This was identified within WS04 at a depth of 1.00mbgl. Due to the detection, the borehole was terminated. Recommendations for further assessment under the supervision of a UXO engineer have been made. This should involve excavating the material around WS04 and completing a visual and magnetometer assessment by a UXO engineer. |

| | |
|---|---|
| **13.8** | **Verification** |
| 13.8.1 | Once the groundworks has commenced and the watching brief has been undertaken. The information obtained onsite should be collated into a verification document. This should include site inspection records, photographs, laboratory results, details from the inspection of formation levels, inspection of gas protection measures, records where unexpected contamination are encountered, a review of Duty of Care / transfer records for the reuse, disposal and transport of soils. |
| 13.8.2 | Imported soils should be tested at source by the supplier. The validation engineers should then make spot checks as and when necessary once material has been imported. |
| 13.8.3 | Provision should also be made for dealing with further localised hotspots of contamination, which may come to light during construction. Any such soils should be inspected by the validation engineers and appropriate remedial action taken as necessary. |

## 14.0 GEOTECHNICAL DISCUSSION

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| **14.1** | **Ground Conditions – Geotechnical Discussion** |
| 14.1.1 | Made Ground was encountered in every exploratory hole. The base was reached in BH01 and WS05, where it was between 3.50m and 4.50m thick, and the base was not reached in WS02 at 5mbgl. The Made Ground was predominantly granular with little cohesive material. The density of the granular material was variable from very loose to medium dense and the consistency of the cohesive material was 'very soft'. |
| 14.1.2 | The granular Made Ground was predominantly concrete and brick, occasionally with glass, mixed lithologies, slag, ceramic, tile, flint and roots and cobbles of concrete and brick. Shallow concrete obstructions were encountered in WS01a-b and WS03 at a top depth between 0.20m and 0.45mbgl. WS04a was terminated at 0.30mbgl due to refusal in Made Ground. |
| 14.1.3 | Alluvium was encountered in WS05 and BH01 only and consisted of grey peaty gravelly clay. The gravel comprised of mixed lithologies. An SPT 'N' value of 27 was recorded at the base of the alluvium, however it is likely that this test struck gravel at depth, giving an artificially high value for the alluvium. |
| 14.1.4 | Lynch Hill Gravel Member was encountered in WS05 only and consisted of orange and brown sandy gravel. The gravel comprised of flint. |
| 14.1.5 | London Clay was only reached in one borehole with the top of weathered London Clay at 25.86mOD. Nearby boreholes indicate that the top of the London Clay is approximately 25mOD in the surrounding area, deepening north of the site. |
| 14.1.6 | In summary, the ground conditions on site are variable, comprising a significant thickness of Made Ground over superficial deposits of alluvium or Lynch Hill Gravel Member, with the London Clay at depth. The ground conditions on site appear to have been influenced by the nearby River Crane to the east of the site, and there is the potential for further alluvium to be present associated with this river. |

**14.2 Geotechnical Design Parameters**

14.2.1 Geotechnical design parameters are based on the in-situ Soil Penetration Tests (SPTs), results of the laboratory testing and published data for the well-studied London geology. Parameters have been provided in Table 17.

14.2.2 ***Table 17. Summary of In-situ and Laboratory Strength Testing***

| Stratum | Design Level (mOD) | Bulk Weight, $\gamma_b$ (kN/m$^3$) | Undrained Cohesion, $c_u$ (kPa) [c'] | Angle of friction, φ' (°) | Young's Modulus, $E_u$ (MPa) [E'] |
|---|---|---|---|---|---|
| Made Ground (Granular) | 31.80 | 18 | - [0] | 29[a] | - [12][b] |
| Made Ground (Cohesive) | 31.80 | 18 | 5 | 20 | 900 [675] |
| Alluvium | 0.5m thick | 18 | 40 [5][c] | 25[d] | 16[e] [9.6][f] |
| Lynch Hill Gravel Member | (26.99) | 19 | - [0] | 32[a] | - [40][b] |
| London Clay | 25.90 | 20 | 60 + 8z[g] [5][c] | 25 | 36 + 4.8[h] [27 + 3.6][i] |

a. Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310.
b. Based on design SPT x 2MPa
c. Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200
d. BS 8002:2015 Code of practice for Earth retaining structures, British Standards institution.
e. Based on $400c_u$
f. Based on $0.6E_u$ - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200
g. Z is depth below the top of the strata
h. Based on $600c_u$
i. Based on $0.75E_u$ - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200

**14.3 Groundwater**

14.3.1 No groundwater strikes were recorded during drilling.

14.3.2 Groundwater monitoring was undertaken following the site investigation. The monitoring results can be found in Appendix 6. The monitoring results are summarised in Table 18.

14.3.3 **Table 18. Groundwater Monitoring Results**

| ID | Elevation (mAOD) | Groundwater Level (mbgl) [mAOD] | | | |
|---|---|---|---|---|---|
| | | 8.7.2021 | 15.7.2021 | 23.7.2021 | 3.8.2021 |
| BH01 Deep | 30.86 | 2.62 [28.24] | 2.51 [28.35] | N/A | 2.50 [28.36] |
| BH01 Shallow | 30.86 | 2.52 [28.34] | 2.51 [28.35] | N/A | 2.55 [28.31] |
| WS02 | 31.34 | 2.97 [28.37] | 2.98 [28.36] | 2.99 [28.35] | 3.00 [28.34] |
| WS05 | 31.78 | 2.27 [29.51] | 2.30 [29.48] | 2.35 [29.43] | 2.32 [29.46] |

14.3.4 Based on the results of monitoring rounds, a design groundwater level within the Made Ground and Lynch Hill Gravel Member of 29.50mOD is recommended.

## 14.4 Shallow Foundations

14.4.1 The findings from the site investigation show a variable thickness of Made Ground across the site. Soft Alluvium was present in BH01 and WS05 and may be present in other areas across the site.

14.4.2 Given the thick and variable Made Ground, soft Alluvium and concrete obstructions present across the site, shallow foundations are not recommended.

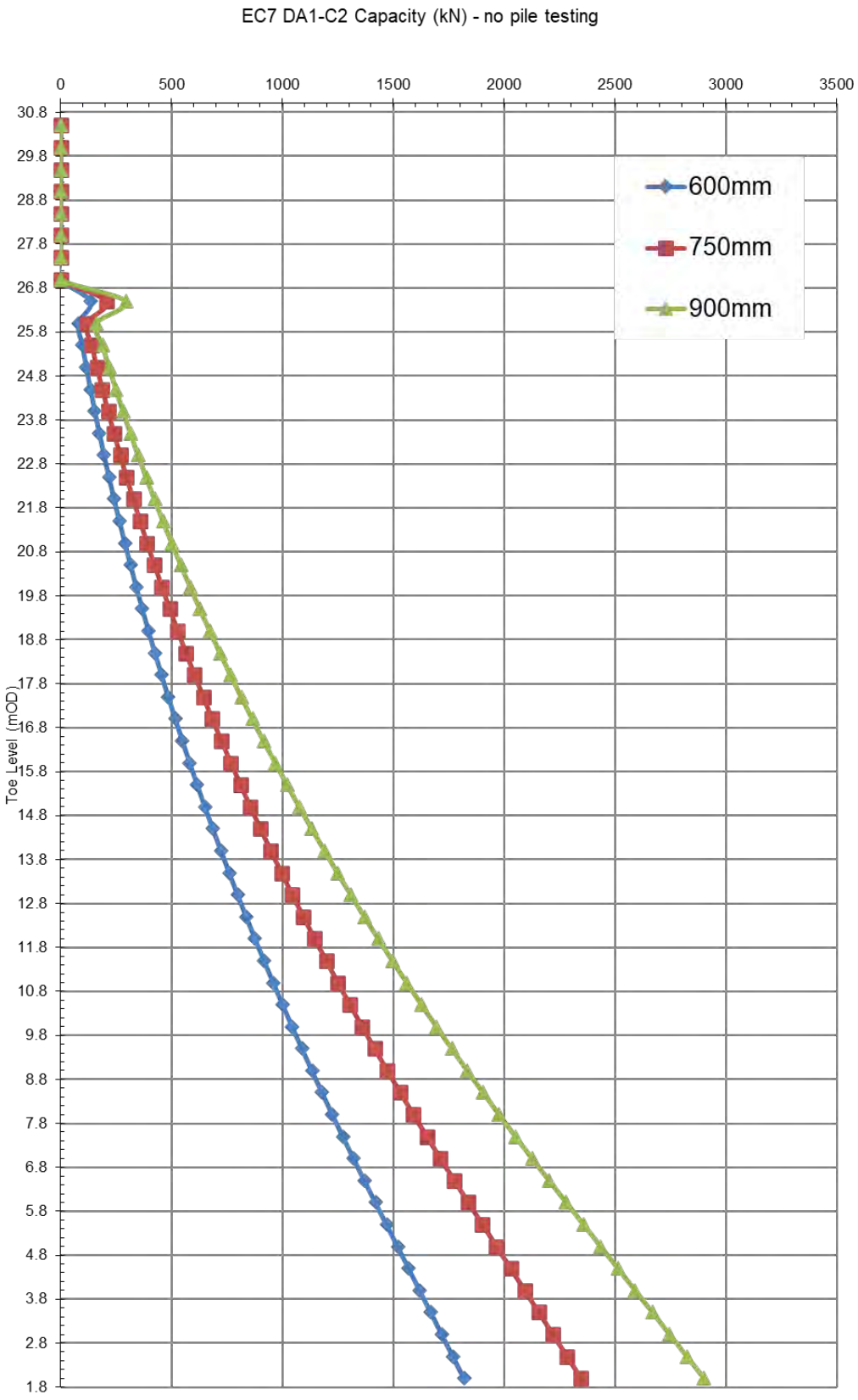
## 14.5 Piled Foundations

14.5.1 Pile foundations are considered feasible for the proposed scheme. Continuous Flight Auger (CFA) or bored piled foundations with isolated pile caps are considered suitable for the proposed development. CFA piling is typically limited to around 32m depth, while rotary bored piles are typically limited to 75m. It is recommended that a piling contractor be consulted to discuss the most appropriate pile construction method. Groundwater conditions should be taken into consideration when selecting piling methodology.

| | |
|---|---|
| 14.5.2 | A preliminary pile design has been undertaken in accordance with Eurocode 7 Design Approach 1, Combination 2. The preliminary pile design is presented in Plate 5. The following assumptions have been made regarding the preliminary design.<br>• All piles will be cast in-situ, Continuous Flight Auger (CFA) or bored;<br>• A pile cut-off level of 30.5mOD and a pile platform level of 31mOD have been used;<br>• The preliminary design has been carried out in accordance with Eurocode 7 Design Approach 1, Combination 2 assuming no working or preliminary pile loads:<br>• Combination 2 applies partial factors to the dead and live loads of 1.0 and 1.3 respectively, with geotechnical partial factors of 1.6 for the skin friction, 2.0 for the base capacity and 1.4 for the model factor (model factor value is based on the case of no working or preliminary pile load tests);<br>• The contribution from the Made Ground has been assumed to be negligible;<br>• The top of the London Clay has been assumed to be 23mOD. The capacity calculation for the stratum assumes an end bearing capacity factor (Nc) of 9, an adhesion value of 0.6 and a limited skin friction of 110kPa; |

14.5.3

**Plate 5. Preliminary pile design**



14.5.4 Eurocode 7 recommends that for pile foundations, the minimum borehole depth should be the largest of the following; note that current investigation data extends to 35m (approximately -2mOD), therefore on this data, pile toe levels should be restricted to a minimum level of +3mOD.

- Pile length + smaller side of the rectangle circumscribing the group of the piles forming the foundation at the level of pile base;
- Pile length + 5m;
- Pile length + (3 times the pile base diameter)

14.5.5 The current site investigation has proven the ground conditions to 35m below ground level. A further site investigation should be undertaken, if the recommended minimum investigation depth required under Eurocode 7 exceeds the existing site investigation depth.

## 14.6 Buried Concrete Sulphate Durability Classification

14.6.1 Soil samples from Made Ground, Alluvium and Lynch Hill Gravel Member were sent for laboratory testing to determine the sulfate concentrations and pH in general accordance with Building Research Establishment (BRE) SD1 guidance[1]. The test results can be found in be found in Appendix 5. A summary of the Design Sulphate (DS) and Aggressive Chemical Environment for Concrete [ACEC] classes are provided in Table 19. Total sulphur concentrations were not available, therefore classes based on total potential sulphate are not provided.

14.6.2 **Table 19. Design Sulphate (DS) classification for encountered soil strata**

| Stratum | pH | Water Soluble Sulphate as $SO_4$ (2:1) mg/l | Total Sulphate as $SO_4$ (mg/kg) | Design Sulphate (DS) Class [ACEC] |
|---|---|---|---|---|
| Made Ground | 7.9 to 10.3 | 34 to 830 | 540 to 4300 | DS-2 [AC-2] |
| Alluvium | 8.4 | 190 | 680 | DS-1 [AC-1] |
| Lynch Hill Gravel Member | 8.4 | 84 | 380 | DS-1 [AC-1] |

## 14.7 Floor Slabs

14.7.1 Given the variability of the Made Ground, the likelihood of obstructions in the ground and the presence of live services across the site, suspended floor slabs are recommended.

## 14.8 Pavements and Roads

14.8.1 A design CBR value of less than 2.5% is recommended for pavements and roads. If site levels are increased consideration should be given to potential long-term settlement and consolidation of organic/peat layers that may be present within the alluvium.

[1] Building Research Establishment. (2005). Special Digest 1 – Concrete in aggressive ground, third edition.

| | |
|---|---|
| **14.9** | **Excavations** |
| 14.9.1 | The Made Ground has been found to contain areas of very soft/loose material which could be unstable during excavations. It is therefore recommended that all excavations are supported. Due to the shallow groundwater level across the site excavations will likely require groundwater mitigation measures, such as sump pumps. |