Colt Data Centre Services

London4, Hayes

Ground Contamination Risk Assessment and Remediation Strategy

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Background

This ground contamination risk assessment report has been prepared to support the first phase of redevelopment at a site at Beaconsfield Road, Hayes, UB4 0SL (the site). The site comprises three parcels of land and this report relates to the first phase of development at Trinity Data Centre in the east and Tudor Works in the centre of the site (shown as a purple area in the plan below).

A second, later development phase (including investigation and assessment) will be undertaken in the Veetec Motor Group area in the west of the site, which will remain as a vehicle repair and servicing facility until 2024 (shown as an orange area in the plan below). This report relates to Phase 1 of the development only.

A contaminated land desk study and preliminary risk assessment was previously prepared by Arup and submitted to the London Borough of Hillingdon (LBH) to support the planning application. This report has been prepared to support partial discharge of Condition 17 part (i) of the planning consent, in so far as it relates to Phase 1 of the redevelopment only. It is not intended to support partial discharge of the condition in relation to Phase 2 of the redevelopment.

Site setting

The proposed development will involve the construction of a data centre campus on piled foundations. Piling will terminate in the London Clay. Most of the site will be occupied by buildings or hardstanding, with limited areas of soft landscaping. The development sensitivity is therefore low.

A principal aquifer is present in superficial deposits beneath the site and Yeading Brook flows just offsite to the east. The environmental sensitivity of the site has been assessed to be moderate to high as a result.

The site comprised agricultural fields prior to 1945. The eastern half of the site was then occupied by a laboratory and research facility from the 1960s until around 2000 when it was redeveloped for use as a data centre. The west of the site has been used for various light industrial or commercial uses since the 1960s. An aboveground and an underground fuel storage tank are present on the site.

A large gasworks was historically present offsite 100m to the southeast (at its closest point). That site has been remediated and is being developed for residential use. Surveys in the north of that site indicate that Yeading Brook flows over the London Clay. Geological maps also show superficial deposits are absent along the line of the brook which would mean there is no potential onsite migration pathway. A historical registered landfill is present offsite, approximately 50m to the southeast, associated with backfilled extraction works. One area was used for disposal of canal dredgings and gasworks waste which Arup understands was more than 200m to the south of the site.

Ground investigation and monitoring

The ground investigation was undertaken by Concept Engineering Consultants Limited (Concept) between August and November 2021. Ground gas, vapour and groundwater monitoring and sampling was undertaken between October and December 2021. Groundwater was recorded within the Lynch Hill Gravel during monitoring. The Concept factual report is included as Appendix A.

Made Ground was encountered in all locations with an average thickness of approximately 1m. Superficial deposits (Langley Silt and/or Lynch Hill Gravel) were encountered in most locations and underlain by the London Clay Formation and Lambeth Group.

Potential fragments of asbestos containing material (ACM) were encountered in the Made Ground in two locations. There was no visual indication of contamination staining, oils or seepages within Made Ground or natural soils. Slight hydrocarbon odours were recorded in three locations, but corresponding photoionisation detector readings (PID) were low. Elevated PID readings (up to 132ppm) were recorded in one location in Tudor Works, where staining on the building walls and hardstanding was also present but no post-fieldwork vapour monitoring was possible.

Analytical results

Contaminant concentrations in soil were relatively low and below commercial generic assessment criteria (GAC). Concentrations of volatile organic compounds (VOCs) were recorded below the laboratory method detection limit (MDL) in all soil samples analysed, including those where elevated PID readings were recorded or where samples were collected near to the underground fuel tank.

Hydrocarbon fractions (aliphatic >C_8 to C_{10} and aromatic >C_8 to C_{10}) in soil vapour samples were recorded marginally above the chronic soil vapour GAC in two of the six samples. Asbestos was detected in 21% of Made Ground samples at relatively low concentrations (<0.001% to 0.06% w/w).

Contaminant concentrations in soil leachate from overlying soils and in groundwater samples from the Lynch Hill Gravel aquifer were generally low and typical of the industrial setting of the site. Concentrations of volatiles in groundwater were below commercial groundwater vapour GAC. Ground gas concentrations and flow rates were typically low and the ground gas regime at the site has been assessed to pose a very low risk, which does not require gas protection measures.

Risk assessment

The table below summarises the results of the risk assessment.

Description	**Classification (with mitigation)**
Environmental sensitivity	Moderate to high
Development sensitivity	Low
Risk assessment	
Risk of harm to human health during construction	Very low
Risk of harm to human health during operation	
Risk of pollution to groundwater	Very low
Risk of pollution to surface water	
Risk to construction materials and services	
Risk to planting in landscaped areas	

Recommendations

No significant risks to human health or controlled water receptors have been identified that require a specific advance phase of remediation based on the results of the current ground investigation. Given the historical light industrial site use, there is the potential for localised contamination, principally further asbestos, and hydrocarbons which are more likely around tanks and operation areas.

A remediation strategy is presented in this report which describes a range of mitigation measures that should be implemented during the construction process to ensure that any contamination encountered is appropriately controlled and managed. This includes details of tank decommissioning, enhanced health and safety measures to mitigate risks from asbestos in soils, a contamination watching brief and testing of imported materials. The outcome of the works should be confirmed in line with the verification plan and a verification report submitted to LBH at the end of the project.

Additional ground investigation is required in the west of the site to characterise the ground conditions in advance of the Phase 2 development. This should include vapour sampling in the vicinity of WS210 and nearby hydrocarbon-stained hardstanding.

1 Introduction

1.1 Background

Ove Arup and Partners Limited (Arup) has been commissioned by Colt Data Centre Services (Colt DCS) to prepare a ground contamination risk assessment and remediation strategy to support redevelopment the site occupied by the Trinity Data Centre, Tudor Works and Veetec Motor Group at Beaconsfield Road, Hayes, UB4 0SL (the site).

A contaminated land desk study and preliminary risk assessment [1] was previously prepared by Arup and submitted to the London Borough of Hillingdon (LBH) to support the planning application (reference 38421/APP/2021/4045). The proposed development comprises construction of a data centre campus, including two new data centre buildings.

1.2 Report objectives

This report presents a ground contamination risk assessment and remediation strategy to support the first phase of development of the site (the area occupied by Trinity Data Centre and Tudor Works), as illustrated on Figure 1. The assessment is based on data collected from a ground investigation and subsequent monitoring undertaken in this part of the site between August and December 2021. The area occupied by Veetec Motor Group is leased until 2023 and will be investigated and assessed during a later development phase.

Figure 1 Site phasing plan

Extract from Drawing no. DCS20109-NWA-DC-01-LP-DR-A-10204, Revision B

This report has been prepared to support the partial discharge of Condition 17 part (i) in so far as it relates to Phase 1 of the redevelopment. Condition 17 part (i) is a pre-commencement condition and is reproduced below:

(i) Prior to the commencement of the development, or each development phase, the development shall not commence until a scheme to deal with contamination has been submitted to and approved by the Local Planning Authority (LPA). All works which form part of the remediation scheme shall be completed before any part of the development, or development phase is occupied or brought into use unless the Local Planning Authority dispenses with any such requirement specifically and in writing. The scheme shall include the following measures unless the LPA dispenses with any such requirement specifically and in writing:

> *a) A site investigation, including where relevant soil, soil gas, surface and groundwater sampling, together with the results of analysis and risk assessment shall be carried out by a suitably qualified and accredited consultant/contractor. The report should also clearly identify all risks, limitations and recommendations for remedial measures to make the site or part of the site suitable for the proposed use; and*
>
> *(b) A written method statement providing details of the remediation scheme and how the completion of the remedial works will be verified shall be agreed in writing with the LPA prior to commencement, along with the details of a watching brief to address undiscovered contamination. No deviation shall be made from this scheme without the express agreement of the LPA prior to its implementation.*

1.3 Scope of works

The scope of works informing this report includes:

- presentation and description of the results of the ground investigation undertaken in accordance with the Arup specification;
- a generic quantitative risk assessment of the results of the ground investigation;
- an update of the initial conceptual site model provided in the Arup desk study;
- consideration of the potential implications and recommendations for the development scheme; and
- a proposed remediation strategy for the scheme.

1.4 Report structure

This report has the following structure:

- Section 2 describes the current configuration of the site and the proposed development;
- Section 3 provides a summary of key information from the desk study;
- Section 4 outlines the scope of ground investigation and presents the findings;

- Section 5 describes the assessment methodology used and the results of the ground investigations;
- Section 6 presents the risk assessment;
- Section 7 provides a summary of the soil preliminary waste classification based on the results of the ground investigation;
- Section 8 sets out the conclusions and presents recommendations, the remediation strategy and verification plan.

1.5 Limitations

This report has been produced by Arup for use by Colt DCS in connection with the proposed redevelopment of the site. It takes into account our client's particular instructions and requirements and addresses their priorities at the time. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party in relation to it, except as provided for in Arup's agreement with Colt DCS.

Arup has based the site appraisal on the sources of information detailed within the report text and believes them to be reliable but cannot and does not guarantee the authenticity or reliability of this third-party information. Notwithstanding the efforts made by the professional team in undertaking this contamination assessment it is possible that ground conditions and contamination other than those potentially indicated by this report may exist at the site.

This report provides an assessment of the potential for contamination in the ground. The report does not provide an assessment of the potential for hazardous materials in the building fabric [now demolished] and the implications of those hazardous materials. A survey of hazardous materials in the building, for example asbestos containing materials, has not been carried out by Arup as part of this assessment.

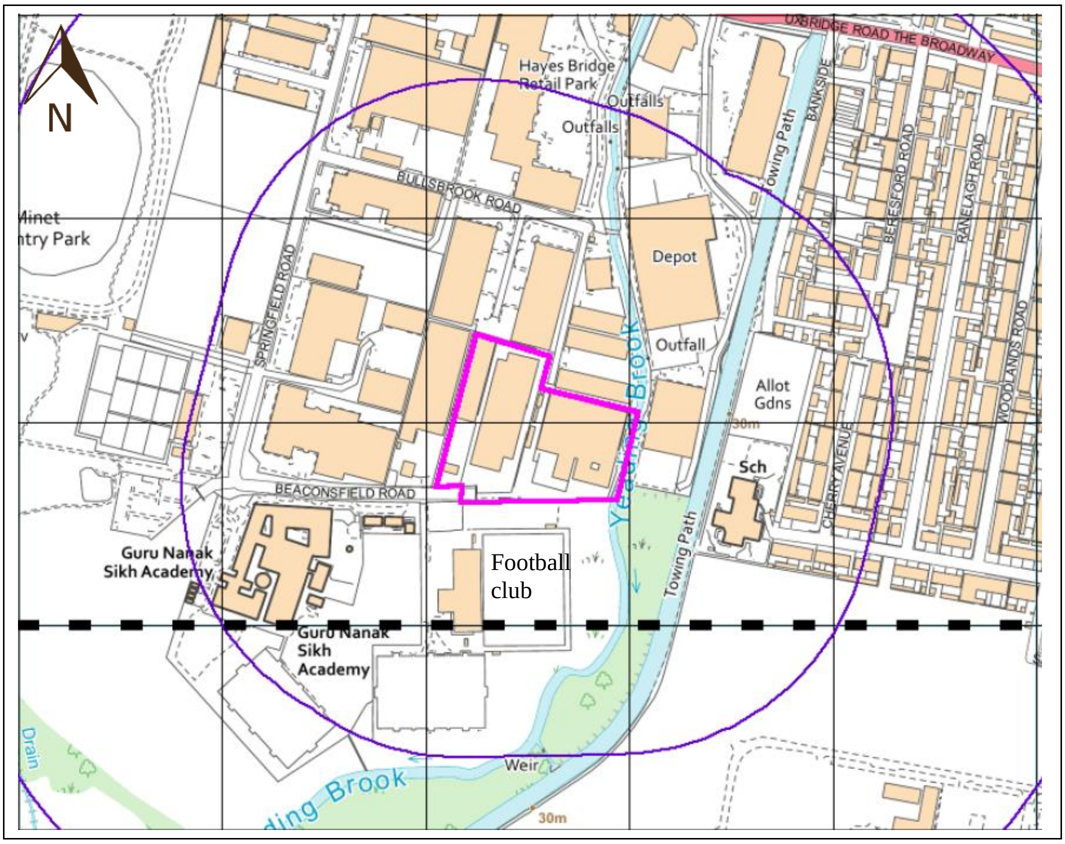
2 The site

2.1 Location and current condition

The site is part of the Springfield Industrial Estate in Hayes, within the London Borough of Hillingdon, at approximate national grid reference 511510, 180204. The site is broadly L-shaped and covers approximately 2.2 hectares (ha). The site location is illustrated in Figure 2.

The site is bounded by Beaconsfield Road to the south, with the Hayes and Yeading football club beyond. Warehouse buildings associated with the Springfield Industrial Estate and Brook Industrial Estate are present to the north, east and west. A primary school, allotments and residential area are located approximately 100m to the east, beyond Yeading Brook, and the Guru Nanak Sikh Academy is approximately 50m to the southwest. A large mixed-use development site (formerly Southall gasworks) is present 100m (at its closest point) to the southeast and Minet Country Park is 250m to the west.

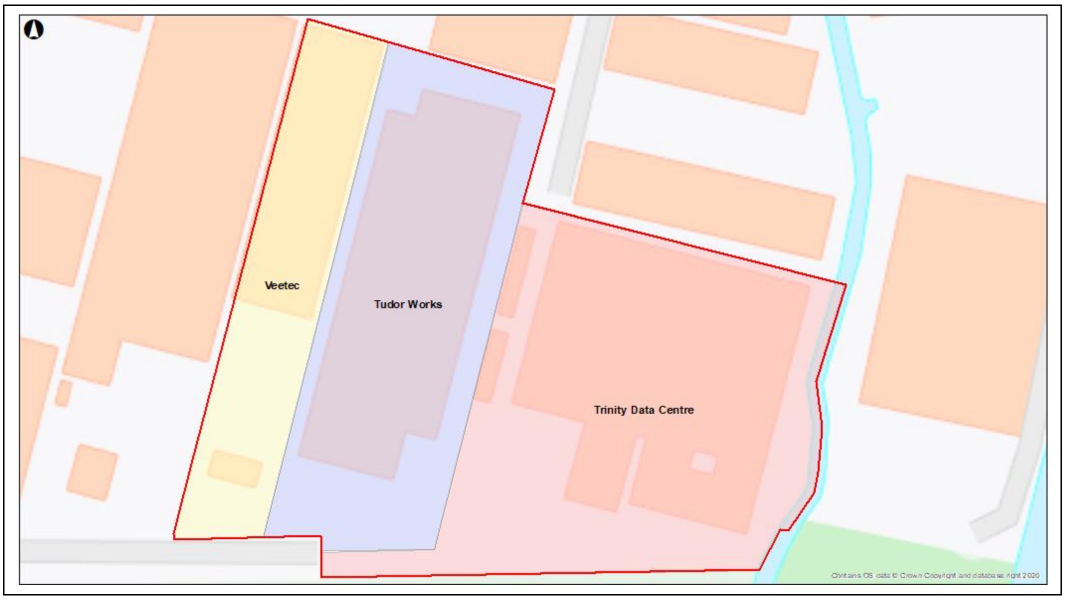
Figure 2 Site location plan



Extract from Envirocheck report (order no.: 279491051)

The site comprises three parcels of land, occupied by the Trinity London data centre in the east, and Tudor Works and Veetec Motor Group in the west. An existing site layout plan (prior to demolition) is presented as Figure 3. Approval for demolition of the existing data centre and Tudor Works buildings was granted in October 2021 and this work is ongoing. Demolition of the Veetec buildings is anticipated in 2024 following expiry of the lease.

Figure 3 Existing site layout plan (pre-demolition)



The following site descriptions are summarised from the Arup desk study [1] and observations made during a site reconnaissance visit undertaken in April 2021, unless otherwise stated.

2.1.1 Trinity Data Centre

The eastern parcel of land is predominately occupied by a two-storey steel frame warehouse building, which has been used as a data centre since around 2001. Half of the warehouse roof area is flat and houses generators, transformers, condensers and air conditioning units. The warehouse is adjoined to the south by a two-storey brick office block and raised platform which houses mechanical and electrical plant (MEP) associated with the data centre, including transformers, condensers, back-up generators and eight diesel aboveground storage tanks (AST). The tanks are understood to be bunded and fitted with bund alarms and fill guard alarms. Plant on the roof and within the MEP area had been removed by the time of a groundwater monitoring visit in October 2021.

A 70,000 litre fuel underground storage tank (UST) is located to the south of the office block. The UST is understood to be connected to a generator through pipework routed within a trench around the perimeter of the raised MEP compound.

A 70,000 litre diesel AST is located on the western site boundary. It is double-skinned and was installed in 2001. Fuel pipes run beneath the hardstanding and up the external side of the warehouse building to fuel the back-up generators on the roof. A large water tank for the sprinkler system and an electrical substation are also present to the west of the data centre warehouse. A petrol interceptor is present on the eastern boundary and an 'outfall to river' is in the northeast corner, which appears to be connected to the surface water drainage system.

2.1.2 Tudor Works

The central parcel of land is occupied by a series of light industrial units, collectively referred to as 'Tudor Works'. Most units are single storey with roller shutter doors. The roofs, drainpipes and guttering of these units may contain asbestos containing material (ACM). Prior to mid-2021, businesses operating from the units included manufacturers of double-glazed windows, furniture, doors, kitchen cabinets, awnings and canopies, an MOT and vehicle maintenance garage and a vehicle servicing and engine reconditioning company.

Possible fly-tipped material, including mattresses, furniture and tyres was observed in the southeast of the area. Bins and waste materials were noted along the eastern and western sides of the units and included wooden pallets, tyres, paint cans, empty oil drums, possible ACM and a metal fuel or oil non-bunded AST (approximately 500 litres). These materials had all been removed prior to commencement of ground investigation in August 2021.

Staining on the external building western wall and hardstanding was noted in the unit occupied by the vehicle servicing and engine reconditioning company. A freestanding overhead crane is present in the far north of the site and an electricity substation is present inside Unit 7 in the west.

2.1.3 Veetec Motor Group

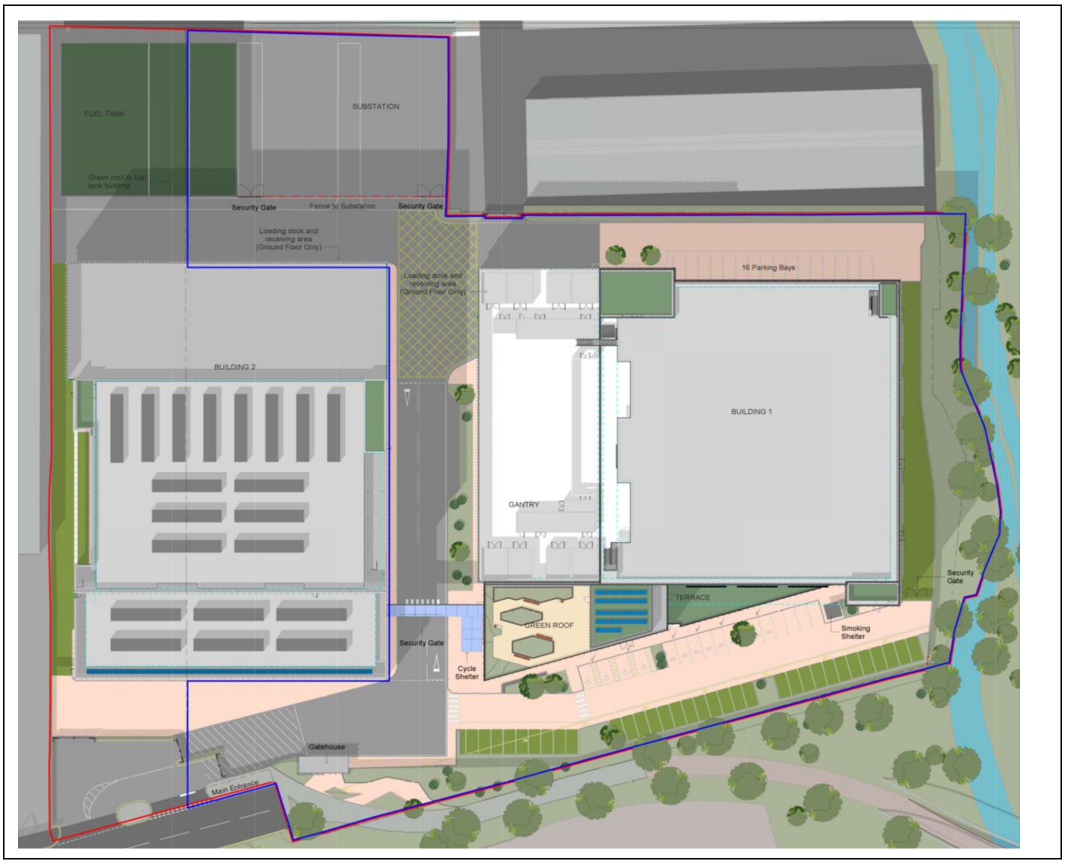
The land occupied by Veetec includes a three-storey office building in the south and a large warehouse in the north. The warehouse comprises a large central open plan area for vehicle repairs and spraying, with offices, workshops and plant rooms at the perimeter. No site reconnaissance has been undertaken for this part of the site due to access constraints. There is the potential for ACM to be present within the office and warehouse structures. The assessment presented in this report does not relate to this area, which will developed later during Phase 2.

2.2 Proposed development

A planning application (reference: 38421/APP/2021/4045) for redevelopment of the site was submitted to LBH in November 2021. The proposed site layout is presented in Figure 4. Two data centre buildings will occupy most of the site. A substation and fuel store are proposed in the north for switchgear and generator fuel tanks, respectively.

It is proposed that buildings will be five storeys high (maximum 36m) and will house data processing equipment, standby generators and offices [2]. The buildings will be constructed with a 250mm thick reinforced concrete suspended ground floor slab. Mechanical ventilation will be provided in all occupied areas of the buildings and in the data halls for cooling. The buildings will require piled foundations which are anticipated to be rotary bored cast insitu piles or continuous flight auger (CFA) piles extending into the London Clay. The pile design will be undertaken in accordance with the Arup specification for piling [3].

Figure 4 Proposed site layout plan

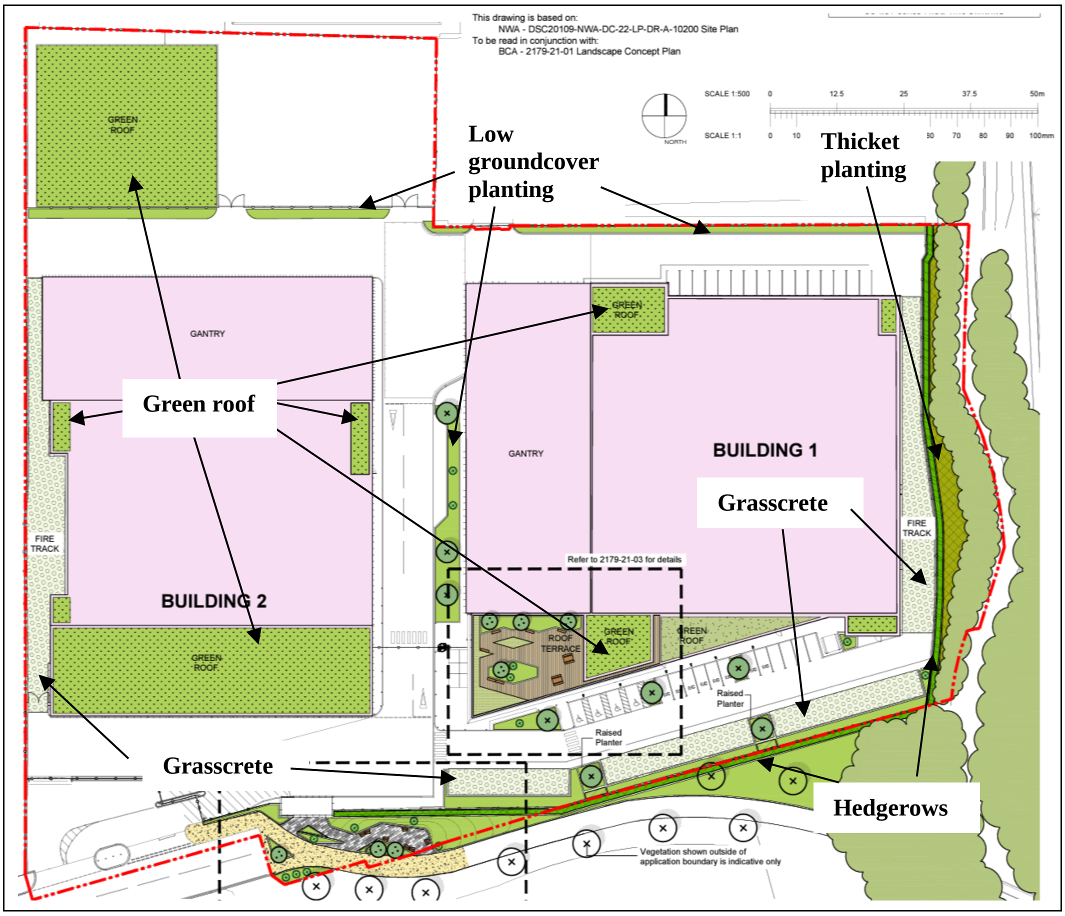


Extract from drawing no. DCS20109-NWA-DC-01-LP-DR-A-10201, revision A

Construction will be undertaken in two phases, as shown on Figure 1. Phase 1 in the east of the site (shown in purple) is anticipated to commence in Q3 2022 and includes construction of Building 1 in the east, the substation, and associated hard and soft landscaping. Phase 2 in west of the site (shown in orange) will commence in Q3 2024 and will comprise construction of Building 2 in the west, the fuel store and associated hard and soft landscaping.

The landscape proposal is illustrated in Figure 5. Ground level soft landscaping will comprise small areas of low groundcover planting, raised planters and tree pits, hedgerows and thicket planting. Grasscrete (cellular permeable grassed paving) along the eastern, western and southern boundaries. Where low ground cover planting is proposed, the landscape strategy requires 300mm of topsoil over 300mm of subsoil. For hedgerows, the strategy requires 300mm topsoil and 600mm subsoil. Tree pits will be between 750mm and 900mm deep and will be filled with topsoil.

Figure 5 Proposed landscaping



Extract from Barry Chin Associates Limited, Landscape Concept Proposal, Drawing no. 01, Revision F

3 Desk study information

3.1 Introduction

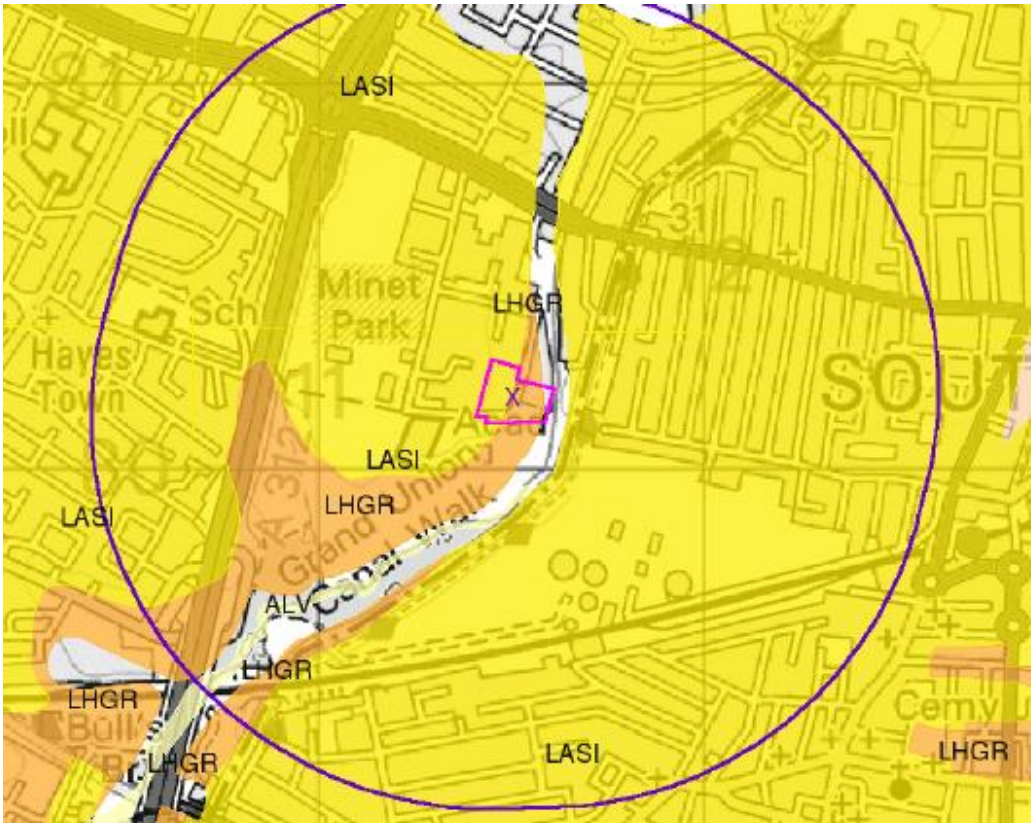
A summary of the Arup desk study [1] is presented in Section 3.2 to Section 3.6. This is intended to provide sufficient context for the subsequent quantitative assessment and updated conceptual model. An additional review of publicly available information and Arup's records has been undertaken for this report and is described in Section 3.7.

3.2 Environmental setting

3.2.1 Geology

Published geological records indicate that the site is underlain by the Langley Silt Formation and the Lynch Hill Gravel Member superficial deposits. The Langley Silt is anticipated to be absent in the east of the site, as shown in Figure 6, and all superficial deposits may be absent in the northeast corner of the site. The bedrock geology comprises the London Clay Formation, which is underlain by the Lambeth Group and the Chalk.

Figure 6 Mapped superficial geology



Key:

LASI = Langley Silt (yellow), LHGR = Lynch Hill Gravel (orange) which underlies the Silt.

3.2.2 Hydrogeology

The Lynch Hill Gravel is designated as a principal aquifer. The Langley Silt and London Clay are classified as unproductive strata. The Lambeth Group is a secondary A aquifer and the Chalk is a principal aquifer. There are no groundwater abstractions within 500m of the site and no abstractions for potable water supply within 1.5km. The site is not within a source protection zone (SPZ).

3.2.3 Hydrology

The Yeading Brook is adjacent to the eastern site boundary and flows from north to south. It joins the River Crane approximately 1km southwest of the site. The Grand Union Canal (Paddington Branch) is approximately 80m east and flows from north to south.

3.2.4 Radon

The site is within a lower probability radon area where less than 1% of homes are estimated to be at or below the action level. The Envirocheck report stated that no radon protection measures are necessary in the construction of new buildings in these areas.

3.3 Previous investigation

A ground investigation at the existing data centre was undertaken by Ramboll in 2020 to support initial due diligence for the purchase of the site. The ground investigation scope was very limited and included five shallow window sample boreholes (WS01 to WS05) to investigate shallow ground conditions. The locations are illustrated on Drawing 1.

Concrete obstructions were encountered in WS03, WS04 and WS05. The Made Ground was proven in two locations, to 1.4m bgl in WS01 and to 1.3m bgl in WS02. In these locations, natural clay was encountered beneath the Made Ground, which was described as soft or firm grey mottled light brown gravelly clay. This is likely to be the Langley Silt Formation. Firm to stiff light grey mottled light brown clay was encountered from 2.4m bgl in WS01 and from 2.5m bgl in WS02, which may be indicative of the top of the weathered London Clay. The Lynch Hill Gravel was absent in these locations in the southeast corner of the site.

A strong hydrocarbon (diesel) odour was recorded in WS01 (adjacent to the UST) between 2.0m and 2.4m bgl with a corresponding photoionisation detector (PID) reading of 27.7ppm. Asbestos was detected in one of the five soil samples and reported as loose fibres of amosite in WS01. ACM was also identified in WS01 as cement type material.

3.4 Site history

The site history was described in detail in the Arup desk study [1] and a summary is provided below.

Historical maps show that the site comprised agricultural fields prior to 1945. By 1961, the east of the site had been developed by Wimpey Laboratories Ltd, comprising office blocks, laboratories and a car park. Two 'works' buildings had been constructed in the west of the site, which expanded to the north in the 1970s. The buildings in the east were labelled as research depot on the 1973 map and two tanks were shown on the 1988 map. The research depot extended offsite to the north and northwest. The east of the site underwent several phases of demolition and construction over subsequent decades and has been used as a data centre since circa 2000.

A large gasworks (100m southeast at its closest) is first identified on historical maps from 1897, along with chemical works and associated railway sidings and docks. Multiple phases of ground investigation and detailed assessments of the former gasworks have been undertaken since 2000. Remediation and redevelopment is ongoing to provide a mixed-use development. The north of the development site is adjacent to the southern boundary of the study site, because it includes a proposed bridge (the Springfield Road Bridge) over the Grand Union Canal and Yeading Brook, which links to Beaconsfield Road in order to provide access to Springfield Road and Minet Country Park.

As part of the Arup desk study, the Contaminated Land Officer (CLO) at LBH was contacted for information regarding previous historical land uses and potential for contamination at the site. The CLO stated that the site is part of an industrial area which has been identified for inspection under the council's contaminated land inspection strategy (recorded as 'Brook Estate Various'). An inspection visit was undertaken in October 2010, but no further work under Part 2a of the Environmental Protection Act 1990 has been conducted since.

The closest historical landfill site ('Land at Yeading') is approximately 50m to the southeast based on LBH records. This relates to an area of land bounded by the Yeading Brook to the west and the Grand Union Canal to the east. It is understood that it was used for the disposal of canal dredgings and gasworks waste prior to 1950. LBH has identified the potential for ground gas associated with the landfill as 'low'. Historical maps from the 1960s onwards indicate this area to be covered by scrub land. Further desk-based assessment has been undertaken since issue of the desk study and is presented in Section 3.7.

3.5 Initial conceptual site model

Potential historical and current onsite sources of ground contamination at the site were identified in the Arup desk study, as follows:

- site-wide Made Ground;
- current and historical USTs, ASTs and associated pipework;
- onsite historical substations; and
- historical and industrial land uses including laboratories, a data centre and vehicle servicing, repair, respraying and engine reconditioning.

Offsite sources include the historical landfill, former gas works and historical and current industrial land uses, including works, factories and depots.

A summary of the initial plausible contaminant linkages (PCL) identified in the desk study are presented in Table 1.

Table 1 Initial plausible contaminant linkages (PCL)

Sources	Pathways	Receptors	PCL ref.
Onsite potentially contaminated Made Ground (including ground gas) Onsite fuel storage tanks and associated pipework Onsite historical and current industrial uses Offsite historical landfills, gasworks and other historical and current land uses	Ingestion, inhalation or dermal contact with soil, dust or fibres Migration via the unsaturated zone and inhalation of ground gas or vapours Lateral migration of dissolved phase contaminants	Construction workers and site visitors Neighbouring site users during construction	PCL1
		Commercial site users and visitors during operation Maintenance workers during operation	PCL2
Onsite Made Ground Onsite fuel storage tanks and associated pipework Current and historical onsite industrial uses Offsite historical landfills, gasworks and other historical and current land uses	Rainwater infiltration and leaching of contaminants Vertical and lateral migration of dissolved phase contaminants Creation of preferential pathways during construction Surface runoff	Yeading Brook Lynch Hill Gravel principal superficial aquifer	PCL3
Onsite Made Ground Onsite fuel storage tanks and associated pipework Current and historical onsite industrial uses	Direct contact of concrete and services with contaminated soils or groundwater	Onsite building materials and services	PCL4

No PCL has been identified between contaminants in the Made Ground or superficial deposits and lateral migration to the Grand Union Canal. The canal is 80m east of the site and is likely to be lined. BGS maps indicate the Lynch Hill Gravel to be absent to the east of the site along the line of the Yeading Brook, which would limit the potential for contaminant migration.

No PCL has been identified between contaminants in the Made Ground or superficial deposits and vertical migration to the onsite groundwater in the secondary A (granular Lambeth Group) and principal (Chalk) aquifers. Piles will terminate within the low permeability London Clay and no preferential pathways will be created.

3.6 Preliminary risk assessment

A summary of the preliminary risk assessment from the Arup desk study is presented in Table 2.

Table 2 Summary of preliminary risk assessment

Description	Risk classification
Environmental sensitivity	Moderate to high
Development sensitivity	Low
Potential for significant contamination	Generally low, but may be moderate to high around onsite point sources (such as tanks and pipework) and in the south (close to the offsite historical landfill and gas works)
Risk of harm to human health (construction workers and site visitors) during construction	Moderate
Risk of harm to human health (neighbouring site users) during construction	Low
Risk of harm to human health (commercial site users, visitors and maintenance workers) during operation	Low to moderate
Risk of pollution to groundwater (principal Lynch Hill Gravel aquifer)	Moderate
Risk of pollution to groundwater (Lambeth Group secondary aquifer and Chalk principal aquifer)	Negligible
Risk of pollution to surface water (Yeading Brook)	Moderate
Risk to onsite building materials and services	Low to moderate

3.7 Further desk-based review

3.7.1 Publicly available information

A further review of publicly available information was undertaken during preparation of this report. Further information on ground conditions to the south of the site was sought to characterise the potential for contaminant migration onto site from the offsite landfill. Historical BGS borehole records were reviewed online, but there are no investigation locations shown in the area between Southall gasworks and the site. Ground investigation is known to have been undertaken in this area and is discussed in Section 3.7.2.

The LBH and London Borough of Ealing (LBE) planning portals were also reviewed. A search of the LBE planning portal was undertaken as far as reasonably practical but no ground investigation data could be found related to Southall gasworks planning submissions. However, LBH provided comments on an ‘out of borough’ consultation for the Southall gasworks redevelopment in 2008 (LBH ref. 39704/app/2009/1917). The landfill is on LBH owned land referred to as ‘Minet Island’ which was historically excavated for gravel for the canal embankments and backfilled with domestic and construction waste, dredgings and gasworks waste. LBH commented that the northern end of Minet Island is thought to be less contaminated than the area to the south.

The consultation comments included recommendations for a range of measures to be implemented if planning permission was granted for remediation of the gasworks site (including dust, vapour and odour monitoring). The reason for these measures was stated as being ‘to ensure that the works did not cause harm to human health and wider environment’.

Cross-section drawings and topographical surveys were located for the proposed Springfield Road Bridge to be constructed over the Grand Union Canal and Yeading Brook to the south of the site. The plans indicate the base of the Yeading Brook to be at 25.15mOD at the proposed bridge crossing point just to the south of the site. This is a lower elevation than the level of the top of the London Clay recorded in the southeast of the site during the onsite Ramboll ground investigation (26.20mOD). The Yeading Brook separates the site from the offsite landfill and BGS maps indicate the absence of any superficial deposits directly adjacent to the brook which would prevent onsite migration of contamination from this direction.

The West Southall Masterplan environmental statement (ES), dated October 2008, refers to two historical boreholes drilled to the west of the Yeading Brook in the landing position of the proposed bridge. Soil contamination testing was undertaken and did not indicate significant impact, with slightly elevated concentrations of arsenic and petroleum hydrocarbons. The ES states that *“land gas monitoring was undertaken but no gases were recorded above detection levels”.*

3.7.2 In-house knowledge on ground conditions and contamination

Arup has worked on a confidential project in the local area which included reviewing information regarding the offsite landfill. While information from that work cannot be reproduced or referenced, Arup’s understanding is that disposal of the gasworks waste and canal dredgings occurred at the southern end of Minet Island, over 200m south of the site. Arup has reviewed data from ground investigation undertaken in the north of Minet Island, between Southall gasworks and the site, which shows that contamination was not identified.

Based on the above additional information, the offsite landfill and gasworks have been discounted as potential offsite sources of contamination because the information sources reviewed indicate that a viable onsite migration pathway is not present.

4 Ground investigation

4.1 Scope

A ground investigation was undertaken by Concept Engineering Consultants Limited (Concept) between 10 August and 8 November 2021. The Concept factual report is included as Appendix A. An exploratory hole plan is presented as Drawing 2.

The investigation was undertaken in accordance with a specification prepared by Arup dated 3 June 2021 (ref. DCS20109-ARUP-DC-CO-XX-SP-C-00003).

The original scope of the ground investigation comprised the following:

- hand dug inspection pits to a depth of 1.2m at each cable percussion and window sampler location prior to drilling;
- six cable percussion boreholes (BH101 to BH106) to a maximum of 60m bgl;
- 18 window sampler holes (WS201 to WS218) to approximately 5m bgl or 1m into the London Clay;
- Four machine excavated trial pits (TP301 to TP304) to 3m bgl;
- Six hand excavated foundation inspection trial pits (TP305 to TP310);
- One trial trench (TT401) to investigate the UST;
- Two trial trenches (IT501 and IT502) for infiltration testing;
- Installation of dual 50mm gas/ vapour monitoring standpipes and groundwater monitoring standpipes in cable percussion boreholes;
- Installation of 50mm groundwater monitoring standpipes in selected window sampler holes.
- Installation of 50mm gas/ 19mm vapour monitoring standpipes in selected window sampler holes.
- Six rounds of post-fieldwork groundwater level monitoring and ground gas monitoring;
- Collection of six ground gas samples from standpipes (one per round);
- Collection of six vapour samples from standpipes using Summa canisters on two occasions;
- Collection of groundwater samples from standpipes on two occasions;
- Measurement and collection of NAPL from standpipes if encountered;
- Collection of two surface water samples from the Yeading Brook on two occasions; and
- Geoenvironmental laboratory testing of soils, groundwater, surface water, ground gas and vapour samples.

Following identification of a potential drift-filled hollow in the northwest of the site, an additional four cable percussion boreholes (BH107 to BH110) were undertaken, primarily for geotechnical purposes. Soil samples were collected for geoenvironmental laboratory testing from these additional locations and a 50mm groundwater monitoring standpipe was installed in BH108 for post-fieldwork groundwater sampling.

4.2 Ground investigation locations

Table 3 provides a summary of the ground investigation locations undertaken. Several locations had to be moved due to multiple underground services or concrete obstructions. The window sampler locations rarely reached the proposed termination depth due to refusal in dense gravels or collapse due to water ingress. Table 3 details any variations from the proposed locations in the specification.

Table 3 Summary of ground investigation locations

Location	Type	Depth (m bgl)	Comments/ variations
BH101	CP	57.0	None
BH102B	CP	22.5	BH102 terminated at 0.8m due to presence of foundation and relocated to BH102A. BH102A terminated at 1.8m due to presence of a thick concrete slab and relocated to BH102B. WS216 terminated at 1.2m and continued as BH102B. BH102B terminated at 22.5m due to water seepage.
BH103A	CP	40.0	BH103 terminated at 1.1m due to an unidentified service and relocated to BH103A.
BH104C	CP	50.45	BH104 terminated at 1.7m due to potential underground service and relocated to BH104A. BH104A terminated at 1.5m due to potential underground service and relocated to BH104B. BH104B terminated at 0.73m due to concrete obstruction and potential service and relocated to BH104C. BH104C drilled in the same location as IT501.
BH105	CP	48.5	Falling head test undertaken due to cancellation of IT502.
BH106	CP	47.5	None
BH107	CP	49.5	Supplementary GI to investigate the presence of the suspected drift-filled hollow.
BH108	CP	25.45	Supplementary GI to investigate the presence of the suspected drift-filled hollow.
BH109	CP	25.0	Supplementary GI to investigate the presence of the suspected drift-filled hollow. Drilled in the same location as WS215.
BH110	CP	48.45	Supplementary GI to investigate the presence of the suspected drift-filled hollow.
WS201	WS	3.00	Terminated at 3.0m due to refusal on dense gravels and collapsed to 2.7m.
WS202	WS	3.00	Terminated at 3.0m due to refusal on dense gravels.

Location	Type	Depth (m bgl)	Comments/ variations
WS203	WS	2.00	Terminated at 2.0m due to refusal on dense gravels.
WS204	WS	1.60	Terminated at 1.6m due to refusal on dense gravels.
WS205A	WS	4.00	WS205 terminated at 0.7m due to concrete obstruction and relocated to WS205A. WS205A collapsed to 3.0m due to water ingress.
WS206	WS	4.00	North of the UST. Collapsed to 2.6m upon completion.
WS207C	WS	6.00	South of the UST. WS207 terminated at 1.0m due to underground services and relocated to WS207A. WS207A terminated at 0.6m due to concrete obstruction and relocated to WS207B. WS207B terminated at 0.6m due to concrete and brick obstruction and relocated to WS207C.
WS208	WS	3.00	Terminated at 3.0m due to refusal on dense gravels.
WS209	WS	4.00	Terminated at 4.0m due to refusal on dense gravels and collapsed to 3.55m.
WS210	WS	2.00	Terminated at 2.0m due to refusal on dense gravels. Located in area of diesel staining within Tudor Works.
WS211	WS	2.00	Terminated at 2.0m due to refusal on dense gravels.
WS212	WS	2.00	Terminated at 2.0m due to refusal on dense gravels.
WS213	WS	4.00	Terminated at 4.0m due to refusal on dense gravels.
WS214	WS	4.00	Terminated at 4.0m due to collapse.
WS215	WS	4.00	Terminated at 4.0m due to collapse.
WS216	HP	1.20	Terminated at 1.2m and continued as BH102B.
WS217	WS	1.60	Terminated at 1.6m due to refusal in dense Made Ground.
WS218A	HP	0.37	WS218 terminated at 0.48m due to concrete obstruction and relocated to WS218A. WS218A terminated at 0.37m due to concrete obstruction.
TP301	HP	1.18	Foundation inspection pit.
TP302	TP	3.10	None
TP303	TP	3.00	None
TP304	TP	3.00	None
TP305	HP	1.20	Foundation inspection pit.
TP306	HP	0.90	Foundation inspection pit.
TP307	HP	0.70	Foundation inspection pit.
TP308	HP	0.90	Foundation inspection pit.
TP309A	HP	1.30	Foundation inspection pit. TP309 terminated at 1.0m due to concrete obstruction and relocated to TP309A
TP310	HP	1.00	Foundation inspection pit.
TT401A TT401B TT401C	TT	0.67 to 1.60	Trial trench to investigate the UST. Undertaken as three separate pits.

Location	Type	Depth (m bgl)	Comments/ variations
IT501	TP	2.20	Trial pit for infiltration testing.
IT502	TP	N/A	Cancelled due to multiple underground services.

4.3 Coverage and constraints

The coverage achieved by the ground investigation within the Phase 1 development area is generally good. This is the area for which this report has been submitted to support partial discharge of Condition 17 part (i). Thick concrete obstructions or dense Made Ground prevented drilling to the proposed depth in the southern part of the Trinity Data Centre building.

The coverage across the Phase 2 development area was limited to six locations (WS209, WS210, WS211, WS212, TP308 and BH108). This was largely because access restrictions prevented investigation in the area occupied by Veetec Motor Group. Further ground investigation will be undertaken within the Phase 2 area prior to construction. Recommendations are included in Section 8.

4.4 Standpipe installations and monitoring

Details of the standpipe installations are presented in the Concept factual report (included in Appendix A). A summary of standpipe installations relevant to this report is provided in Table 4 and shown on Drawing 3 and Drawing 5.

Table 4 Summary of gas/vapour and groundwater monitoring standpipes

Location	Response zone		Type	Diameter (mm)	Stratum
	m bgl	mOD			
BH101	0.5 to 1.0	29.18 to 28.68	GG	50	MG/ LS
	9.5 to 18.0	20.18 to 11.68	GWS	50	LHG
BH102B	3.07 to 5.07	26.11 to 24.11	GWS	50	LHG
BH103A	1.20 to 11.7	28.50 to 18.00	GWS	50	LHG
BH104C	2.0 to 6.0	27.28 to 23.28	GWS	50	LHG
BH105	0.5 to 1.2	28.04 to 27.34	GG	50	MG
BH106	1.2 to 1.7	28.50 to 28.00	GG*	50	LHG
	3.7 to 6.7	26.00 to 23.00	GWS	50	LHG
BH108	2.0 to 9.0	27.79 to 20.79	GWS	50	LHG
WS201	0.4 to 1.4	29.39 to 28.39	GG	50	LS
WS204	0.5 to 1.2	28.41 to 27.71	GG	50	MG
WS205A	2.4 to 3.0	26.55 to 25.95	GWS	50	LHG
WS206	0.5 to 2.0	28.48 to 26.98	GG	50	MG/ LS
WS207C	0.5 to 1.2	28.36 to 27.66	GG	50	MG
WS209	2.0 to 3.55	27.81 to 26.26	GWS	50	LHG
WS213	1.0 to 4.0	28.26 to 25.26	GWS	50	LHG

Location	Response zone		Type	Diameter (mm)	Stratum
	m bgl	mOD			
WS214	1.0 to 1.7	28.18 to 27.48	GG	50	MG
Notes: m bgl – metres below ground level, mOD – metres above Ordnance Datum, GWS – Groundwater sampling standpipe, GG – Ground gas monitoring standpipe, MG – Made Ground, LS – Langley Silt, LHG – Lynch Hill Gravel, LC – London Clay *A shallow ground gas monitoring standpipe was incorrectly installed in the LHG in BH106					

The ground gas monitoring standpipes were installed with a dual gas tap (and tube) to allow ground gas measurements at the top and bottom of the well, followed by recirculation monitoring. Ground gas monitoring was undertaken on six occasions in eight installations (as shown on Drawing 3) between 26 October and 1 December 2021. A PID was also used to measure the well headspace for volatile hydrocarbons. Additional confirmatory gas samples were collected during the monitoring rounds and submitted for laboratory testing.

The additional confirmatory gas sample could not be collected during the first round of monitoring due to equipment failure. Gas samples were collected from WS201 and WS214 during the second round of monitoring, from WS201 during the third and fourth rounds and from BH106 during the fifth and sixth rounds.

Sampling of vapour was undertaken on two occasions; samples were collected from BH106, WS106 and WS107C during the third and fifth rounds of monitoring.

Groundwater level monitoring was undertaken weekly on six occasions in all installations. Groundwater samples were collected on two occasions from eight groundwater monitoring standpipes (BH101, BH102B, BH103A, BH104C, BH106, BH108, WS205A and WS213). WS209 was also sampled during the first visit, but there was insufficient water for sampling during the second visit. The 19mm standpipe in BH102B was sampled by mistake by Concept during the first sampling visit. The groundwater monitoring locations are shown on Drawing 5.

4.5 Chemical analysis

4.5.1 Soil

Laboratory analysis was undertaken by Chemtest and i2 Analytical Environmental Science laboratory to UKAS and MCERTS accredited methods, where appropriate and available.

99 soil samples were submitted for analysis of determinands listed in Suite E1, E3 and E4, as outlined in Table 5. The samples comprised 55 Made Ground, 16 Langley Silt, 25 Lynch Hill Gravel and three London Clay. 47 Made Ground samples were submitted for asbestos identification (Suite E2), of which 10 were submitted for quantification following confirmed identification. One sample of concrete was submitted for asbestos identification only and one sample of potential ACM from WS206 was submitted for bulk asbestos analysis.

11 samples were scheduled for volatile organic compound (VOC) and semi-volatile organic compound (SVOC) analysis (suite E5) based on observations of contamination and PID readings. Based on potential source areas identified in the desk study and to ensure a distribution of sampling locations:

- 34 samples were submitted for PCB (suite E6) analysis; and
- 20 samples were submitted for speciated phenols (suite E10).

Soil leachability and waste acceptance criteria (WAC) testing (suite I) was undertaken on 56 samples, comprising 30 Made Ground, 12 Langley Silt, 12 Lynch Hill Gravel and two London Clay.

Table 5 Summary of chemical analysis (soil and leachability)

Determinand
E1 General
Antimony, arsenic, beryllium, boron, cadmium, chromium (total), chromium (hexavalent), copper, lead, mercury, nickel, selenium, vanadium, zinc, pH, phenol (total monohydric), total organic carbon, moisture content and cyanide (total)
E2 Asbestos
Asbestos identification and quantification in accordance with HSG248 to 0.001%
E3 TPH CWG
Speciated total petroleum hydrocarbons (TPH) by GC-FID with aliphatic/aromatic class separation with criteria working group (CWG) banding
E4 PAH and BTEX
Polycyclic aromatic hydrocarbons (PAH) (USEPA16) by GCMS Benzene, toluene, ethyl benzene, m,p-xylene and o-xylene (BTEX) and Methyl Tertiary Butyl Ether (MTBE)
E5 VOC and SVOC
Volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) by GCMS
E6 PCB
Polychlorinated biphenyls (PCB) (WHO 12)
E10 Speciated phenols
Catechol, resorcinol, cresols (o-, m-, p-), total naphthols (sum of 1- and 2- naphthol), 2-isopropylphenol, phenol, trimethylphenol (2,3,5-), total xylenols and ethylphenols
I Waste acceptance criteria (WAC) leachability in line with BS EN 12457 Part 2
Arsenic, barium, cadmium, chromium (total), copper, mercury, molybdenum, nickel, lead, antimony, selenium, zinc, phenol index, chloride, fluoride, sulphate, total dissolved solids and dissolved organic carbon

4.5.2 Groundwater and surface water

Groundwater samples were collected from 10 standpipe locations during the second round of monitoring and from eight locations during the fourth round of monitoring. Surface water samples were also collected from the Yeading Brook from two locations; one upstream of the site and one downstream of the site. Samples were scheduled for analysis of the determinands summarised in Table 6.

Table 6 Summary of chemical analysis (water)

Determinand
Suite F1 General
Antimony, arsenic, beryllium, cadmium, calcium, chromium (total), copper, lead, mercury, manganese, magnesium, nickel, selenium, zinc, ammoniacal nitrogen (as N), dissolved organic carbon (DOC), hardness (total), pH, cyanide (total), phenol (total monohydric) and chloride.
Suite F2 TPH CWG
Speciated total petroleum hydrocarbons (TPH) by GC-FID with aliphatic/aromatic class separation with criteria working group (CWG) banding
Suite F3 PAH and BTEX
Polycyclic aromatic hydrocarbons (PAH) (USEPA16) by GCMS Benzene, toluene, ethyl benzene, m,p-xylene and o-xylene (BTEX) and Methyl Tertiary Butyl Ether (MTBE)
Suite F4 VOC and SVOC
Volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) by GCMS
Suite F5 PCB
Polychlorinated Biphenyls (PCB) (WHO 12)
Suite F8 Hexavalent chromium
Chromium (hexavalent)
Suite F9 Speciated phenols
Catechol, resorcinol, ethylphenol and dimethylphenol, cresols, naphthols, isopropylphenol, phenol and trimethylphenol
Suite F14 Other parameters
Iron, magnesium, sodium, potassium, sulphate (as SO_4), sulphide, chloride, nitrate (as N and NO_3), nitrite (as N and NO_2) and alkalinity (as $CaCO_3$)

4.5.3 Ground gas and vapour

One confirmatory gas sample was collected using a Tedlar bag during each of the gas monitoring rounds. Gas samples were scheduled for a suite of analysis including carbon dioxide, hydrogen, methane, nitrogen, oxygen and hydrogen sulphide. The gas samples provide an additional line of evidence supporting and verifying the insitu gas monitoring results.

Vapour samples were collected from three installations (BH106, WS106 and WS107C) on two occasions using Summa canisters during the third and fifth rounds of monitoring and scheduled for VOC and speciated TPH analysis. These locations were installed with vapour wells because they are close to potential vapour sources identified in the desk study. BH106 is in the southwest of Tudor Works and close to where hydrocarbon staining was observed on the hardstanding, whilst WS106 and WS107C are adjacent to the UST at the Trinity Data Centre.

4.5.4 Deviating samples

11 soil samples collected from five locations (TP301, BH101, WS201, WS209 and WS211) were recorded as deviating by the laboratory for analysis of petroleum hydrocarbons, pH, boron, total cyanide and VOCs. This was due to the sample age exceeding the stability time (from sampling to extraction) because of a delay in the samples being collected in the field by Concept which delayed the chain of custody forms being supplied to Arup for sample scheduling by several days. The deviating samples represent a small proportion of the samples tested and are not considered to have a significant impact on the assessment.

4.6 Ground conditions

4.6.1 Summary

The ground conditions encountered during the investigation are summarised in Table 7.

Table 7 Summary of ground conditions encountered

Stratum	Top of stratum (mOD)	Base of stratum (mOD)	Depth to base (m bgl)	Thickness (m)
Made Ground	28.54 to 30.5	29.77 to 25.68	0.16 to 3.5	0.16 to 3.5
Langley Silt	26.86 to 29.62	29.28 to 25.36	0.5 to 3.5 (locally absent)	0.34 to 1.5
Lynch Hill Gravel	25.68 to 29.77	26.18 to 11.78	2.80 to 17.9 (locally absent)	0.80 to 16.3
London Clay	11.78 to 26.54	-15.40 to -18.22	45.0 to 47.5	27.6 to 44.5
Harwich Formation	-18.22 to -15.40	-17.60 to -19.92	47.2 to 49.2 (locally absent)	0.95 to 2.2
Lambeth Group	-19.92 to -15.82	Not proven (>27.32)	Not proven (>57.0)	Not proven (>11.5)

A geological cross-section from ground level to 10mOD is presented as Drawing 3.

4.6.2 Hardstanding and Made Ground

Hardstanding was encountered in most exploratory hole locations as reinforced concrete, asphalt or a thin layer of asphalt overlying concrete. No hardstanding was encountered in TP302, TP304 or WS205A.

Made Ground was encountered in all 54 locations and proven in 30 locations to depths of between 0.16m to 3.5m. The greatest proven depth of concrete and Made Ground was encountered in BH102B to a depth of 3.5m bgl (25.68mOD). BH102B is inside one of the data halls of the Trinity Data Centre building.

The Made Ground was variable in consistency across the site, comprising silty sand, sandy gravelly silt, gravelly sandy clay, very gravelly sand or sandy gravel of flint, sandstone or limestone. Anthropogenic inclusions comprised frequent concrete, brick and asphalt fragments, occasional glass, ceramic, clinker, rare ash and mortar.

Several shallow obstructions were encountered during the investigation, as summarised in Table 8.

Table 8 Summary of obstructions encountered

Location	Description	Depth	
		m bgl	mOD
BH102	Brickwork and concrete	0.8	28.21
BH102A	Concrete slab	0.82 to >1.8	28.35 to <27.37
BH102B	Concrete	2.6 to 3.3	26.58 to 25.88
BH104B	Concrete	0.35 to >0.73	28.80 to <28.42
WS205	Concrete	0.7	28.16
WS207A	Concrete	0.6	28.18
WS207B	Concrete and brickwork	0.6	28.11
WS207C	Concrete	1.1 to 1.2	27.76 to 27.66
WS213	Concrete	0.7 to 1.0	28.57 to 28.26
WS217	Concrete	0.8 to 0.9	28.81 to 28.71
WS218	Concrete	0.48	28.45
WS218A	Concrete	0.37	28.55
TP306	Concrete	0.5 to 0.8	28.38 to 28.08
TP309	Concrete	1.0	29.50
TT401	Concrete	1.2	27.48

4.6.3 Langley Silt

The Langley Silt was encountered as soft to firm dark grey/ orangish brown mottled light grey/ bluish grey mottled greenish brown and bluish grey slightly sandy silty clay or slightly gravelly sandy silt. Pockets of peat were encountered in WS207C between 2.0m and 3.5m bgl.

The Langley Silt was absent in BH102B, BH106, BH107, BH108, WS204, WS208, WS209, WS213, TP301, TP303, IT501 where the Made Ground was encountered overlying the Lynch Hill Gravel.

4.6.4 Lynch Hill Gravel

The Lynch Hill Gravel was encountered in most locations and described as medium dense to very dense orangish brown/ yellowish brown/ brownish orange sandy gravel of flint or gravelly sand. The Lynch Hill Gravel was absent in BH105 and WS207C in the southeast corner where the Langley Silt was encountered overlying the London Clay. This is consistent with the previous ground investigation undertaken in this area by Ramboll in 2020.

A greater depth of Lynch Hill Gravel was encountered in BH101 (to 17.9m bgl) and BH103A (to 11.7m bgl) in the northwest which is potentially indicative of a drift-filled hollow or scour feature. Four additional boreholes (BH107 to BH110) were undertaken to investigate the extent of this feature, which was identified to depths of 13.9m bgl (BH107), 9.1m bgl (BH108), 7.35m bgl (BH109) and 12.6m bgl (BH110). Concept identified localised variable pockets of firm orangish brown sandy gravelly clay or firm gravelly silty clay within the Lynch Hill Gravel in BH101, BH107, BH108, BH109 and BH110 as ‘Alluvium/ Lynch Hill Gravel Member’.

4.6.5 London Clay

The London Clay was encountered in 13 locations as a thin layer of weathered London Clay, described as firm to very stiff brown/ orangish brown silty clay. The underlying non-weathered London Clay was encountered as very stiff extremely to very closely fissured greyish brown silty clay with occasional to frequent pockets of silty fine sand, bands of claystone, pyrite nodules and shell fragments.

The proven thickness ranged from 27.6m in BH101 (in the northwest) to 44.5m in BH105 (in the southeast). The proven base depth ranged from 45m bgl (-15.40mOD) in BH110 to 47.5m bgl (-18.22mOD) in BH104C. At its shallowest, the London Clay was encountered at 2m bgl (26.54mOD) in BH105 and at 3.5m (25.36mOD) in WS207C where the Lynch Hill Gravel was absent.

4.6.6 Harwich Formation

The Harwich Formation was encountered beneath the London Clay in four locations (BH104C, BH105, BH106 and BH110) as grey slightly sandy silt or very stiff grey/ greyish brown slightly micaceous silty clay with occasional shell fragments.

4.6.7 Lambeth Group Formation

The Lambeth Group was encountered in five locations as very stiff greyish brown/ light bluish grey /yellowish brown/ orangish brown silty clay.

4.6.8 Observations

Headspace screening of soil samples was undertaken by Concept using a PID fitted with a 10.6eV bulb. The PID readings are provided on the exploratory hole logs in the Concept factual report (included in Appendix A). The PID readings were typically 1ppm or below and most were below the instrument detection limit (<0.1ppm).

Slightly elevated PID readings (between 18ppm and 132ppm) were recorded in the superficial deposits in WS210. No visual or olfactory evidence of contamination was recorded. No gas or vapour monitoring standpipe was installed in WS210 as these PID readings were not provided by Concept to Arup at the time of requesting installation details. Soil samples were collected from WS210 and analysed for VOCs. A discussion of the results is provided in Section 5.2 and recommendations are provided in Section 8.

A slight hydrocarbon odour was recorded between 0.6m and 0.9m (at the top of the Langley Silt Member) in BH101. A hydrocarbon odour was recorded at 6.0m in BH107 and a medium strong hydrocarbon odour was recorded between 4.0m and 4.6m in BH110 within the Alluvium/ Lynch Hill Gravel. Corresponding PID readings were very low (0.3ppm and below).

A potential fragment of asbestos containing material ACM was encountered at 0.20m in WS202 and at 0.6m in WS206.

4.7 Groundwater

A summary of groundwater encountered during the ground investigation is presented in Table 9.

Table 9 Summary of groundwater encountered during the ground investigation

Location	**Depth of water strike**		**Depth after 20 minutes**		**Stratum**
	m bgl	**mOD**	**m bgl**	**mOD**	
BH101	9.50	20.18	3.70	25.98	Alluvium/ Lynch Hill Gravel
BH102B	21.75	7.43	20.24	8.94	London Clay
	22.50	6.68	21.87	7.31	
BH104C	3.10	26.18	3.10	26.18	Lynch Hill Gravel
	48.45	-19.17	48.45	-19.17	Harwich Formation
BH105	46.2	-17.66	46.2	-17.66	London Clay
BH106	9.50	20.20	9.50	20.20	London Clay
BH107	7.50	22.18	5.30	24.38	Lynch Hill Gravel
BH110	3.27	26.33	3.27	26.33	Alluvium/ Lynch Hill Gravel
WS205A	2.80*	26.06*	-	-	Lynch Hill Gravel
WS208	2.50*	26.66*	-	-	Lynch Hill Gravel
WS209	3.20*	26.61*	-	-	Lynch Hill Gravel
WS213	3.00*	26.26*	-	-	Lynch Hill Gravel
WS214	2.80*	26.38*	-	-	Lynch Hill Gravel
WS215	2.80*	26.37*	-	-	Lynch Hill Gravel

Notes:
* water level recorded upon borehole completion

A summary of groundwater levels recorded during the six weeks of post-fieldworks monitoring is presented in Table 10. Results from standpipes installed in the London Clay have not been included. The sixth round of monitoring could not be undertaken in WS213 due to access constraints.

Table 10 Summary of groundwater levels during post-fieldwork monitoring

Location	Response zone (m bgl)	Stratum	Maximum level		Minimum level	
			m bgl	mOD	m bgl	mOD
BH101	0.5 to 1.0	MG/ LS	Dry	Dry	Dry	Dry
	9.5 to 18.0	LHG	3.17	26.51	3.53	26.15
BH102B	3.07 to 5.07	LHG	2.15	27.03	2.21	26.97
BH103A	1.2 to 11.7	LHG	3.19	26.51	3.36	26.34
BH104C	2.0 to 6.0	LHG	2.57	26.71	2.97	26.31
BH105	0.5 to 1.2	MG	Dry	Dry	Dry	Dry
BH106	1.2 to 1.7	LHG	Dry	Dry	Dry	Dry
	3.7 to 6.7	LHG	3.15	26.55	3.32	26.38
BH108	2.0 to 9.0	LHG	3.25	26.54	3.42	26.37
WS201	0.4 to 1.4	LS	Dry	Dry	Dry	Dry
WS204	0.5 to 1.2	MG	Dry	Dry	Dry	Dry
WS205A	2.4 to 3.0	LHG	2.18	26.77	2.59	26.36
WS206	0.5 to 2.0	MG/ LS	1.99	26.99	Dry	Dry
WS207C	0.5 to 1.2	MG	Dry	Dry	Dry	Dry
WS209	2.0 to 3.55	LHG	3.17	26.64	3.36	26.45
WS213**	1.0 to 4.0	LHG	2.54	26.72	2.74	26.52
WS214	1.0 to 1.7	MG	Dry	Dry	Dry	Dry
Notes: * three rounds of monitoring ** five rounds of monitoring						

The groundwater level monitoring does not indicate a consistent flow direction within the Lynch Hill Gravel. It is likely that the overall groundwater flow direction within the aquifer is to the east towards the adjacent Yeading Brook. Close to Yeading Brook it is also likely to be to the south, in the same flow direction as the Brook.

Topographical plans for the Southall gasworks development reviewed on the LBH planning portal indicate that the Yeading Brook is at an elevation of approximately 25.15mOD to the southeast of the site. The results of the ground investigation indicate the Lynch Hill Gravel to be absent in the southeast of the site and the top of the London Clay to be at 26.54mOD. This suggests limited local hydraulic continuity, and therefore limited potential for contaminant migration, between groundwater in the Lynch Hill Gravel onsite and the offsite Yeading Brook.

5 Data evaluation

5.1 Assessment methodology and criteria

5.1.1 Rationale

The human health and controlled waters assessment criteria were selected based on the conceptual model and proposed site use summarised in Sections 2 and 3. The evaluation of ground investigation data has been carried out in accordance with the risk assessment methodology presented in Appendix B and the Environment Agency land contamination risk management (LCRM) guidance [4].

The results are discussed in Sections 5.1.2 to 5.1.6 below. They have initially been compared to criteria that are protective of the potential human and environmental receptors and are conservative given the form of development. Results above the initial criteria do not necessarily represent an unacceptable risk, but rather that a more detailed assessment is required, taking into account site-specific details. This is a tiered approach and aligns with national guidance on risk assessment.

5.1.2 Human health soil criteria

Arup has derived GAC using the Contaminated Land Exposure Assessment (CLEA) v1.071 software. Input data for the toxicological effects, physical characteristics and contaminant fate and transport parameters for the determinands have been taken from sources published by the Environment Agency and other industry sources (including Land Quality Management (LQM)/Chartered Institute of Environmental Health (CIEH) (licence no. S4UL3227) and Contaminated Land: Application in Real Environments (CL:AIRE)). However, for some parameters such as lead it has been necessary to apply the toxicological data published by Defra for the ‘acceptable low’ risk scenario rather than minimal risk, as the latter is not currently available.

Soil data have been initially compared against GAC derived for a commercial end use which considers a typical three-storey pre-1970 office building. This end use models the exposure of a working female adult receptor aged between 16 and 65 years, undertaking office-based or relatively light physical work indoors with standard hour days with short outside breaks.

The soil organic matter (SOM) level is an important aspect in deriving the GAC for organic contaminants because these compounds partition to the organic matter in the soil. A higher level of soil organic matter in the soil means more of the contaminant is sorbed to soil particles and less is available for exposure to the receptor. The total organic carbon (TOC) content has been multiplied by 1.72 to provide an indicative SOM. The SOM content in the soil samples analysed generally ranged from <0.17% to 8.08%. One high value (17.2%) was recorded in WS211, which is attributed to an elevated TPH concentration in this location. Excluding this high value, the SOM content within the different strata is outlined below:

- SOM in the Made Ground ranged from <0.17% to 8.08% with an average of 1.70%.
- SOM in natural strata ranged from <0.17% to 2.58% with an average of 0.68%.

Criteria based on the lowest available SOM content (1%) have therefore been used in the first instance in the assessment for the initial generic screening exercise.

There are no published GAC for asbestos in soils in the UK. Work with asbestos, including asbestos in soils, is regulated under the Control of Asbestos Regulations 2012. The soil testing results have been assessed using multiple lines of evidence to identify the potential significance for construction and waste assessment based on the latest guidance in CAR-SOIL™ [5] and CIRIA C733 [6]. In the first instance the presence of asbestos has been flagged for initial assessment.

Asbestos in soil quantity descriptions provided in this assessment have been determined in line with the values provided within the CAR-SOIL Joint Industry Working Group (JIWG) Decision Support Tool as shown below:

- Large quantity: >0.1% w/w
- Moderate quantity: >0.05 to <0.1% w/w
- Low quantity: >0.01 to <0.05% w/w
- Very low quantity: <0.001 to 0.01% w/w

The ground conditions discussed in Section 4.6 have been considered as part of the assessment.

5.1.3 Human health soil vapour criteria

The chronic human health risks associated with volatile contaminants have been assessed in accordance with CIRIA C682 [7]. Arup has used a health criteria value (HCV) based on tolerable and mean daily intakes for threshold contaminants or index doses for non-threshold contaminants given in relevant sources such as C4SL/TOX reports. The sub-model used by CLEA to simulate the migration of soil vapour through the unsaturated zone and migration into indoor air is based on the Johnson and Ettinger (J&E) model. The criteria represent acceptable concentrations of vapours in air for an adult, assuming migration of soil vapour into the building through cracks or openings in the floor or walls. This provides a conservative approach for the initial assessment of risks to onsite receptors, as the model assumes that the source of contamination is infinite and evenly distributed beneath the building and that no attenuation or degradation occurs.

Acute human health risks to construction workers associated with volatile contaminants have been assessed by comparing measured soil vapour concentrations with EH40/2005 Workplace exposure limits (WEL) [8].WELs are British occupational exposure limits which have been set to help protect the health of workers. They are concentrations of hazardous substances in the air, averaged over 15 minutes (short term) or 8 hours (long term).

5.1.4 Controlled waters criteria

The leachate, groundwater and surface water concentrations have been compared with published water quality standards (WQS) for potential contaminants of concern. The controlled water receptors identified in the conceptual site model include both groundwater within a principal aquifer and a freshwater surface watercourse. Therefore, the lowest value of the following published environmental standards has been prioritised as the most appropriate WQS for the potential contaminants of concern:

- Environmental Quality Standard (EQS) listed in the Water Framework Directive (WFD) 2015 [9];
- other values not listed in WFD and taken from Environment Agency (EA) operational EQS [10]; and
- UK Drinking Water Standards (UK DWS) [11].

Where no UK published value exists then other published values have been selected in the following hierarchy:

- EU Drinking Water Standards (EU DWS) [12];
- World Health Organisation (WHO) drinking water standards [13][14]; and
- United States Environmental Protection Agency (USEPA) 2018 drinking water standards [15] and national aquatic life criteria [16].

Hardness, pH and dissolved organic carbon (DOC) within surface waters can affect the bioavailability of copper, lead, manganese, nickel, lead and zinc. Where concentrations of these metals have been recorded above the WQS, site-specific Predicted No Effect Concentrations (PNECs) have been derived using the WFD-UKTAG metal bioavailability tool (M-BAT) [17] and the Pb (lead) Screening Tool [18]. The Yeading Brook was sampled on two occasions, at one location upstream of the site and at one location downstream of the site. The average pH (7.95), average calcium concentration (122.5µg/l) and median DOC concentration (9.28µg/l) were used in the derivation of the site-specific PNECs.

5.1.5 Human health groundwater vapour criteria

Groundwater results have also been compared to the Society of Brownfield Risk Assessment (SoBRA) groundwater vapour GAC (GAC_{gwvap}) for a commercial land use, to assess vapour risks to human health from volatile contaminants in groundwater [19]. The GAC_{gwvap} have been developed for assessing the chronic risk to human health from inhalation of vapours derived from groundwater, assuming a depth to source of 0.65m bgl. Groundwater has been encountered during monitoring at between 1.33m and 3.53m bgl and so the GAC_{gwvap} are an initial conservative assessment for the site. The GAC_{gwvap} represent the estimated concentration in groundwater below which the long-term risks to human health from vapour migration and inhalation can be considered low.

5.1.6 Ground gas

The following guidance on the assessment of ground gas has been used in the assessment:

- BS 8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings [20]; and
- Wilson, Card and Haines (2009) Ground gas handbook [21].

The above references describe a process of deriving gas screening values (GSV) for hazardous ground gases. The process defines a range of characteristic situations (CS1 to CS6) based on borehole gas emission flow rate and the concentration of methane and carbon dioxide. The GSV is calculated by multiplying the borehole flow rate (litres per hour) by the gas concentration (% v/v).

5.2 Human health assessment

5.2.1 Soil data

The soil results have been compared with GAC for a commercial end use based on a SOM content of 1%, as outlined in Section 5.1.2. The screening table is included as Appendix C1 and the results are summarised below:

- Concentrations of metals were recorded below the GAC in all 99 samples analysed;
- PAHs were recorded below the method detection limit (MDL) in 54 of 99 samples. Concentrations of all individual PAHs were below the GAC;
- Petroleum hydrocarbons (total aliphatic and aliphatic >C_5 to C_{44}) were below the MDL in 61 of 99 samples. Concentrations of all speciated hydrocarbon bands were below their respective GAC;
- Total cyanide was recorded below the MDL in 96 of 99 samples. , Three low concentrations were recorded ranging from 1.0 mg/kg to 2.8mg/kg, which are well below the GAC (168mg/kg);
- Total phenols, MTBE and most BTEX compounds were recorded below the MDL in 98 samples. M & p-xylene was recorded at a very low concentration (1.7µg/kg) in one sample which is orders of magnitude below the GAC;
- Speciated phenols were recorded below the MDL in all 20 samples analysed;
- PCBs were recorded below the MDL in all 34 samples analysed; and
- The large number of speciated VOCs and most SVOCs were recorded below the MDL in all 11 samples analysed.

Asbestos was detected in 10 of 47 Made Ground samples (21%). A summary of the asbestos results is provided in Table 11 and illustrated on Drawing 6.

Table 11 Summary of asbestos results

Location	Depth (m bgl)	Asbestos type	Quantification (% w/w)
BH103A	0.30	Chrysotile fibres/ clumps	0.008
WS207B	0.30	Chrysotile loose fibres	<0.001
BH102	0.20	Chrysotile loose fibrous debris	<0.001
BH102	0.50	Amosite loose fibres	<0.001
TP305	0.20	Chrysotile and amosite loose fibres	<0.001
WS206	0.20	Chrysotile loose fibres	<0.001
BH107	0.30	Chrysotile, amosite and crocidolite loose fibres and chrysotile hard/ cement type material	0.06
BH108	0.30	Chrysotile loose fibres	<0.001
WS213	0.30	Chrysotile loose fibres	<0.001

Where detected, asbestos was generally recorded at very low or low quantities. Asbestos was recorded at a borderline moderate quantity (0.06%) in one location; however, this result is regarded as low.

The potential fragment of ACM encountered in WS206 was sampled and submitted for bulk asbestos analysis. The laboratory confirmed the sample to be asbestos in the form of chrysotile hard/ cement type material.

Generally, the soil results are low. A risk assessment is presented in Section 6.

5.2.2 Ground gas data

Ground gas monitoring was undertaken during six weekly visits in eight standpipes. A summary of the atmospheric pressures recorded during the monitoring visits is presented in Table 12.

Table 12 Atmospheric pressure recorded during ground gas monitoring

Monitoring visit	Dates	Barometric pressure (mb) (before)	Barometric pressure (mb) (after)	Trend
1	26/10/21	1016	1018	Rising
	27/10/21	1018	1015	Falling
2	02/11/21	996	1000	Rising
	03/11/21	1000	1008	Rising
3	10/11/21	1022	1023	Stable
	11/11/21	1022	1019	Falling
4	16/11/21	1025	1018	Falling
	17/11/21	1019	1027	Rising
5	24/11/21	1028	1015	Falling
	25/11/21	1015	1011	Falling
6	01/12/21	996	1006	Rising
Source: Weather Underground website [22], mb – millibar				

Gas emission rates from the ground are likely to be at their highest when there are sharp falls in barometric pressure. A fall in barometric pressure by less than 4mb over three hours is defined as a gradual fall and a fall between 4mb and 8mb is defined as a sharp fall. Four of the six monitoring visits were undertaken during gradually falling pressure conditions, but no sharp falls in pressure were recorded during any of the monitoring visits.

The initial CSM identified onsite Made Ground as a potential source of ground gas. The ground investigation indicates that the Made Ground does not contain organic degradable materials, is relatively thin (maximum of 3.5m thick and an average of 0.8m thick) and generally has a low TOC (average 1.7%).

The ground gas results from the seven standpipe installations in the Made Ground have been assessed as outlined in Section 5.1.6 and are described below:

- gas concentrations were typically low, with methane recorded below 1% in all monitoring rounds at all locations and carbon dioxide mostly recorded below 5%;
- oxygen concentrations ranged from 0.9% to 18.5%;
- most recorded concentrations of carbon monoxide and hydrogen sulphide were below the instrument detection limit; and
- steady gas flow rates were typically below the instrument limit of detection and maximum flow rates were generally low.

Gas screening values (GSVs) have been calculated for each location in accordance with BS8485 [20], using the recorded flow rates and gas concentrations. Where no measurable flow rate or gas concentrations were recorded, the instrument detection limit has been used in the calculation. The GSV at all locations with standpipe installations in the Made Ground equate to a characteristic situation (CS) of 1, indicating a very low risk from ground gas. An assessment table is presented in Appendix C2.

A steady gas flow rate of 2.3 l/hr and a steady carbon dioxide concentration of 3.4% v/v were recorded during the sixth round of monitoring in BH106. The GSV of 0.0782 l/hr is just above the threshold for CS1 (0.07) and equates to CS2. The standpipe was incorrectly installed at the top of the natural Lynch Hill Gravel which is not considered a potential source of ground gas. It is not uncommon to measure slightly elevated gas concentrations or gas flow rates in natural strata. In summary, the recorded gas concentrations and flow rates will not result in significant gas emission from the ground.

The ground gas laboratory test results from WS201, WS214 and BH106 support the insitu gas monitoring results and the CS1 assessment. The results of the six ground gas results are summarised below:

- carbon dioxide concentrations ranged from 0.37% to 4.9%;
- methane concentrations ranged from below the MDL (<0.0005%) to 0.00096%;

- carbon monoxide, hydrogen and hydrogen sulphide were recorded below the MDL; and
- oxygen concentrations ranged from 14% to 21%.

A risk assessment is presented in Section 6.

5.2.3 Soil and groundwater vapour data

Measured PID concentrations during the six rounds of monitoring were very low (5.0ppm or below). Vapour samples were collected from BH106, WS106 and WS107C during the third and fifth rounds of monitoring. The results have been assessed as outlined in Section 5.1.3. The screening table is included as Appendix C3 and a summary of the results is provided below:

- concentrations of chlorinated solvents, including vinyl chloride and trichloroethene were below the MDL in all six samples. Tetrachloroethane was recorded above the MDL in WS206 on one occasion, but at a low concentration (25µg/m^3) and below the chronic criterion (35µg/m^3);
- other VOC concentrations (including BTEX compounds) were recorded below the MDL or at very low concentrations in all six samples;
- the aliphatic TPH >C_8 to C_{10} fraction was recorded above the MDL (30µg/m^3) in four of six samples and marginally above the chronic criterion (500µg/m^3) in one sample (BH106) at a concentration of 520µg/m^3;
- the aromatic TPH >C_8 to C_{10} fraction was recorded above the MDL (30µg/m^3) and marginally above the chronic criterion (100µg/m^3) in one sample (WS206) at a concentration of 110µg/m^3; and
- concentrations of all measured determinands were below the 8 hour WEL.

The recorded concentrations are not significant and do not require vapour protection to be incorporated into new buildings.

As outlined in section 5.1.4, the groundwater results were compared to SoBRA GAC_{gwvap} for a commercial end use. Concentrations of all measured determinands were below the GAC_{gwvap}. A risk assessment is presented in Section 6.

5.3 Controlled waters assessment

5.3.1 Leachate data

The 30 Made Ground and 26 natural soil leachate samples have been compared with relevant WQS as outlined in Section 5.1.3. The screening table is included as Appendix C4 and a summary of the leachate results above the WQS is provided in Table 13 and Table 14.

Table 13 Summary of leachate results above WQS (Made Ground)

Determinand	Max. conc. (µg/l)	WQS (µg/l)	No. above WQS	Location of max(s) [depth (m bgl)]
Antimony	44	5[a]	9	BH103 [0.3]
Arsenic	30.4	10[a]	5	WS204 [0.6]
Cadmium	0.43	0.25[b]	1	WS211 [0.3]
Chromium	93	4.7[b]	13	TP309A [0.3]
Copper	53	1[b]	30	BH110 [0.3]
Lead	23	1.2[b]	17	WS204 [0.6]
Nickel	28	4[b]	9	WS204 [0.6]
Zinc	52	12.3[b]	3	WS204 [0.6]
Fluoride	2,100	1,000[c]	1	WS204 [0.6]
Sulphate	970,000	250,000[a]	3	BH105 [0.6]
Phenol	15	7.7[b]	2	WS213 [1.55] BH110 [0.3]

Notes:
[a]UK Drinking Water Standard (DWS)
[b] Environmental Quality Standard (EQS) listed in the Water Framework Directive (WFD)
[c]Environment Agency (EA) operational environmental quality standard (EQS)

Table 14 Summary of leachate results above WQS (natural strata)

Determinand	Max. conc. (µg/l)	WQS (µg/l)	No. above WQS	Location of max(s) [depth (m bgl)] [stratum]
Arsenic	11.5	10[a]	1	TP305 [1.1] [LHG]
Chromium	110	4.7[b]	2	BH106 [0.5] [LHG]
Copper	11	1[b]	20	TP305 [1.1] [LHG]
Lead	8.4	1.2[b]	9	WS206 [1.5] [LS]
Mercury	1.5	1.0[a]	1	TP303 [2.0] [LS]
Nickel	7.2	4[b]	5	BH105 [1.2] [LS]
Selenium	23	10[a]	1	BH104C [6.0] [LC]
Zinc	31	12.3[b]	2	TP305 [1.1] [LHG]

Notes:
[a] UK Drinking Water Standard (DWS)
[b] Environmental Quality Standard (EQS) listed in the Water Framework Directive (WFD)
LS – Langley Silt, LHG – Lynch Hill Gravel, LC – London Clay

Site-specific PNECs have been derived using the M-BAT [17] or Pb Screening Tool [18] for copper, lead, nickel and zinc. Concentrations of these determinands in natural soil leachate samples were recorded below the respective PNECs. Three Made Ground leachate samples recorded copper above the PNEC and one (WS204 at 0.6m) recorded concentrations of lead, nickel and zinc above the PNEC.

The results indicate the potential for several inorganic contaminants to leach from the Made Ground and natural soils at concentrations marginally above relevant WQS. A risk assessment is presented in Section 6.

5.3.2 Groundwater data

The 18 groundwater samples have been compared with relevant WQS as outlined in Section 5.1.4. The screening table is included as Appendix C5 and the results are described below:

- concentrations of total cyanide, phenols, petroleum hydrocarbons, PCBs, SVOCs, VOCs and BTEX compounds were recorded below the MDL in all 18 groundwater samples analysed;
- concentrations of metals were generally low, with concentrations of hexavalent chromium and mercury recorded below the MDL; and
- the pH was generally neutral ranging from 6.9 to 9.6. An alkaline pH (11.6 and 11.7 pH units) was recorded in both groundwater samples from BH101.

A summary of the groundwater results above WQS is provided in Table 15.

Table 15 Summary of groundwater results above WQS

Determinand	**Max. conc. (µg/l)**	**Mean conc. (µg/l)**	**WQS (µg/l)**	**No. above WQS**	**Location of max [monitoring round]**
Sulphate (as SO_4)	339,000	90,000	250,000[a]	1	BH102B [2]
Ammoniacal nitrogen (as N)	4,500	869	1,100[b]	5	BH102B [2]
Ammoniacal nitrogen (as NH_4)	5,786	996	500[a]	8	BH102B [2]
Nitrite (as NO_2)	9,000[c]	565	500[a]	2	BH101 [2]
Copper	8.90	3.81	1[b]	18	WS205A [2]
Manganese	410	113	50[a]	10	BH103A [1]
Nickel	9.60	4.95	4[b]	10	BH103A [2]
Selenium	18	3.28	10[a]	1	BH104C [1]
Zinc	29	7.06	12.3[b]	3	WS205A [1]

Notes:
[a] UK Drinking Water Standard (DWS)
[b] Environmental Quality Standard (EQS) listed in the Water Framework Directive (WFD)
[c] The laboratory reported that the nitrite results from BH101 were reported from a high dilution and should be interpreted with care

As outlined in Section 5.1.4, where concentrations of copper, manganese, nickel and zinc have been recorded above the WQS, site-specific PNECs have been derived using the M-BAT tool [17]. All measured concentrations of copper, nickel and zinc were below their respective PNECs of 30µg/l, 16.6µg/l and 43.8µg/l. The two samples from BH103A and the two samples from WS205A recorded concentrations of manganese above the PNEC of 242µg/l. However, they are within the same order of magnitude as the PNEC, ranging from 260µg/l to 410µg/l.

Typically, where concentrations of determinands in groundwater have been recorded above the WQS, they are only marginally above or within the same order of magnitude as the WQS. Nitrite was recorded an order of magnitude above the WQS in the two samples from BH101. However, the laboratory report noted that the results were reported from a high dilution and should be interpreted with care. Ammoniacal nitrogen (as NH_4) was recorded an order of magnitude above the WQS in five samples (two from BH102B, two from WS213 and one from BH106). The results above are not unusual for the environmental setting and a risk assessment is presented in Section 6.

5.3.3 Surface water data

Concentrations of determinands in samples from the Yeading Brook were similar to concentrations recorded in groundwater. Ammoniacal nitrogen was recorded at a concentration of 1,400µg/l which is above the EQS (1,100µg/l) in one downstream sample, but concentrations of all other measured determinands were below EQS. Typically, concentrations of determinands were similar in the downstream sample compared to the upstream sample, indicating that any contamination at the site does not appear to be impacting the Yeading Brook.

6 Risk assessment

6.1 Risk classification definitions

The potential risks to the identified receptors have been considered in the context of the conceptual model of the site and details of the proposed development in accordance with the current UK approach to contaminated land assessment.

The method for risk evaluation has been based on a qualitative assessment taking into consideration the magnitude of the potential severity of the risk as well as the probability of the risk occurring. The risk characterisations provided below have been assessed on a scale from very high to very low and negligible based on the CIRIA guidance C552 [23]. A summary of each risk classification is provided in Table 16.

Table 16 Risk classification

Risk classification	Description of risk
Very high	There is a high probability that severe harm could arise to a designated receptor from an identified hazard, or there is evidence that severe harm to a designated receptor is currently happening. The risk, if realised, is likely to result in substantial liability. Remediation is likely to be required.
High	Harm is likely to arise to a designated receptor from an identified hazard. Realisation of the risk is likely to present a substantial liability. Remedial works may be necessary.
Moderate	It is possible that harm could arise to a receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Some remedial works may be required.
Low	It is possible that harm could arise to a receptor from an identified hazard but it is likely that this harm, if realised, would typically be mild.
Very low	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised the consequence would at worst be mild.
Negligible	There is no relevant pollutant linkage due to the absence of a pathway or receptor (without any intervention).

6.2 Human health risk assessment

6.2.1 During construction (PCL1)

The initial CSM identified the following PCL affecting human health during construction:

- Exposure of groundworkers and site visitors to contaminated soil, vapours, gases, contaminated dust, fibres and contaminated groundwater during construction via dermal contact, ingestion or inhalation.
- Exposure of site neighbours to contaminated dust or fibres during construction via inhalation.

Concentrations of most contaminants in soil were low or below the MDL. Asbestos was detected in 10 of 47 Made Ground samples (21%), typically in very low and low quantities (<0.001% to 0.06% w/w). Potential fragments of ACM were encountered in two locations (WS202 and WS206) and subsequent laboratory analysis of one fragment confirmed it contained asbestos. Analysis on the other fragment was instructed, but the sample was not received by the laboratory. There is the potential for further asbestos or ACM to be present within Made Ground and recommendations are included in Section 8.

Hydrocarbon odours were recorded in three locations during the ground investigation. However, PID readings of soil samples taken during the ground investigation and monitoring were mostly below 5ppm or below the instrument detection limit (<0.1ppm) and concentrations of VOCs in soil samples were below the laboratory MDL. Concentrations of volatile contaminants recorded during vapour sampling in BH106, WS206 and WS207 were low and orders of magnitude below EH40/2005 8 hour WELs. Slightly elevated PID readings (between 18ppm and 132ppm) were recorded in the superficial deposits in WS210, close to where staining was observed on the hardstanding within Tudor Works. No standpipe for vapour sampling was installed in this location and recommendations for additional ground investigation and monitoring in the Phase 2 area are provided in Section 8.

Risks to construction workers from contaminants in soil and groundwater can be mitigated through good construction measures and controls, such as preventing the creation of dusts, control of odour emissions and monitoring for volatile contaminants during excavation works in the Made Ground and (if necessary) wearing personal protective equipment (PPE) and respiratory protective equipment (RPE). A watching brief and discovery strategy for asbestos and hydrocarbons should be implemented. The Control of Asbestos Regulations 2012 make the duty to manage asbestos a legal requirement. For asbestos in soils these regulations are implemented by CAR-SOIL. The risk from asbestos in soils can be managed through implementation of specific controls which are outlined in Section 8.

The risk to human health during construction works is generally **low** without mitigation, although this could increase if significant asbestos is uncovered. This can be managed and reduced to **very low** once the recommendations provided in Section 8 are implemented.

6.2.2 During operation (PCL2)

The CSM identified the following PCL affecting human health during operation of the development:

- Exposure of future site users (commercial site users and visitors) to contaminated soil, fibres, dust, vapours and gases via dermal contact, ingestion or inhalation.
- Exposure of future maintenance workers to contaminated soil, fibres, dust, vapours and gases via dermal contact, ingestion or inhalation and to

contaminated groundwater (migrating from offsite) via dermal contact or ingestion.

A generic risk assessment has been undertaken and no contaminant concentrations in soil were recorded above the commercial GAC. No concentrations of volatile contaminants in groundwater were recorded above commercial SoBRA GAC_{gwvap}. Asbestos was detected in 10 of 47 Made Ground samples (21%) in very low quantities (<0.001% to 0.008% w/w) or relatively low quantities (0.06% w/w). Most of the proposed development will comprise buildings or hardstanding, which will prevent exposure of future site users to potentially contaminated. A previous onsite investigation by Ramboll recorded asbestos fibres in one of five locations and cement type ACM in one location. Recommendations regarding appropriate control measures for asbestos in soils are included in Section 8.

Within samples of soil vapour, concentrations of aliphatic TPH $>C_8$ to C_{10} in BH106 and aromatic TPH $>C_8$ to C_{10} in WS206 were marginally above the relevant criterion. BH106 is in the southwest of the Tudor Works, adjacent to the building formerly used by a vehicle servicing and engine reconditioning company. WS206 is in the southeast adjacent to the 70,000 litre UST, close to the location where Ramboll previously recorded a strong diesel odour.

The criteria used are highly conservative and if they included attenuation and degradation processes along the migration pathway would be significantly higher. These marginal exceedances therefore do not represent a potential chronic risk to human health but are indicative of localised hydrocarbon impact to soils in these areas. The UST will be decommissioned, and any visually impacted or odorous soils encountered across the site will be removed during the enabling works (as outlined in Section 8). The risk to future site users during operation from inhalation of vapours is therefore considered to be very low to negligible. The UST decommissioning and groundworks will be verified.

No significant onsite ground gas source has been identified and the buildings will be constructed with 250mm thick reinforced concrete suspended ground floor slabs, which would provide a structural barrier to any ground gas ingress, and mechanical ventilation will be provided in all occupied areas of the buildings and in the data halls for cooling. Concentrations of hazardous ground gases monitored in standpipes were typically low or very low and indicative of CS1 which represents very low risk and does not require gas protection measures.

The development includes limited areas of soft landscaping, consisting of shrub and wildflower planting, raised planters and tree pits. Imported topsoil and subsoil will be used in areas of soft landscaping. The imported materials will need to be appropriately certified and chemically suitable for use as discussed in Section 8. It is proposed that a minimum of 300mm of topsoil and 300mm subsoil will be placed in areas of planting and tree pits will be filled with between 750mm and 900mm topsoil. Where Made Ground remains onsite, a marker sheet shall be placed below the imported soils to demarcate the boundary between clean imported material and underlying Made Ground. This clean cover layer and marker sheet will prevent exposure of future site users to potentially contaminated Made Ground soils which may remain onsite.

Risks to future maintenance workers can be mitigated by ensuring that service trenches are backfilled with clean imported material and lined with a marker sheet where residual Made Ground remains. Future maintenance workers may be exposed to residual Made Ground where belowground works penetrate the marker sheet. Risks can be further mitigated using PPE and adhering to health and safety protocols, such as maintaining good hygiene.

Based on the results of the ground investigation and the sensitivity of the proposed development, the risk of harm to future site users, visitors and below-ground maintenance workers during operation is **low**. The risk will be reduced to **very low** once the recommendations provided in Section 8 are implemented.

6.3 Controlled waters risk assessment (PCL3)

The CSM identified the following PCL affecting controlled waters receptors during construction and operation of the development:

- Creation of a preferential pathway through the Langley Silt from the Made Ground and vertical contaminant migration to the Lynch Hill Gravel principal aquifer during piling works.
- Surface runoff and contaminant migration via the existing drainage network affecting the Yeading Brook during construction.
- Increased rainwater infiltration in soft landscaped areas and vertical and lateral contaminant migration affecting the Lynch Hill Gravel principal aquifer and the Yeading Brook during operation.

6.3.1 Risk during construction

The cohesive Langley Silt was encountered in most locations overlying the granular Lynch Hill Gravel and may form an aquitard between the Made Ground and the superficial principal aquifer. The proposed buildings will be founded on 900mm diameter, cast insitu reinforced concrete rotary bored or CFA piles terminating in the London Clay. These piling methods minimise the potential to create preferential pathways and cause contamination of the underlying aquifer.

No perched water has been encountered within the Made Ground and contaminant concentrations in soils were low. Concentrations of several inorganic compounds recorded in groundwater samples from the Lynch Hill Gravel aquifer were generally only marginally above or within an order of magnitude of the WQS and are typical of groundwater quality within this type of setting.

The UST will be decommissioned, and any visually impacted or odorous soils encountered across the site will be removed during the enabling works (as outlined in Section 8) prior to piling.

Based on the identified ground conditions, the environmental sensitivity, the groundwater quality and the proposed construction methods, the risk of pollution to the Lynch Hill Gravel during construction is **low**. This is reduced to **very low** after implementation of mitigation measures.

Due to the proximity of the Yeading Brook (adjacent to the east), the risk of surface water runoff affecting the Brook during construction is **moderate**. Pollution prevention and control measures during construction will reduce the risk to **very low**.

6.3.2 Risk during operation

The soil leachability analysis typically indicated low leachable concentrations of inorganic compounds in the Made Ground and natural soils. Most concentrations were below or within the same order of magnitude as the WQS. This is typical of a brownfield environment and is not assessed to pose a risk to controlled waters.

A PCL was identified between contamination within the Made Ground and groundwater in the Lynch Hill Gravel aquifer via leaching due to infiltration of rainwater. The site will mostly be covered by buildings or hardstanding, reducing infiltration and the potential for leaching and vertical migration of contaminants. Small areas of soft landscaping are proposed where infiltration will occur. These areas will be formed by excavating Made Ground and placement of chemically validated imported topsoil and subsoil (as described in Section 8). The risk to groundwater is therefore assessed to be **very low.**

The thickness of the Lynch Hill Gravel reduces towards the east of the site and it is absent in the southeast. The laterally discontinuous nature of these granular superficial deposits will prevent the lateral migration of contaminants in groundwater to the Yeading Brook. Existing drainage systems will be removed by the demolition contractor. Existing land drains which are intercepted during the provision of new land drainage will be cleaned out, connected to the new drainage system and the disused end of the old drain sealed with impermeable puddle clay, in accordance with the requirements of the belowground drainage specification [24]. The risk to the Yeading Brook during operation is therefore **very low** and no mitigation measures are required.

6.4 Building materials and services (PCL4)

The CSM identified the following PCL affecting building materials and services during operation:

- Direct contact of concrete and services with contaminated soils or groundwater.

No significant contamination (such as free phase product) was encountered during the ground investigation or subsequent monitoring. Concrete and water supply pipe materials will be designed and specified to resist chemical attack in accordance with relevant guidance, such as BRE Special Digest 1 (2005, amended 2017) Concrete in aggressive ground [25] and UKWIR (2010) Guidance for the selection of water supply pipes to be used in brownfield sites [26]. The general requirements for concrete are set out in the Civils Works – Specification Appendices [27]. On this basis, the risk to building materials and services is **very low**.

6.5 Planting in landscaped areas

An additional PCL has been considered as a result of the scheme design shown in Figure 5 and described in Section 2.2 which includes limited soft landscaped areas with planting at ground level. This comprises small areas of low groundcover planting, raised planters and tree pits, hedgerows and thicket planting.

The landscape strategy requires 600mm of clean cover (imported topsoil and subsoil) for low ground cover planting, 900mm for hedgerows and between 750mm and 900mm for tree pits. These imported landscaped soils will be verified.

The risk of harm to new planting is therefore considered to be **very low**.

6.6 Revised conceptual site model

The initial CSM, described in the Arup desk study and summarised in Section 3.5, has been updated based on the findings of the ground investigation and risk assessment. The revised conceptual site model is presented in Table 17.

Table 17 Revised conceptual site model

PCL	PCL active?	Risk	Mitigation measures (refer to Section 8)	Residual risk
Human health during construction				
Ingestion, inhalation or dermal contact with soil or dust by workers. Inhalation of ground gas, vapours or fibres by workers.	**Yes** Low levels of contamination and asbestos in Made Ground. Potential for higher quantities of asbestos, ACM and localised hydrocarbons to be encountered during groundworks.	Low to moderate	Good construction practices, use of PPE and RPE. Preparation of CAR-SOIL assessment, plan of work and asbestos management plan. Watching brief and discovery strategy for asbestos and hydrocarbons. Dust prevention, dust and odour suppression during groundworks and boundary air monitoring if required.	Very low
Inhalation of ground gas, vapours or fibres by neighbours.		Very low		Negligible
Human health during operation				
Accumulation of gases and vapours in confined spaces and inhalation by site users. Ingestion, inhalation or dermal contact with soil, dust or fibres by site users.	**Yes, but limited** Very low gas risk. Buildings will include a reinforced suspended slab and mechanical ventilation. Hard surfacing will cover most of the site.	Very low	The tanks, associated pipework and any unexpected contaminated soils will be removed during groundworks if significant. Areas of soft landscaping will include a clean capping layer and marker sheet. Imported materials will be tested.	Negligible