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LEA BRIDGE GASWORKS ENVIRONMENTAL SITE ASSESSMENT

RAMBOLL

LEA BRIDGE GASWORKS
ENVIRONMENTAL SITE ASSESSMENT

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Made by	**Jennifer Gill, Alice Kilner**
Checked by	**Simon Stoker**
Approved by	**Matthew Pannett**

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Ramboll
240 Blackfriars Road
London
SE1 8NW
United Kingdom
T +44 20 7808 1420
www.ramboll.co.uk

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EXECUTIVE SUMMARY

Ramboll UK Limited ("Ramboll") was instructed by St William Homes LLP (the "client"), to undertake an environmental site assessment (ESA) at the former Gasworks site in Lea Bridge (the "site"). The report is required in connection with the proposed redevelopment of the former gasworks site for a residential end use.

The site has been in use as a gas works since at least 1899, when Gas Holder 5 located in the centre of the site was constructed, which appeared to be in connection with the off-site Lea Bridge Gas Works which had been present since at least 1870). Prior to 1899, the site was occupied by a fireworks manufactory which appeared to be focused to the north of the site. By 1936, Lea Bridge Gas Works (of which the site formed approximately a third of the total area) had expanded and a second gas holder was present in the east of site. Subsequent development of site included dry gas & benzole plant and coal gas purifiers, coal storage and a third gas holder which was constructed in 1962. The three gas holders were decommissioned in early 2019.

Historically in the near surrounds, Lea Bridge Gas Works was located approximately 100m north-west of site and comprised a number of gas holders, tanks and associated buildings incl. oil tanks, tar tanks, liquor tanks and retort houses. By the 1930s, expansion of the gas works incorporated the subject site and residential land use was present adjacent to the north of site at this time. By the mid-1980s, the off-site portion of Lea Bridge Gas Works had been redeveloped as Fairways Business Park.

The site is located within a setting of medium environmental sensitivity given the presence of underlying Secondary Aquifers and Principal Aquifer (at depth), its location within a groundwater Source Protection Zone 2, and nearby water features including a culverted stream in the south-west corner of the site. It is considered likely that the culvert is associated with the River Lea flood relief channel and that it connects the flood relief channel to the Dagenham Brook, located approximately 250m north-east of the site at it closest point. The flood relief channel for the River Lea is present approximately 220m south-west of site. The site lies within a Flood Zone 2 and is adjacent to a Zone 3 along the western boundary.

Several phases of investigation and remediation have been undertaken in the past, including two separate third-party investigation, dated 2019. This has aided Ramboll's assessment and also confirmed that gross contamination has previously been removed from the site.

Ramboll's Phase II investigation comprised the excavation of 18 trial pits, one hand dug pit, drilling of five cable percussive boreholes and 16 rotary boreholes for soil, groundwater and ground gas assessment. The scope of the investigation has allowed a comprehensive coverage of the site in terms of sampling points and as such provides a good understanding of the site and potential contamination.

Ground conditions comprised Made Ground of anthropogenic material ranging from 0.7m to 3.5m bgl. Alluvium and/or River Terrace Deposits were found underlying the Made Ground to depths of 9.5m. A distinct separation between the Alluvium and River Terrace Deposits was not noted and are considered to be a single shallow aquifer. The superficial geology was underlain by the Lambeth Group (average 11m thickness, comprising lower permeability clay, sand and silt) and Thanet Sands Formation (depth not proven). The Lambeth Group will restrict vertical downwards migration of contaminants.

Groundwater was encountered in all of the 17 installed monitoring wells at depths between 1.70m (3.64m AOD) at CP303 and 3.61m (3.44m AOD) at RH311. The inferred groundwater flow direction is in an approximate south-west direction.

Generally, Made Ground across the site was not observed to be significantly visually or olfactorily contaminated with typical gas works contaminants such as hydrocarbons, tars or blue billy. Photo ionisation detector (PID) readings of soil samples ranged between 2.7 – 55.9ppm (PID is an on-site instrument that screens soil samples for the presence of volatile organic compounds (VOCs).

Evidence of contamination within the natural deposits was observed within the area of previous remediation in the north of site and along the western boundary of the site. PID readings from impacted natural deposits ranged from 55.1 – 293.6ppm. At CP303 and RH312, more visually significant contamination was observed within the sands and gravels, with an obvious oily substance noted and a very strong hydrocarbon odour. PID readings at CP303 recorded 1,779ppm and at RH312 recorded 204.6ppm.

During Ramboll's groundwater sampling, varying degrees of visual and olfactory evidence of contamination was noted at most locations with the exception of RHA - RHD, RH303, RH306, RH313 and RH315. A notable sheen was observed on the groundwater at CP303 and a slight sheen at RH312 and RH305. Significantly, no light or dense non-aqueous phase liquids were detected (LNAPL or DNAPL) which are often a common source of pollution at gas works.

Soil samples were collected and scheduled for a suite of analysis comprising inorganics, total petroleum hydrocarbons (TPH), polychlorinated biphenyls (PCBs) polycyclic aromatic hydrocarbons (PAHs), speciated phenols, free, total and complex cyanide, thiocyanate, ammonia, metals volatile and semi-volatile organic compounds (VOCs and SVOCs) and asbestos. Groundwater samples were submitted for a similar suite as the soil samples (but excluding asbestos).

The investigation has identified elevated concentrations of contaminants that are considered typical for a gas works site. The investigation data shows that there are distinct localised contamination hotspots of TPH, cyanide and PAHs, with wider spread 'background' levels of contaminants typical of a brownfield site. The soil chemical analyses are consistent with field observations and also the groundwater results (see below). It is likely that some form of remediation will be required to mitigate risks from the soil hotspots; the exact extent and nature of remediation will be confirmed by Detailed Quantitative Risk Assessment and a remediation strategy (as explained later in this report).

Typical gas works contaminants were also identified in groundwater, comprising site wide modest concentrations of ammonia, sulphate and cyanide and relatively isolated areas of more substantial hydrocarbon impact. A Detailed Quantitative Risk Assessment will be required to determine if the concentrations recorded in groundwater require remediation in order to reduce risks. Groundwater monitoring has enabled contaminants to be 'mapped' and shows hydrocarbons to be relatively static and not migrating. The many sampling points close to the culvert do not indicate significant contamination is discharging into this surface water feature. Based on the site investigation data, Ramboll's initial view is that likely groundwater remediation would comprise removal of the soil hotspots which may be considered a source of groundwater contamination, as well as the localised application of in-situ treatment of groundwater.

From the information obtained to date, ground gas has been assessed to represent a low risk (Characteristic Situation 2 – CS2) at site and on the basis of the data appropriate gas protection measures in-line with BS8485:2015 would be required as part of a future residential development.

Conclusion

In Ramboll's experience, the contamination identified at Lea Bridge Gas Works is relatively modest in comparison with many other gas works. Hotspots of contamination have been identified that were visually obvious and confirmed by chemical testing of the soil and groundwater. Industry standard remediation techniques are likely to be appropriate to mitigate risks from the identified contamination.

Sensitive environmental receptors that will drive remediation include groundwater within the shallow aquifer, the on-site culvert or nearby surface water receptors and new residential site users. Groundwater and surface water are low-moderately sensitive in this location and detailed quantitative risk assessment is required to fully understand remediation requirements.

'Standard' development-led mitigation measures for protection of human health are likely to comprise building / hardstanding cover 'barriers' to the soil, capping in landscaped areas and gas / vapour membrane (if required).

Recommendations

Following the assessment as part of the ESA, the following is recommended:

- Human Health Vapour Risk Assessment: required in order to determine if the contaminants in soils pose a risk to future site users and therein determine if mitigation and /or remediation is required.
- Controlled Waters Detailed Quantitative Risk Assessment: required in order to firstly determine if the concentrations recorded in soils required remediation for the protection of controlled waters and secondly to inform on the remediation requirements (i.e. extent) of the identified impact and recorded elevated concentrations in groundwater for the protection of controlled waters on and off-site.
- Remediation Strategy: the findings of the DQRAs will be utilised to inform the mitigation and/or remediation that is required on site to reduce the identified risks. The document shall set out the overall objectives and outline methodologies to be used to undertake the mitigation/ remediation. The Remediation Strategy will outline criteria that the remediation should meet in order to demonstrate that risks have been suitably reduced. The Remediation Strategy will also describe the verification and validation requirements for mitigation and remediation works.
- Remediation Implementation Plan: this is a design document to be undertaken by or in conjunction with a remediation contractor and will confirm the detailed design of how the remediation objectives outlined in the Remediation Strategy will be achieved and validation undertaken.
- Materials Management Plan: If re-use of site won soils is proposed as part of the development (i.e. a cut and fill exercise, the appropriate materials management plans should be produced and agreed with relevant qualified persons and regulators.
- Ground Gas Mitigation: Appropriate gas protection measures commensurate with Characteristic Situation 2 and in-line with BS 8485 will be required as part of a future residential development. The chosen gas protection measures will require subsequent validation in-line with CIRIA C735: 2014.
- A programme of groundwater monitoring is recommended in order to complement the information obtained by this investigation and recent third-party investigations, and in order to build a baseline data set for the site (prior to development works).
- Hotspot Protocol: During redevelopment a 'Hotspot Protocol' will need to be implemented to allow groundworkers to act appropriately upon encountering or suspecting the presence of previously unidentified ground contamination.
- Foundation Works Risk Assessment (FWRA): Contaminants in soils could potentially pose a risk to controlled waters and therefore, an appropriate risk assessment of the preferred foundation solution (assuming piled foundations) will be required.
- Development Considerations: A proposed redevelopment will need to consider typical precautions for redeveloping a brownfield site, including inter alia appropriate health and safety management for construction workers, waste soil classification, and method statements for unexpected contamination. These are considered normal and standard for a brownfield site redevelopment.
- Health & Safety: Appropriate H&S management precautions will need to be followed prior to and during the construction phase. The data generated by the investigation should therefore be considered in the appropriate pre-works health and safety assessment, together with the appropriate shorter exposure times for construction workers and more direct contact with the ground. It is anticipated that these short-term risks can be appropriately addressed through the use of appropriate, health and safety plans, safe working procedures and the use of personal protective equipment (PPE), in line with relevant legislation and guidance. Groundworks undertaken by the contractor should be given to CAR 2012 (or CAR-SOIL guidance) when undertaking works at the site.

1. INTRODUCTION

1.1 Background

Ramboll UK Limited ("Ramboll") was instructed by St William Homes LLP (the "client"), to undertake an environmental assessment at the Former Gasworks Site in Lea Bridge (the "site"). The report is required in connection with the proposed redevelopment of the former gasworks site for a residential end use.

This report presents the objectives, scope, findings and conclusions of an intrusive environmental investigation undertaken at the site.

1.2 Objectives

The objectives of the environmental site assessment (ESA) were to:

- document and interpret the environmental ground conditions encountered;
- assess the potential for risks to both human health and environmental receptors (including controlled waters) based on the data collected;
- carry out a contaminated land risk assessment based on a contaminant-pathway-receptor methodology;
- present a refined Conceptual Site Model (CSM) based on the findings of the ground investigation;
- provide a commentary on contaminated land risks under the proposed end use; and
- assess the requirement for further investigation, assessment and/or remedial measures.

This investigation has been designed and undertaken for the proposed redevelopment of the site for a residential use, which comprises a range of apartments as discussed next.

1.3 Proposed Development

The detailed design is still being finalised, but it is anticipated that the proposed development will comprise the following:

- 550 new residential units (C3 Use), in six buildings ranging from approximately 3 to 18 storeys;
- 550m2 community space (A3/D1/D2 Uses);
- 5,350m2 community amenity and playspace provision;
- 96 car parking spaces and approximately 1,000 cycle parking spaces;
- a priority junction extending from Orient Way providing a new primary access to and from the site;
- new pedestrian and cycle routes; and
- landscaping, drainage and new biodiverse features, including a new linear park.

1.4 Project Context

The site has previously been characterised and remediated during several phases of groundworks and documented in the following reports:

- Ernest Green Partnership Ltd, Report Ref. 5695/A/NT13- Contamination Desk Top Study for Lea Bridge Road, Leyton, dated September 1993;
- Ernest Green Environmental Ltd, Report Ref. 7502/NE/Nov 97/EA-INT/V2- Ground Contamination Environmental Assessment for Lea Bridge Road, Leyton, dated November 1997;

- White Young Green Environmental, Report Ref. 750/DW/Feb 1999/VR(B&C)/FAC/FINAL- Factual Validation Report of the Soil Remediation Works Areas B and C completed at Lea Bridge Road, Leyton, dated February 1999;
- White Young Green Environmental, Report Ref. 7502/NE/February 1999/CR(B&C)/V1- Validation Report of the Soil Remediation Works completed at Lea Bridge Road, Leyton Areas B and C, dated February 1999;
- WYG Environment, Report Ref. G007502-7- Site Investigation Factual Report at Lea Bridge Road Gas Holders and PRS Site, dated February 2013;
- WYG Environment, Report Ref. G007502-7- Site investigation Factual Report at NGP Land to the South of Lea Bridge Road Gas Holder Site, dated February 2013;
- WYG, Report Ref. G007502-11- Factual Preliminary Dismantling Assessment, dated March 2018;
- RSK Environment Ltd, Letter Ref. 301093 L01 TC- Lea bridge Gasworks, Leyton-Technical Review of Existing Reports, dated September 2018;
- Patrick Parsons Limited, Report Ref: L18145G, Phase I and Preliminary Phase II Site Investigation Report, Former Lea Bridge Gasworks, dated March 2019; and
- WYG, Factual Supplementary Site Investigation Report Lea Bridge Road, Leyton (G007502-23), dated December 2019.

Further detail on these reports and associated actions at the site are given in Section 3 of this report.

1.5 Scope of Works

The scope of work undertaken during this investigation was as follows:

- Exploratory locations were marked out and cleared by a specialist underground service clearance contractor before the start of intrusive works.
- One hand-dug pit in the north of the site, in the vicinity of a substation. Due to the level of services within this area, only a hand-dug pit could be excavated.
- 18 trial pits to a depth of approximately 3-4m below ground level (bgl) across the site to provide coverage of the shallow soil conditions.
- Eight 'window sample' boreholes to depths of up to 4m bgl also to allow for collection of shallow soil samples and installation of monitoring wells for ground gas (WS01 – WS08).
- A total of five cable percussion boreholes to depths of between 20 and 30m bgl to assess deeper geology and hydrogeology. One borehole was installed with a groundwater monitoring well for environmental monitoring and sampling (CP303).
- 14 rotary boreholes to between 6m and 7m bgl for collection of soil and groundwater samples from the shallow aquifer. Monitoring wells were installed in RH302 – RH306, RH308, RH310, RH312, RH313, RH315 and RHA-D.
- Two rotary boreholes to 11m bgl to assess ground conditions adjacent to the base of Gas Holder 5. Both boreholes were installed with monitoring wells for groundwater sampling (RH309 and RH311).
- Supervision of drilling works by a Ramboll field engineer, who logged the soil arisings, collected samples for in-situ testing of volatile organic compounds and laboratory analysis.
- Attendance on site of an unexploded ordnance (UXO) engineer from Fellows International to monitor for the presence of potential UXOs during site investigation works.
- Collection of 60 soil samples for environmental analysis at an accredited (UKAS and MCerts) laboratory. The suite of analysis included inorganics, total petroleum hydrocarbons (TPH),

polychlorinated biphenyls (PCBs) polycyclic aromatic hydrocarbons (PAHs), speciated phenols, free, total and complex cyanide, thiocyanate, ammonia, metals volatile and semi-volatile organic compounds (VOCs and SVOCs) and an asbestos screen (and quantification were detected).

- Monitoring of resting groundwater levels, where present within the monitoring wells, followed by collection of 17 groundwater samples, which were submitted for environmental laboratory analysis for a similar suite as the soil samples (but excluding asbestos).
- Monitoring of ground gases on six occasions.
- The production of an interpretative report, to include comparison of the analytical results with Generic Assessment Criteria (GAC) derived in accordance with UK guidance on risk assessment, a qualitative contaminant-pathway-receptor risk assessment (based on residential use of the site) and production of a conceptual site model.

In preparation of this report Ramboll has made reference to relevant UK regulatory guidance. British Standards and 'good practice' industry guidance and methodologies, including, but not limited to:

- CLR11 Model Procedures for the Management of Land Contamination (Environment Agency, 2004);
- BS 10175:2011+A2:2017 Code of Practice for the Investigation of Potentially Contaminated Sites; and
- EA Guiding Principles for Land Contamination (GPLC).

1.6 Limitations and Reliance

This report has been prepared by Ramboll UK Limited ("Ramboll") exclusively for the intended use by St William LLP (the "client") in accordance with the agreement (proposal reference number LQ1620006510/L001, dated 30th April 2019) between Ramboll and the client defining, among others, the purpose, the scope and the terms and conditions for the services. No other warranty, expressed or implied, is made as to the professional advice included in this report or in respect of any matters outside the agreed scope of the services or the purpose for which the report and the associated agreed scope were intended, or any other services provided by Ramboll.

In preparation of the report and performance of any other services, Ramboll has relied upon publicly available information, information provided by the client and information provided by third parties. Accordingly, the conclusions in this report are valid only to the extent that the information provided to Ramboll was accurate, complete and available to Ramboll within the reporting schedule.

Ramboll's services are not intended as legal advice, nor an exhaustive review of site conditions and / or compliance. This report and accompanying documents are initial and intended solely for the use and benefit of the client for this purpose only and may not be used by or disclosed to, in whole or in part, any other person without the express written consent of Ramboll. Ramboll neither owes nor accepts any duty to any third party, unless formally agreed by Ramboll through that party entering into, at Ramboll's sole discretion, a written reliance agreement.

Unless otherwise stated in this report, the scope of services, assessment and conclusions made assume that the site will be developed for residential use as per the proposed development figure provided within Appendix 1, without significant changes either on-site or off-site.

The site investigation works were undertaken during a discrete period of time. The findings and conclusions presented in this report are accordingly factually limited by these circumstances and, unless stated otherwise in the report, are preliminary. The field investigations were restricted to

a level of detail necessary to meet the stated objectives of the services. The results of any measurements taken may vary spatially or with time and further confirmatory measurements should be made after any significant period of time has elapsed since the sampling took place. The interpretation of the geological and environmental quality conditions is based on extrapolation from point-source data in a heterogeneous environment. Accordingly, more detailed investigation may be appropriate dependent upon the client objectives.

Unless stated otherwise, the geological information provided is for general environmental interpretation and should not be used for geotechnical and/or design purposes. A separate geotechnical report will be produced by Ramboll.

This report provides information on the distribution and concentration of contaminants identified as part of Ramboll's investigation and is not a method statement or risk assessment on how to deal with asbestos.

During the investigation, access to the gasholder footprints was not granted and therefore, no exploratory locations have been positioned within these areas. Given the shallow groundwater, investigation into the gasholder bases was not deemed possible due to the potential for allowing groundwater to potentially enter the bases and flood the gas holders. Moreover, investigation into soils within shallow groundwater e.g. through trial pits etc. would be limited as accurate observations and sample collection would not be possible.

Access constraints also included the presence of the PRS installation (operated by Cadent) and easement, as well as the associated underground services, notably the medium, low and intermediate pressure gas mains which each have a 15m easement either side of the utility. There are also a number of trees present on the site boundary and on the site, which have root protection zones surrounding which restricted access for the investigation. A culvert is present running through the south-western portion of the site and associated easement which also restricted access for exploratory locations. Areas of overgrown vegetation were present in the south of the site and the north-east. Limited vegetation clearance works (by a third party) were undertaken in these areas prior to the intrusive investigation commencing, however, access was still limited within these areas. Furthermore, within the vegetated area in the south of the site Giant Hogweed was reported to be present which further limited access within this area (i.e. access was only granted to areas where vegetation was cleared and where Giant Hogweed was not present).

1.7 Report Layout

The report is structured as follows:

Section 1: Describes the background to the report and sets out the objectives of the investigation.

Section 2: Provides a description of the current site layout and setting.

Section 3: Provides a summary of the previous third-party investigation and remediation works.

Section 4: Introduces a preliminary conceptual site model for the site, which has been used in designing the investigation strategy and sets out the sampling and analysis rationale.

Section 5: Details the ground and groundwater conditions and field observations of potential contamination encountered during the investigation.

Section 6: Summarises the laboratory chemical analysis results for soils and groundwater and screens the data against risk based generic assessment criteria (GAC) for human health derived by Ramboll.

Section 7: Summarises the laboratory chemical analysis results for groundwater (Controlled Waters) and screens the data against available water quality standards.

Section 8: Presents the results of ground gas monitoring and discusses potential risks to the built environment.

Section 9: Presents a preliminary waste classification assessment.

Section 10: Presents a revised conceptual site model based on information obtained during the investigation and sets out a qualitative source-pathway-receptor risk assessment.

Section 11: Provides a summary and the conclusions and recommendations of the investigation.

2. SITE DESCRIPTION

2.1 Introduction

The site is a roughly square shaped plot of land of 2.53 hectares (ha), situated in a mixed residential and commercial area, approximately 0.5km south-east of Lea Bridge train station, North East London. The National Grid Reference is 536641, 186977. A site location and site layout plan are attached as Figure 1 and Figure 2 in Appendix 1 respectively.

The natural topography of the site and surrounding area is generally flat ranging from approximately 6m above ordnance datum (mAOD) in the northern part of the site to 7mAOD in the southern portion of the site.

The site is occupied by the remnants of a land parcel which was formerly part of the wider Lea Bridge Gasworks (see figure in Appendix 1). Three gasholder bases remain present on site after the gas holder superstructures were demolished in early 2019:, details of the gas holders is provided below:

- Gasholder 5: Below ground holder of 37m diameter, of brick construction and approximately 9.3m deep. Built in 1899.
- Gasholder 6: Above-ground gasholder of 52m diameter, of concrete construction and approximately 2.5m deep. Built in 1922.
- Gasholder 7: Above-ground gasholder of 58m diameter, of concrete construction and approximately 2.5m deep. Built in 1962.

The site is currently unused with the exception of a pressure reduction station (PRS) in the centre of site, operated by Cadent. A telecom communication mast is present in the west of site adjacent to the site boundary, and a small building understood to house telemetry infrastructure is located to the north of the PRS.

The surface of the site is mostly gravelled with concrete roadways linking the site's access via Clementina Road / Perth Road at the north-western corner on the site to the PRS.

Heavily vegetated areas of site are present in the north-east of the site (formerly a tennis court) and in a 'L' shaped plot of land in the south, separated from the 'main' site by metal palisade fencing. Prior to commencing the intrusive investigation, limited vegetation clearance works were undertaken to allow coverage within these areas. Ramboll understands that Giant Hogweed is present within the southern 'L' shaped plot of land and the clearance works to allow investigation access were undertaken in areas where the invasive species was not present.

A mixture of commercial and residential land surrounds the site, as described below.

2.2 Site Setting

The site is located in an area of residential and commercial use in Leyton, in the London Borough of Walthamstow, at National Grid Reference 536641, 186977. Adjacent and surrounding land uses are detailed in Table 2.1 below.

Table 2-1: Adjacent and Surrounding Land Uses

Direction	Occupant	Activities	Distance
North	Residential - Clementina and Perth Road	Residential area, terraced housing.	Adjacent to northern site boundary
	Residential housing, Sybourn Primary School and Lea Bridge High Street	Residential land use, school and mixed commercial.	Residential housing from approx. 15m north

Table 2-1: Adjacent and Surrounding Land Uses

			Sybourn Primary School approx. 115m north and Lea Bridge High Street 200m north of site
East	Leyton Jubilee Park Lammas School and residential housing	Recreational park / sports ground School and sixth form Residential land use	Adjacent 85m east of eastern site boundary.
South	Leyton Jubilee Park Oliver Road Allotments	Recreational park Allotment gardens locally owned.	Adjacent 60m south
West	Warehouse units, tenants include: Buildbase Leyton, UK Snacks and Wanis International foods	Industrial / commercial warehouse units	Adjacent to western site boundary
	Filter Beds Nature Reserve	Nature Reserve	280m west of western site boundary

2.3 Site History and Surrounds

2.3.1 Site

Prior to development, the site formed part of the Leyton Marsh and Hackney Marsh. A stream was present in the south of the site that ran approximately diagonally through site and flowed in an easterly direction.

By 1896, the site was occupied by a fireworks manufactory which appeared to be focused to the north of the site.

By 1936, Lea Bridge Gas Works was present on site and comprised a gas holder in the centre of site and a large gas holder in the east of site. The site formed part of the wider Lea Bridge Gas Works which was present off-site to the east (off-site since circa 1880s). Rail sidings connecting to the wider gas works were present adjacent to the centrally located gas holder and buildings were present in the north-west of site. A bowling green and tennis courts were located in the north and centre of site. Note: whilst historical mapping does not depict the presence of gas works land use on the subject site until 1936, information provided by third-parties states that the first gasholder on site was constructed in 1899 and a second in 1922.

By 1949, a tank and buildings were present in the north of the site and a coal yard was present in the south of site.

By 1962, a third gas holder had been constructed in the south of the site and rail lines were present to the north of the gas holder, linking to the wider gas works site. The stream in the south was no longer present.

By 1971, further development had occurred in the north of site, including numerous tanks and an electrical substation adjacent to the northern site boundary.

Subsequent map editions depict the removal of buildings and tanks in the north of the site as well as the rail sidings on site.

2.3.2 Surrounds

By 1870, Lea Bridge Gas Works was located approximately 100m north-west of site and by 1890 had increased in scale to comprise a number of gas holders, tanks and associated buildings. Nurseries were present to the north of the site.

By 1915, Lea Bridge Gas Works had expanded up to the subject site (the site comprised approximately one third of the total wider gas works site). The wider gas works comprised gas holders, tar tanks, oil tanks, retort houses, purifiers, liquor tanks and coal and coke storage. Residential land use was present adjacent to the north of site and a nursery present to the east of site. A figure depicting the scale of the Former Lea Bridge Gas Works and highlighting the area that relates to the subject site is provided in Appendix 1

By 1936, further expansion of Lea Bridge Gas Works had taken place and a sports ground and playground were to the east and south-east of site. Historic maps and anecdotal information suggest Lea Bridge Gas Works expanded onto the site in the late 1800s or early 1900s.

By 1985, Lea Bridge Gas Works had been redeveloped as Fairways Business Park.

2.4 Geology and Hydrogeology

According to BGS records, the site is underlain by superficial Alluvium deposits of clay, silt, sand and peat. The superficial geology is classified by the Environment Agency (EA) as a Secondary Undifferentiated Aquifer. Superficial geology comprising River Terrace Deposits is present off-site and may underly the Alluvium on-site. Previous third-party investigations reference the presence of River Terrace deposits at site, however, reports are not consistent in differentiating these two lithologies. The River Terrace Deposits, if present, is a Secondary A Aquifer.

The bedrock geology comprises the Lambeth group (clay silt and sand - formerly the Woolwich and Reading Beds Formation), which is classified by the EA as a Secondary A Aquifer. Beneath the Lambeth Group are the Thanet Sands and Chalk (Secondary Aquifer (A) and Principal Aquifer respectively).

The site is located within a groundwater Source Protection Zone (SPZ) II in relation to a potable water abstraction approximately 600m south-west of the site. An SPZ I is located is approximately 250m south-west of the site at its closest point. Previous third-party data states that the abstraction 600m south-west is from the Chalk aquifer.

2.5 Hydrology

The nearest surface water feature is a culverted stream in the south-west corner of the site, running north-west to south-east. It is considered likely that the culvert connects the River Lea flood relief channel (approximately 220m south-west of site) to the Dagenham Brook, approximately 250m north-east of the site.

The site lies within a Flood Zone 2 and is adjacent to a Zone 3 along the western boundary.

There are two small surface water features located within 250m of the site boundary. One at approximately 49m south-west (appears to connect the River Lea Flood Relief Channel to the on-site culvert – appears dry according to satellite imagery) and one at 220m north-east.

3. PREVIOUS INVESTIGATION AND REMEDIAITON

3.1 Introduction

A number of intrusive investigations have been undertaken at the site. The reports provided to Ramboll are listed and summarised below.

- Ernest Green Partnership Ltd, Report Ref. 5695/A/NT13- Contamination Desk Top Study for Lea Bridge Road, Leyton, dated September 1993.
- Ernest Green Environmental Ltd, Report Ref. 7502/NE/Nov 97/EA-INT/V2- Ground Contamination Environmental Assessment for Lea Bridge Road, Leyton, dated November 1997.
- White Young Green Environmental, Report Ref. 750/DW/Feb 1999/VR(B&C)/FAC/FINAL- Factual Validation Report of the Soil Remediation Works Areas B and C completed at Lea Bridge Road, Leyton, dated February 1999.
- White Young Green Environmental, Report Ref. 7502/NE/February 1999/CR(B&C)/V1- Validation Report of the Soil Remediation Works completed at Lea Bridge Road, Leyton Areas B and C, dated February 1999.
- WYG Environment, Report Ref. G007502-7- Site Investigation Factual Report at Lea Bridge Road Gas Holders and PRS Site, dated February 2013.
- WYG Environment, Report Ref. G007502-7- Site investigation Factual Report at NGP Land to the South of Lea Bridge Road Gas Holder Site, dated February 2013.
- WYG, Report Ref. G007502-11- Factual Preliminary Dismantling Assessment, dated March 2018.
- RSK Environment Ltd, Letter Ref. 301093 L01 TC- Lea bridge Gasworks, Leyton-Technical Review of Existing Reports, dated September 2018.
- Patrick Parsons Limited, Report Ref: L18145G, Phase I and Preliminary Phase II Site Investigation Report, Former Lea Bridge Gasworks, dated March 2019.
- WYG, Factual Supplementary Site Investigation Report, Lea Bridge Road, Leyton, Ref G007502-23, dated December 2019.

3.2 Previous Investigation and Assessment Summary

Ernest Green Partnership Ltd, Report Ref. 5695/A/NT13- Contamination Desk Top Study for Lea Bridge Road, Leyton, dated September 1993;

The earliest reports provide limited information of the subject site and their focus was on the wider former Lea Bridge Gas Works off-site to the west. Much of the text, data and figures throughout the reports have also been redacted.

Desked-based research identified the following structures were historically on-site:

- Former tanks to north and east of Gas Holder No.5, including Dry Gas & Benzole Plant and Coal Gas Purifiers (c.1949 – 1980s).
- Garages and rubbish store & oil store on north-western corner of site (c.1936 – 1992).
- Coal storage area (c.1949 – 1962).
- Meter house and small buildings (c.1949 – 1980s).

Ernest Green Environmental Ltd, Report Ref. 7502/NE/Nov 97/EA-INT/V2- Ground Contamination Environmental Assessment for Lea Bridge Road, Leyton, dated November 1997;

Intrusive investigation undertaken in 1997 comprised four boreholes (to depths between 8 and 10m bgl), three trial pits and four trial trenches. The majority of investigation locations were situated in the west and the north west of the site.

Each of the boreholes was installed with gas and groundwater monitoring wells that were screened within the Made Ground and River Terrace Deposits, with one well targeting the upper layer of Lambeth Group strata. Two subsequent rounds of groundwater and land gas monitoring were completed.

Records of observations of potential contamination within Made Ground included pockets of tarry staining and odours, ammonia odours, occasional pockets of 'blue billy', occasional ash and / or clinker and lime waste. Tarry odours were also recorded within the River Terrace Deposits extending to 6.8m in the south of the site in the vicinity of the former coal store.

Laboratory analysis of soil samples collected confirmed the presence of polycyclic aromatic hydrocarbons (PAH), cyanide and ammoniacal compounds originating from former gas works waste / contamination. Subsequent groundwater sampling identified elevated concentrations of PAH, phenol, ammonium and free and total cyanide.

Land gas monitoring (on two occasions) identified methane concentrations (between 6-11%) at one location and carbon dioxide (5.1-9.5%) in the three monitoring wells screened in the Made Ground and River Terrace Deposits.

White Young Green Environmental, Report Ref. 750/DW/Feb 1999/VR(B&C)/FAC/FINAL & 7502/NE/February 1999/CR(B&C)/V1, Factual Validation Report of the Soil Remediation Works Areas B and C completed at Lea Bridge Road, Leyton, dated February 1999;

On the basis of the preceding investigation, soil remediation works were undertaken in 1999. The remediation works focused on two main areas:

- an area central to the site comprised excavation of 1,250m^3 of soils which targeted tarry deposits and elevated hydrocarbons; and
- an area in the south of the site comprised excavating 50m^3 of soils which targeted total and free cyanide.

Soil validation samples were collected on completion of the remediation works from the walls and base of each of the excavations. Residual elevated concentrations of PAH compounds (specifically benzo(a)pyrene) and TPH were recorded within the validation samples tested.

WYG Environment, Report Ref. G007502-7- Site Investigation Factual Report at Lea Bridge Road Gas Holders & PRS Site and NGP Land to the South of Lea Bridge Road Gas Holder Site, dated February 2013;

Another investigation was undertaken in 2013 comprising seven boreholes, two window sample borings and thirteen trial pits, to depths of 0.7m bgl to 7.7m bgl.

Laboratory analysis of soil samples collected identified elevated concentrations of metals, PAH, TPH, sulphate, ammoniacal nitrogen and cyanide. Within groundwater and soil leachate samples elevated concentrations of metals, PAHs, phenols, ammoniacal nitrogen, sulphate and cyanide were detected. Land gas monitoring identified no detectable concentrations of methane and concentrations of carbon dioxide of up to 7.7%.

RSK Environment Ltd, Letter Ref. 301093 L01 TC- Lea bridge Gasworks, Leyton-Technical Review of Existing Reports, dated September 2018

The RSK document provides a technical review for the Lea Bridge Gasworks site which comprised summarising previous reports. The review concluded that significant demolition / enabling works, backfilling of the gas holders and the removal of infrastructure, plant and services will be required in order to facilitate the redevelopment of the site for a residential end use. Based on the site's current use RSK concluded that it is plausible that soil and groundwater remediation and a subsequent cover system in garden areas will be required to facilitate the sites reuse for residential purposes. RSK noted that further assessment is required to fully quantify risks to controlled waters.

Patrick Parsons Limited, Report Ref: L18145G, Phase I and Preliminary Phase II Site Investigation Report, Former Lea Bridge Gasworks, dated March 2019.

Patrick Parsons undertook a preliminary investigation in 2019. This included four rotary boreholes to a maximum depth of 9.0m bgl, to assess ground conditions and obtain samples for laboratory analysis. Ground conditions were reported as Made Ground (generally comprising clayey or sandy gravel with brick, concrete, clinker, wood plastic and metal) overlying clayey gravel Alluvial deposits. None of the boreholes penetrated into the underlying Lambeth Group. Laboratory analysis identified elevated TPH, PAH, metals and cyanide concentrations above relevant assessment criteria protective of human health. Elevated PAH, TPH and cyanide concentrations were also identified within the groundwater samples obtained.

During the ground gas monitoring works, concentrations of VOCs (71ppm WS103) and Carbon monoxide (CO) (42ppm WS102) were also recorded.

WYG, Factual Supplementary Site Investigation Report, Lea Bridge Road, Leyton, Ref G007502-23, dated December 2019.

Intrusive site works were completed in July 2019 and comprised three cable percussive boreholes and four machine excavated trial pits.

Made Ground was encountered in all investigation locations and was recorded to comprise highly variable combinations of silts and clays and granular soils, including concrete, brick, ceramic fragments, metal, clinker and plastic. Underlying the Made Ground was Alluvium which was encountered in all but three locations and was generally comprised as soft to firm gravelly sandy clay or clay. River Terrace Deposits were also recorded in all locations and typically comprised sands and gravel. The Lambeth Group was only encountered within the three deeper boreholes, and generally comprised of sandy clay.

Visual and olfactory evidence of contamination was encountered in 10 locations and comprised possible crushed lime, hydrocarbon odours (mild to strong) and black staining.

Groundwater was encountered in all three borehole and water strikes ranged from 3.1m bgl to 3.2m bgl. The presence of Non-Aqueous Phase Liquids (NAPLs) was monitored using the dual phase interface probe. No discernible NAPL was detected during any of the monitoring visits.

Soil and groundwater samples were obtained during the investigation. In total 15 soil samples and 18 groundwater samples (two sampling rounds of nine boreholes, including previously installed wells), which were scheduled for:

- phenols (speciated);
- PAHs (speciated);
- BTEX & MTBE;
- TPHs (speciated);

- metals (arsenic, cadmium, chromium, hexavalent chromium, cobalt, lead, mercury, molybdenum, selenium, copper, nickel and zinc);
- chloride, Sulphate & Elemental Sulphur;
- cyanides (easily liberated, complex and total); and
- exchangeable Ammonium.

Laboratory analysis of the soil samples recorded the following:

- elevated PAHs with the highest total PAH concentration of 322mg/kg and highest individual PAH of 60.1mg/kg (pyrene). For context, benzo(a)pyrene and naphthalene were recorded at 32.6mg/kg and 1.83mg/kg respectively;
- benzene was recorded in three samples (highest concentration of 0.0145mg/kg) and xylene(o) was recorded in one sample (0.523mg/kg);
- elevated TPH fractions were identified in 14 locations, with a maximum total TPH concentration of 4,600mg/kg;
- phenols were generally not detected (exception being total cresols at 0.103mg/kg); and
- ammoniacal nitrogen was recorded in seven samples at a maximum concentration of 2,690mg/kg.

Laboratory analysis of the groundwater samples recorded the following:

- elevated PAHs with the highest total PAH concentration of 128µg/l and highest individual PAH of 5.85µg/l (acenaphthylene). For context, benzo(a)pyrene and naphthalene were recorded at 0.0286µg/l and 0.439µg/l respectively;
- minimal concentrations of benzene were recorded with the highest concentration of 2.34µg/l and xylene(o, m/p) recorded a maximum concentration of 44µg/l;
- generally low concentrations were recorded, all TPH concentrations bar one sample were detected below 1,000µg/l (highest concentration 1,060µg/l) and three samples recorded concentrations <10µg/l. The highest concentrations for aliphatic / aromatic TPH fractions were 261µg/l (aliphatic C10-12) and 174µg/l (aromatic C10-12). Generally aliphatic fractions were recorded at higher concentrations;
- phenols were not detected above method detection limit;
- free cyanide was recorded at a maximum concentration of 33.3µg/l; and
- ammoniacal nitrogen was recorded at a maximum concentration of 7,590µg/l.

4. SITE INVESTIGATION STRATEGY

4.1 Preliminary Conceptual Site Model

Ground contamination is assessed by identifying whether a pollutant linkage is present (or potentially present) between a contaminant, a pathway and a receptor in the form of a Conceptual Site Model (CSM). The CSM takes into account the known information from the site, surroundings and the environmental setting and is a simplified representation of the possible environmental conditions at and in the vicinity of the site, and is used to initially identify potential sources, potentially sensitive receptors, pathways, and pollutant linkages.

The CSM will be refined by taking into account the specific ground conditions and measured concentrations of contaminants identified during the site investigation and assessment. The refinements as necessary will be discussed within the qualitative risk assessment in Section 10.

The preliminary contaminant source and pathway linkages (assuming a future residential end use (with no private gardens)) are presented in Table 4.1 and receptor analysis in Table 4.2 below.

Table 4-1: Preliminary Conceptual Site Model

Potential Sources of Contamination

Site:

- Historically, a fireworks manufactory was present on site which was present in the north of site.
- From the late 1890s (Gas Holder 5 was constructed in 1899), the site was in use as a gas works. Potential sources of contamination comprised:
- Three Gas Holders (Gas Holder No. 5 (1899), No. 6 (1922) and No. 7 (1962)). All of which were demolished in 2019.
- Former tanks to north and east of Gas Holder No.5. Dry Gas & Benzole Plant and Coal Gas Purifiers (c.1949 – 1980s).
- Garages, waste store & oil store on north-western corner of site (c.1936 – 1992).
- Coal storage area (c.1949 – 1962).
- Substation located in the north of site.
- Previous investigation identified the presence of petroleum hydrocarbons, PAH compounds, volatile organic compounds), metals, cyanide ammonia and asbestos in soils and similar contaminants (excluding asbestos) in groundwater.
- Localised soil remediation was undertaken in two areas of the site in 1999 which focused on areas of tarry deposit, elevated hydrocarbons and total and free cyanide. No remediation of groundwater was completed.
- Giant Hogweed is present within the south of the site.

Surrounds:

- Historically, the wider Lea Bridge Gas Works was present adjacent to the west of the site. Potential sources of contamination on the wider gas works comprised gas holders, tar tanks, oil tanks, retort houses, purifiers liquor tank and coal and coke storage.
- Additional historical potential off-site sources of contamination include railway lines approximately 50m west of site.
- In terms of current potential contaminative source, Fairways Business Park (commercial use) is adjacent to the west of site.

Geology and Hydrogeology:

- According to the British Geological Survey (BGS), the site is directly underlain by superficial deposits (Alluvium), and the bedrock geology of the Lambeth Group. The Thanet Sand and Chalk is present at depth. River Terrace Deposits may be present underlying the Alluvium and overlying the Lambeth Group. River Terrace Deposits may underlie the Alluvium.
- The EA currently classifies the superficial deposits as a Secondary Undifferentiated aquifer and the bedrock geology of the Lambeth group as a Secondary A aquifer. The underlying Chalk at depth is classified as a Principal Aquifer. The River Terrace Deposits are a Secondary A aquifer.
- Groundwater flow is expected to be in a general southerly direction.

Table 4-1: Preliminary Conceptual Site Model
• The site is located within a Source Protection Zone (SPZ) II in relation to a potable water abstraction located approximately 600m south west of the site. An SPZ I is located approximately 250m south-west of the site at its closest point. **Hydrology:** • The nearest surface water feature is a culverted stream in the south-west corner of the site, that flows in an easterly direction. It is considered likely that the stream connects the River Lea Flood Relief Channel (220m south-west) to the nearby Dagenham Brook (250m north-east). • There are two small surface water features located within 250m of the site boundary. One at approximately 49m south-west and one at 220m north-east. **Potential Pathways:** • Dust, particulate or contaminant volatilisation from soil into indoor and outdoor air (inhalation). • Direct contact with impacted soils – ingestion, dermal and direct contact. • Migration of contaminants in soils to third party property and off-site receptors. • Migration of contamination from soils to groundwater via leaching, into the Secondary or Principal Aquifer. • Migration of contaminants within groundwater to the off-site and wider Secondary and Principal Aquifers. • Lateral migration of groundwater to nearby surface water receptors. • Volatilisation of contaminants from groundwater to human receptors – inhalation. • Migration of potentially hazardous ground gases from Made Ground into future residential buildings – inhalation. • Off-site contaminant migration onto the site.

The preliminary conceptual site model is further analysed in Table 4.2 in terms of potential effects to site users and environmental receptors.

Table 4-2: Potential Receptors to Contamination (if Present)			Receptor Present
Humans	On-Site	The site will undergo redevelopment for residential end use (with no private gardens).	Yes
	Off-Site	The site is located within a mixture of residential and commercial land use area in Lea Bridge.	Yes
Water Environment	On-Site	Groundwater: Shallow and deep aquifers Surface Water: culverted watercourse on-site.	Yes
	Off-Site	Groundwater: Aquifers used for potable water supply in the wider region. Surface Water: discharge of surface water to the wider river network.	Yes
Built Environment	On-Site	The site will be re-developed for residential end use (with no private gardens).	Yes
Ecology	On and off-site	Walthamstow Marshes (a SSSI) is located 895m west of site, Lee Valley Special Protection Area (SPA) is located 1.7km north-west which is also a RAMSAR site.	No

The site investigation strategy was designed to assess the key potential contamination sources and potential pollutant linkages identified in the preliminary conceptual site model. The following sections describe the site investigation strategy, the results of laboratory chemical analysis and a qualitative source-pathway-receptor risk assessment; the revised conceptual model is then presented in Section 10.

4.2 Site Investigation Works

4.2.1 Summary of Intrusive Works

The ground investigation was completed by CC Ground Investigations Ltd (CCGI) and is described in their factual report.

The intrusive site investigation was undertaken between the 4th November 2019 and 29th November 2019 and was supervised by Alice Kilner of Ramboll.

The site investigation comprised the following which are pertinent to the assessments contained herein, see Table 4.3.

Table 4-3: Summary of Intrusive Works

Item	No.	Comments
Utilities Clearance Survey	Item	Prior to intrusive works a specialist service location contractor, Rock Power Connections Ltd, was contracted to locate below ground services and mark out drilling locations.
UXO	Item	Prior to intrusive works, at 1m bgl and at 3m bgl, a specialist UXO clearance contractor (Fellows) was contracted to scan and analyse results for the potential presence of unexploded ordnance.
Hand-dug Pit	1 No.	A hand-dug pit was excavated in the north of the site, in the vicinity of a substation. Due to the level of services within this area, only a hand-dug pit could be excavated.
Window Sample Boreholes	8 No.	A terrier window sampling rig was used to advance eight window sample boreholes (WS301 to WS308) to a maximum depth of 4m bgl. Of the above locations, all seven monitoring wells were installed for ground gas monitoring purposes. Wells were of appropriate construction for the ground conditions encountered. The well designs are detailed within the borehole logs presented in Appendix 2.
Rotary / Hollow Stem Auger Boreholes	16 No.	14 boreholes to depths of up to 7m bgl. Two boreholes to depths of up to 11m bgl in the vicinity of Gasholder 5. Monitoring wells were installed in all 16 of the boreholes and used for groundwater monitoring and to obtain groundwater samples.
Cable Percussive / Boreholes	5 No.	4 boreholes to a depth of 30m bgl each. One borehole to a depth of 20m bgl. Monitoring wells installed in borehole CP303 for gas and groundwater monitoring purposes.
Soil Sampling and Analysis	60 No.	During the site investigation, soil samples were recovered from each exploratory hole location and screened on-site using a hand-held photo-ionisation detector (PID) for the presence of volatile organic compounds. Up to three soil samples from each sampling location were submitted for selected laboratory analysis. Selected soil samples were analysed for a predetermined suite of contaminants (see section 3.4), designed to be reflective of the site's historic uses.
Groundwater Sampling and Analysis	17 No.	Groundwater was encountered in all 17 installed groundwater monitoring wells. An oil/water interface probe was used to check for free-phase hydrocarbons and resting groundwater levels were monitored. The 17 groundwater samples were analysed for a suite of contaminants designed to be reflective of the site's historic uses.
Gas Monitoring	6 No.	Six rounds of ground gas monitoring have been completed using a portable gas analyser (GA5000).

Table 4-3: Summary of Intrusive Works

Item	No.	Comments
Waste Characterisation and Disposal	Item	All soil and groundwater arisings along with general waste generated during the works were stored in dedicated skips and IBCs during the investigation. A representative sample of the waste was submitted for chemical testing and was characterised for waste disposal purposes waste (i.e. hazardous or non-hazardous waste). Once characterised, the wastes (soil, water and general waste) were collected (under appropriate consignment notes) and arranged for disposal to a suitably licenced facility.

4.2.2 Sample Location Rationale

The rationale for positioning the sampling locations is described in Table 4.4 below.

Table 4-4: Exploratory Hole Rationale

Exploratory Hole	Rationale	Depth achieved (m bgl)	Installed as Monitoring Well?
CP301- CP305	Site coverage of deep ground conditions for environmental assessment.	CP301- 20m CP302- 30m CP303- 22.5m CP304- 28m CP305- 30m	CP301- No CP302- No CP303- Yes CP304- No CP305- No
WS301	Assess shallow soil conditions in area of previous oil storage.	2.25m	Yes
WS302	Assess shallow soil conditions in area of previous remediation.	3.0m	Yes
WS303	Assess shallow soil conditions in the vicinity of previous remediation areas and historic sources.	4.0m	Yes
WS304	Assess shallow soil conditions in the vicinity of the gasholder and historic sources.	3.20m	Yes
WS305	Assess shallow soil conditions in the vicinity of previous remediation.	0.50m	No - concrete obstruction
WS306	Assess shallow soil conditions along the western boundary of the site.	2.0m	Yes
WS307	Assess shallow soil conditions in the vicinity of the gasholder.	3.0m	Yes
WS308	Assess shallow soil conditions in the area of previous remediation.	4.0m	Yes
RHA, RHC, RHD	Coverage of soil, ground gas and groundwater conditions in the close vicinity to the northern site boundary and off-site sensitive residential land use.	RHA - 5.2m RHC - 7.0m RHD - 7.0m	Yes
RHB	Assess shallow soil conditions in the vicinity of the gasholder.	7.0m	Yes
RH302	Coverage of soil and groundwater conditions on up gradient site boundary.	6.70m	Yes

Table 4-4: Exploratory Hole Rationale

Exploratory Hole	Rationale	Depth achieved (m bgl)	Installed as Monitoring Well?
RH303	Coverage of soil and groundwater conditions up-gradient of historic sources and area of previous remediation.	6.0m	Yes
RH304	Coverage of soil and groundwater conditions in vicinity of western site boundary and to inform of potential migration to or from off-site receptors / sources.	6.70m	Yes
RH305	Coverage of soil and groundwater conditions within area of previous remediation.	7.0m	Yes
RH306	Coverage of soil and groundwater conditions on up-gradient site boundary.	7.0m	Yes
RH308 and RH310	Coverage of soil and groundwater conditions down-gradient of previous remediation and in vicinity of western site boundary; to inform of potential migration to or from off-site receptor / sources.	RH308- 7.0m RH310- 7.0m	Yes
RH309 and RH311	Coverage of soil and groundwater conditions in vicinity of Gas Holder 5 and to obtain site coverage.	RH309- 11.0m RH311- 10.5m	Yes
RH312	Coverage of soil and groundwater conditions down-gradient of Gas Holder 6 and to obtain site coverage.	6.0m	Yes
RH313	Coverage of soil and groundwater conditions in vicinity of western site boundary, in vicinity of Gas holder 7 and to obtain site coverage.	7.0m	Yes
RH315	Coverage of down-gradient soil and groundwater conditions.	7.0m	Yes
TP310, TP311, TP313, TP321.	To provide a general site coverage.	TP310- 3.5m TP311- 2.9m TP313- 0.6m TP321- 3.6m	N/A
TP301, TP305	To provide general site coverage and to provide coverage in vicinity of archaeological Walthamstow Slip (at the request of the archaeological consultant).	TP301- 3.6m TP305- 3.6m	N/A
TP306	Provide coverage in vicinity of historic contaminative sources.	TP306- 0.5m- concrete obstruction.	N/A
TP307, TP308, TP309, TP316, TP327, TP325, TP326	To provide coverage in vicinity of the area of previous remediation.	TP307- 3.2m TP308- 2.2m TP309- 2.6m TP316- 3.5m TP327- 3.2m TP325- 3.3m TP326- 3.5m	N/A

Table 4-4: Exploratory Hole Rationale

Exploratory Hole	Rationale	Depth achieved (m bgl)	Installed as Monitoring Well?
TP312, TP315, TP319, TP320	To provide site coverage and in the vicinity of gasholders.	TP312- 2.1m TP315- 2.1m TP319- 3.5m TP320- 3.6m	N/A
HP302	To provide site coverage in vicinity of substation. (hand-dug pit)	0.5m	N/A

The site investigation also included recording information, on-site testing and collecting samples for a geotechnical assessment, this was undertaken by CCGI. The geotechnical information is factually reported within CCGI's factual report and an interpretative geotechnical report has been undertaken by Ramboll, which is reported separately.

4.2.3 Limitations During the Investigation

The site investigation was limited by the following factors:

- Concrete obstructions in vicinity of WS305 prevented the advancement past 0.50m bgl. This area was broken out by the excavator and a second concrete obstruction was found at 0.80m bgl, preventing further progression of the exploratory location.
- In the vicinity of the substation to the north of the site, it was not possible to progress boreholes or trial pits due to the presence of underground services. A hand pit to 0.5m bgl was completed for the collection of shallow environmental samples.
- Concrete obstructions in the vicinity of TP306 location prevented the advancement of this trial pit past 0.5m. The concrete was of poor quality, with brick inclusions and could possibly be associated with foundations of historic buildings (HP302).
- A high reading from UXO surveying equipment at 2.0m in WS306 prevented the advancement past this depth.

As identified earlier in the report, access to the gasholder footprints was not granted and therefore, no exploratory locations have been positioned within these areas. Given the shallow groundwater, investigation into the gasholder bases was not deemed possible due to the potential for allowing groundwater to potentially enter the bases and flood the gas holders. Moreover, investigation into soils within shallow groundwater e.g. through trial pits etc. would be limited as accurate observations and sample collection would not be possible. Accordingly, test positions have been strategically positioned as close as practicable to gasholder bases.

Overall, Ramboll was able to investigate the identified potential contaminant sources and it is considered that the exploratory holes provide an appropriate coverage across the accessible areas of the site. It should be noted that ground conditions at variance with those recorded in the exploratory holes drilled and excavated at the site could exist in areas of the site that could not be accessed.

4.3 Sampling and Monitoring

4.3.1 Soil Samples

Soil samples were recovered from each of the exploratory locations based at regular intervals and/or changes of strata, within the unsaturated zone. Samples were collected in accordance with BS 10175:2011+A2:2017 and were stored within appropriate sample containers and forwarded to an independent Ramboll approved MCERTS accredited analytical laboratory (i2

Analytical). Selected samples were placed in containers supplied by the laboratory appropriate to the type of analysis being undertaken and stored in cool boxes with ice packs. All samples were dispatched accompanied by chain of custody documentation.

Selected soil samples were tested on-site for the presence of volatile organic compounds (VOCs) using a photo-ionisation detector (PID), calibrated in accordance with Ramboll's Quality Management procedures. Each soil sample tested was placed into a sealed plastic bag and agitated. The PID was then inserted into the headspace and the total VOC reading recorded. The PID screens for a wide range of VOCs but does not indicate a specific compound; therefore, the results of the PID screening provide a semi-quantitative indication of the concentration of VOCs present in soil pore spaces. The results of the PID screening are discussed in Section 5.

4.3.2 Groundwater Monitoring and Sampling

Groundwater monitoring and sampling was undertaken between the 20th and 29th November following the installation of monitoring wells. Prior to sampling, the depth to the resting groundwater level (where present) and base of the monitoring wells were measured using an electronic interface probe. The wells were developed by removing approximately ten times the water well volume using a submersible pump. The wells were then purged of approximately three times the well volume before the sample was taken. The sampling was then undertaken using a peristaltic pump and dedicated tubing to prevent cross contamination.

The groundwater samples were placed in containers supplied by the laboratory appropriate to the type of analysis being undertaken and stored in cool boxes with ice packs. All samples were dispatched accompanied by chain of custody documentation to Ramboll's subcontracted and suitably accredited laboratory (i2 Analytical) for analysis.

4.3.3 Ground Gas Monitoring

To date, six rounds of ground gas monitoring has been undertaken. Ground gas monitoring was completed using a calibrated GA5000 Monitor with reference to CIRIA C665 and BS 8576:2013 Guidance on Investigations for Ground Gas. The following parameters were monitored:

- Methane (% vol);
- Carbon dioxide (% vol);
- Oxygen (% vol);
- Carbon Monoxide (ppm);
- Hydrogen Sulphide (ppm); and
- Flow rate (l/hr).

Gas flow rates were measured at all monitoring boreholes and Ramboll recorded the range in flow rates until a steady state was reached. The results of the ground gas monitoring are discussed in Section 8.

4.4 Laboratory Analysis

4.4.1 Analytical Rationale

Table 4.5 summarises the analytical schedule for soil and groundwater samples together with the rationale for analysis.

Table 4-5: Summary of Analytical Strategy

Analytical Suite	Rationale	No. of soil samples submitted	No. of groundwater samples submitted
Total Petroleum Hydrocarbons Carbon Working Group (TPH CWG) including BTEX	Typically associated with fuels and oils.	60	17
Volatile Organic Compounds (VOCs)	Commonly associated with industrial processes and urban settings.	34	15
Semi-Volatile Organic Compounds (SVOCs)	Commonly associated with industrial processes and urban settings.	15	15
Cyanide (total, complex and free), speciated phenols, thiocyanide and ammonium	Typically associated with historical gasworks sites	60	17
Asbestos Screen Asbestos Quantification	Commonly associated with Made Ground.	36 10	N/A
Metals (including arsenic, cadmium, chromium, lead, mercury, copper, nickel, zinc vanadium, boron, beryllium and selenium)	Typically associated with brownfields sites historically used for industrial purposes.	60	17
Polycyclic Aromatic Hydrocarbons (PAH)	Typically associated with fuels and oils and often found in Made Ground and urban settings.	60	17
Polychlorinated Biphenyls (PCBs)	Associated with electrical equipment.	9	8

4.4.2 Data Quality Assurance

The laboratory selected to perform the analysis is accredited by UKAS to ISO 17025 and MCerts standards. Internal quality assurance checks are carried out by the laboratory data prior to the laboratory certificates being issued.

5. FIELD OBSERVATIONS

5.1 Ground Conditions

Ground conditions are summarised in Table 5.1 below. The information provided below is a summary of the exploratory locations. A full lithological description is recorded on the logs, which are provided as Appendix 2.

Table 5-1: Summary of Ground Conditions

Strata	Description	Depth to Base (m bgl)	Approx. Ave. Thickness (where encountered) (m)
Made Ground	Made Ground (i.e. anthropogenic material deposits overlying natural deposits) was present in all exploratory locations with depths ranging from 0.7m to 3.5m bgl, with the greatest depth observed in the area around Gasholder 5. This generally comprised a gravelly sand and brick with occasional concrete, clinker and siliceous materials with rare glass. Ash and clinker were present in TP319, TP301, TP311 and TP315 to a maximum depth of 1.35m bgl. Made Ground in TP307 and TP308 consisted of a yellow silty sand to 2.75m bgl. This is associated with previous remediation backfill.	0.7 – 3.5m bgl across the site.	2.5m
Alluvium / River Terrace Deposits	Underlying the Made Ground at all exploratory locations was Alluvium. This generally consisted of very gravelly sand. This has been recorded as River Terrace Deposits elsewhere. A distinct separation was not noted.	5.0 – 9.5m bgl	7.0m
Lambeth Group	Varying layers of clay, sands, silts and Upnor formation pebble beds.	17.2 - 21.5m bgl	11m
Thanet Sand Formation	Green-grey sand, encountered in deep cable percussive boreholes.	Encountered from depths of 17.2 – 21.5m. Depth to base not proven.	N/A

The ground conditions encountered across the site are generally comparable to the geology described in the British Geological Survey (BGS) map of the area.

Whilst a high reading from the UXO equipment was noted at one location, no evidence of unexploded ordnance was encountered during the investigation.

5.2 Groundwater

The depth to resting groundwater level was recorded during Ramboll's groundwater monitoring rounds (20th – 29th November 2019). A summary of the groundwater levels throughout the monitoring period is provided in Table 5.2.

Table 5-2: Summary of Groundwater Levels

Exploratory Hole	Borehole Level (m AOD)	Depth to groundwater (m bgl)	Depth to Groundwater (m AOD)	Inferred Horizon Containing Groundwater[1]
RHA	6.56	2.79	3.77	Gravelly sand

Table 5-2: Summary of Groundwater Levels

Exploratory Hole	Borehole Level (m AOD)	Depth to groundwater (m bgl)	Depth to Groundwater (m AOD)	Inferred Horizon Containing Groundwater[1]
RHB	6.97	3.47	3.50	Silty sand and sandy gravel
RHC	5.95	2.10	3.85	Sand and gravel
RHD	5.68	1.77	3.91	Sand and gravel
RH302	6.56	2.52	4.04	Gravelly sand
RH303	6.53	2.85	3.68	Gravelly silty sand
RH304	6.63	2.79	3.84	Sandy clay and gravelly sand
RH305	6.51	2.93	3.58	Silty sand
RH306	6.33	2.36	3.97	Sand and gravel
RH308	6.66	3.16	3.50	Gravelly sand
RH309	6.69	3.27	3.42	Gravelly silty sand
RH310	6.55	3.12	3.43	Sandy clay and coarse gravel
RH311	7.05	3.61	3.44	Gravelly sand
RH312	6.19	2.40	3.79	Clayey and gravelly sand
RH313	6.46	3.06	3.40	Sandy gravel
RH315	6.45	3.16	3.29	Sandy clay
CP303	5.34	1.70	3.64	Gravel

Notes:

[1] The inferred horizon has been identified by comparing the resting groundwater levels against the exploratory hole logs and monitoring well design.

Groundwater was encountered in all 17 of the groundwater boreholes during monitoring, at depths between 1.70m (3.64m AOD) at CP303 and 3.61m (3.44m AOD) at RH311. This gives a variation in groundwater elevation of 0.20m across the site declining from the north-east to the south-west. The inferred groundwater flow direction is in an approximate south-west direction. A figure showing groundwater direction is provided in Appendix 1.

5.3 Field Evidence of Contamination

The section below summarises visual and olfactory evidence of contamination encountered throughout the ground investigation.

5.3.1 Soils

Generally, Made Ground across the site was not observed to be visually or olfactorily contaminated. As with any Made Ground, typical urban contaminants could be present. The following provides information of where notable visually or olfactory impacted soils were recorded:

Table 5-3: Summary of Observations in Soils

Exploratory Location	Depth (mbgl)	Observations

Table 5-3: Summary of Observations in Soils		
Made Ground		
CP304	1.00	Potential asbestos containing material
RBHA	0.39	Slight sulphurous odour
RH305	0.45	Strong hydrocarbon odour
	1.25	Strong hydrocarbon odour
	1.60	Slight hydrocarbon odour
TP301	0.60	Strong hydrocarbon odour and 'glossy' sheen
	2.10	Very strong hydrocarbon odour, pockets of dark staining with oily sheen
TP307	2.75	Strong hydrocarbon odour
	2.80	Oily sheen and strong hydrocarbon odour
TP309	0.40	Strong hydrocarbon odour
TP316	0.20	Slight hydrocarbon odour
	2.4 – 3.4	Strong hydrocarbon odour
TP319	3.00	Strong hydrocarbon odour
	3.40	Glossy sheen on gravel
TP327	0.20	Very strong sulphurous odour
	0.50	'Low' hydrocarbon odour
WS304	1.40	Slight hydrocarbon odour
	2.00	Slight hydrocarbon odour
	2.60	Strong hydrocarbon odour and hydrocarbon sheen
WS305	0.75	Perched water with a sheen
Natural Ground		
CP302	*6.00*	*Slight hydrocarbon odour**
	7.80	*Slight hydrocarbon odour**
CP303	2.50	Strong hydrocarbon odour*
CP304	*4.00*	*Strong hydrocarbon odour**
	5.00	*Slight hydrocarbon odour**
	6.00	*Slight hydrocarbon odour**
RBHA	*4.70*	*Strong hydrocarbon odour**
RBHB	*5.20*	*Slight hydrocarbon odour**
RH304	*4.70*	*Black 'oily' residue – no odour**
RH305	2.20	Oily sheen and strong hydrocarbon odour
RH308	2.55	Oily sheen and strong hydrocarbon odour
RH309	*6.35*	*Slight hydrocarbon odour**
RH310	2.7 – 3.2	Black 'oily' residue

Table 5-3: Summary of Observations in Soils		
RH312	*4.10*	*Strong hydrocarbon odour with black 'oily' residue**
	4.0 - 4.1	*Strong hydrocarbon odour**
	4.50	*Strong hydrocarbon odour and 'oily' sheen**
RH313	*4.35*	*Slight hydrocarbon odour**
TP301	2.40	Dark grey staining with oily sheen
TP312	1.90	Glossy silver sheen (possible hydrocarbons)
TP316	*3.40*	*Strong hydrocarbon odour. Locally with glossy sheen**
TP321	2.30	Hydrocarbon odour
	3.30	Strong hydrocarbon odour and silver sheen.
TP326	1.40	Slight chemical odour
TP327	2.50	Hydrocarbon odour and locally with oily sheen
	3.10	Hydrocarbon odour, dark staining and oily sheen
WS302	2.00	Black staining and hydrocarbon odour
	3.00	Black staining and strong hydrocarbon odour
* Observations in *italics* signifies impact associated with the smear zone and therefore groundwater (i.e. not representative of unsaturated zone soils).		

For those Made Ground samples where contamination was observed, PID readings ranged between 2.7 – 55.9ppm. The presence of 'waste' materials such as ash and clinker were identified in a number of locations. Where recorded, limited amounts of these waste materials were present i.e. a significant thickness or accumulation of these materials was not recorded.

For those Natural Ground samples where contamination was observed, PID readings ranged from 55.1 – 293.6ppm. Soils recorded within the Lambeth Group and Thanet Sands were observed to be 'clean'. At CP303 and RH312, more visually significant contamination was observed within the sands and gravels, with an obvious oily substance noted and a very strong hydrocarbon odour. This was most notable in CP303 at 4.5m bgl and in RH312 at 6.1m bgl with PID readings at CP303 recording 1,779ppm and at RH312 recording 204.6ppm.

5.3.2 Groundwater

During Ramboll's groundwater sampling, varying degrees of visual and olfactory evidence of contamination was noted at most locations with the exception of RHA - RHD, RH303, RH306, RH313 and RH315. This is summarised in Table 5.4 below. A notable sheen was observed in the groundwater at CP303 and a slight sheen at RH312 and RH305. No free phase product (e.g. LNAPL or DNAPL) was observed to be present during Ramboll's groundwater sampling.

Table 5-4: Summary of Observations in Groundwater	
Exploratory Location	**Observations**
RHA	No visual or olfactory evidence of contamination.
RHB	No visual or olfactory evidence of contamination.
RHC	Groundwater has a slightly orangey-brown colour. No odour.
RHD	Groundwater has a slightly orangey-brown colour. No odour.

Table 5-4: Summary of Observations in Groundwater	
RH302	Very slight hydrocarbon odour on probe. Groundwater visually clean.
RH303	Groundwater has a slightly grey-brown colour. No odour.
RH304	Dark grey colour to groundwater. Slight organic odour.
RH305	Slight sheen on groundwater and a hydrocarbon odour.
RH306	Groundwater has a slightly orangey-brown colour. No odour.
RH308	Dark grey colour to groundwater. Slight organic odour.
RH309	Very slight hydrocarbon odour on interface probe. Groundwater visually clean.
RH310	Groundwater had a grey / black colour and a slight hydrocarbon odour.
RH311	Very slight hydrocarbon odour on interface probe. Groundwater visually clean.
RH312	Slight sheen on groundwater and a strong hydrocarbon odour.
RH313	No visual or olfactory evidence of contamination.
RH315	No visual or olfactory evidence of contamination.
CP303	Sheen on groundwater and a strong hydrocarbon odour.

6. HUMAN HEALTH ASSESSMENT

6.1 Assessment Approach

The main environmental legislation relating to contaminated land in the UK is Part 2A of the Environmental Protection Act 1990. The philosophy behind Part 2A is the contaminant-pathway-receptor linkage; for land to be contaminated all three aspects of this linkage must be present (i.e. a contaminant must be present and able to move along a pathway and impact a receptor).

Ramboll has derived generic assessment criteria (GAC) for the interpretation of soil and groundwater chemical analyses. The GAC are threshold, based screening criteria below which a significant risk is not considered to be present. Contaminants at concentrations above the GAC do not infer an unacceptable risk; rather that further assessment is required to more fully understand potential contamination risks (as discussed below).

6.2 Analytical Results

6.2.1 Soils

The soil analytical results obtained during this investigation have been screened against the Ramboll GAC for residential end use with no plant uptake. In general, the soil analytical results compare very well to field observations of contamination.

Exceedances of the Ramboll GAC are provided within Table 6.1 and a summary of the results is below:

The analytical certificates for soils are presented in full in Appendix 5. Exceedance of a Ramboll GAC does not infer that an unacceptable risk is present; the outcome of the screening is assessed further in the context of a qualitative source-pathway-receptor risk assessment presented in Section 10.

Table 6-1: Summary of Soil Exceedances

Determinand	No. of Samples	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg) and location (m bgl)	Ramboll GAC for Residential with no plant uptake (mg/kg)	No. of GAC Exceedances	Location of Exceedance
Metals						
Arsenic	60	3.7	330 RH305 0.6m	40	8	RHA 1.1m WS303 0.75m WS306 1.0m WS306 1.75m RH305 0.60m TP301 0.20m TP301 2.20m TP305 0.40m
Beryllium	60	0.31	9.6 TP305_0.4m	1.7	9	RHC 0.5m TP310 0.3m TP313 0.3m WS304 0.9m WS307 0.60m TP301 0.20m TP305 0.40m TP320 0.50m TP321 0.70m
Lead	60	3.3	6,400 TP305_0.4m	310	15	RHA 1.1m TP313 0.3m WS304 0.9m WS306 1.0m

Table 6-1: Summary of Soil Exceedances

Determinand	No. of Samples	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg) and location (m bgl)	Ramboll GAC for Residential with no plant uptake (mg/kg)	No. of GAC Exceedances	Location of Exceedance
						WS306 1.75m WS307 0.60m WS308 1.3m RH304 0.40m RH305 0.60m TP301 0.20m TP301 2.20m TP305 0.40m TP319 0.30m TP320 0.50m TP315 0.20m
Inorganics						
Cyanide	60	<LoD	1,500 TP301_0.2	49	8	TP327 0.35m WS304 0.9m WS306 1.0m WS306 1.75m TP301 0.20m TP301 2.20m TP319 0.30m TP321 0.70m
Total Petroleum Hydrocarbons (incl. BTEX & MTBE)						
Benzene	60	<LoD	0.34 TP301_2.2	0.15	1	TP301 2.2m

Table 6-1: Summary of Soil Exceedances

Determinand		No. of Samples	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg) and location (m bgl)	Ramboll GAC for Residential with no plant uptake (mg/kg)	No. of GAC Exceedances	Location of Exceedance
Aliphatics	C8-C10	60	<LoD	58 WS302 2.9m	13	1	WS302 2.9m
	C10-C12	60	<LoD	300 TP301_2.2m	62	2	WS302 2.9m TP301 2.2m
	C12-C16	60	<LoD	4,500 TP301_2.2	510	6	RH308 3.0m TP301 2.2m TP319 3.1m TP309 0.40m WS302 2.90m RH313 1.5m
Aromatics	C8-C10	60	<LoD	38 WS302 2.9m	20	1	WS302 2.9m
	C10-C12	60	<LoD	19,000 TP301_2.2	63	2	WS306 1.75m TP301 2.2m
	C12-C16	60	<LoD	41,000 TP301_2.2	1,100	3	WS306 1.75m WS302 2.9m TP301 2.2m
	C16-C21	60	<LoD	39,000 TP301_2.2	1,900	2	WS306 1.75m TP301 2.2m
	C21-C35	60	<LoD	18,000 TP301_2.2	1,900	2	WS306 1.75m TP301 2.2m
Polyaromatic Hydrocarbons							
Acenaphthylene		60	<LoD	2,400 TP301_2.2	2,000	1	TP301 2.20m

Table 6-1: Summary of Soil Exceedances

Determinand	No. of Samples	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg) and location (m bgl)	Ramboll GAC for Residential with no plant uptake (mg/kg)	No. of GAC Exceedances	Location of Exceedance
Benzo[a]pyrene	60	<LoD	300 TP301_2.2	5	14	TP313 0.3m TP327 0.35m WS302 2.9m WS303 0.75m WS304 0.9m WS306 1.75m RH304 0.4m TP301 2.2m TP301 0.2m TP319 0.7m TP320 0.5m RH312 0.5m TP312 1.9m TP321 0.7m
Fluorene	60	<LoD	2,900 TP301_2.2	2,200	1	TP301 2.2m
Naphthalene	60	<LoD	3,700 TP301_2.2	0.99	7	TP310 0.3m WS302 2.9m WS306 1.75m RH308 6.1m TP301 0.2m TP301 2.2m RH312 0.5m

Table 6-1: Summary of Soil Exceedances

Determinand	No. of Samples	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg) and location (m bgl)	Ramboll GAC for Residential with no plant uptake (mg/kg)	No. of GAC Exceedances	Location of Exceedance
Phenanthrene	60	<LoD	6,300 TP301_2.2	1,300	2	WS306_1.75 TP301_2.2
Volatile Organic Compounds						
Trimethylbenzene-1,2,4	28	<LoD	12 TP319_3.1	0.22	3	RH305_2.8 TP301_2.2 TP319_3.1
Trimethylbenzene-1,3,5	28	<LoD	12 TP301_2.2	0.079	3	RH305_2.8 TP301_2.2 TP319_3.1
Asbestos						
Asbestos Screen (quantification %)	36 (10)	<LoD	0.066% WS306 1.75m	Detect	10	RH302 0.5m (<0.001%) RHA 1.1m (<0.001%) RHC 0.5m (<0.001%) TP313 0.3m (0.014%) WS306 1.0m (0.019%) WS306 1.75m (0.066%) TP319 0.3m

Table 6-1: Summary of Soil Exceedances

Determinand	No. of Samples	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg) and location (m bgl)	Ramboll GAC for Residential with no plant uptake (mg/kg)	No. of GAC Exceedances	Location of Exceedance
						(<0.001%) RH312 0.5 (<0.001%) TP320 0.5m (<0.001%) HP302 0.5m (<0.001%)

Notes:

LoD – Limit of Detection

6.2.2 Groundwater (Human Health)

The groundwater analytical results obtained during this investigation have been screened against the Ramboll GAC for residential end use with no plant uptake. The exceedances recorded as part of the screening are summarised in Table 6.2 below.

Contaminants recorded in excess of the GAC relate to just two contaminants (naphthalene and trimethylbenzene-1,2,4) at three locations.

With the exception of mercury, there is no volatilisation pathway for inorganic determinands, and therefore metals are not included in Table 6.2. Groundwater analytical certificates are presented in Appendix 6.

Exceedance of a Ramboll GAC does not infer that an unacceptable risk is present; the outcome of the screening is assessed further in the context of a qualitative contaminant-pathway-receptor risk assessment presented in Section 10.

Table 6-2: Summary of Groundwater Analytical Results (Human Health)

Determinand	Conc. Range (µg/l)	Location of Max. Conc.	Ramboll Water GAC for Human Health (Residential) (µg/l)	Location of Exceedances
Polycyclic Aromatic Hydrocarbons				
Naphthalene	<LoD - 222	RH309	210	RH309
VOCs				
Trimethylbenzene-1,2,4	<LoD - 129	RH305	22.9	CP303 RH305

Notes:
LoD – Limit of Detection

6.3 Discussion of Results

6.3.1 Soils

Asbestos

Each sample from the Made Ground was analysed for the presence of asbestos fibres and asbestos was detected in a total of ten samples out of 36. No visual evidence of asbestos containing materials (ACM) was observed during the site investigation by Ramboll (although it is noted the driller's log recorded potential ACM). Where laboratory analysis identified the presence of asbestos, the relevant samples were scheduled for quantification.

The sampling and analysis demonstrates that asbestos was not identified across the site i.e. does not suggest the site is significantly impacted with the presence of asbestos. Additionally, where detected in quantifiable locations, asbestos concentrations were generally low (i.e. only three of ten samples recorded concentrations above LoD). The results were as follows:

- RH302 0.5m: detected as loose fibres of chrysotile, <0.001% quantification.
- RHA 1.1m: detected as loose fibres of crocidolite, <0.001% quantification.
- RHC 0.5m: detected as loose fibres of chrysotile and crocidolite, <0.001% quantification.
- TP313 0.3m: detected as loose fibres and loose fibrous debris of chrysotile and crocidolite, 0.014% quantification.
- WS306 1.0m: detected as loose fibrous debris of chrysotile, 0.019% quantification.
- WS306 1.75m: detected as 'hard/cement type material' and loose fibrous debris, 0.066% quantification.
- TP319 0.3m: detected as loose fibres of chrysotile, <0.001% quantification.
- RH320 0.5m: detected as loose fibres of chrysotile, <0.001% quantification.
- RH312 0.5m: detected as loose fibres of crocidolite, <0.001% quantification.
- HP302 0.5m: detected as loose fibres of chrysotile, <0.001% quantification.

Inorganics

Cyanide was recorded above the GAC (26mg/kg) in a number of locations with a maximum concentration of 1,500mg/kg recorded at TP301 (0.2m). The next highest concentration recorded as 190mg/kg also at TP301 2.2m. Free cyanide was recorded below LoD. The concentrations do not indicate that significant impact is present a site with a higher accumulation at TP301 (i.e. a hotspot of cyanide).

No elevated concentrations of ammonium (NH4), complex cyanide or thiocyanate were recorded in soils above the Ramboll GAC.

Phenols

Concentrations of phenols were generally below the LoD and where detected were low in concentrations, with the highest concentration of Ethylphenol & Dimethylphenol (8.3mg/kg) recorded at WS306 (1.75m). No exceedances of the Ramboll GAC were recorded.

Metals

The only metals recorded to exceed the GAC were lead, beryllium and arsenic, as follows:

- Lead: The highest concentration for lead was recorded at TP305 0.4m (6,400mg/kg). for context the next highest concentration was 1,000mg/kg at TP301 0.2m;
- Beryllium: was recorded at TP305 0.4m (9.6mg/kg); and
- Arsenic: was recorded at RH305 0.6m (330 mg/kg).

Exceedances of metals correlate with the presence of Made Ground. The concentrations recorded do not demonstrate site-wide impact from metals with most concentrations considered relatively 'typical' for Made Ground and do not appear to relate to a specific source.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs were detected across the site and at 16 locations were recorded in concentrations in excess of the Ramboll GACs. The highest concentrations of PAHs were consistently recorded at TP301 2.2m. The PAH compounds that recorded the highest concentrations were

- Naphthalene: recorded at TP301 (2.2m) at 3,700mg/kg with the next highest concentration of 83mg/kg at WS306 (1.75m).
- Phenanthrene: recorded at TP301 (2.2m) 6,300mg/kg with the next highest concentration of 2,000 mg/kg at WS306 (1.75m).
- A total PAH concentration of 23,100mg/kg was recorded at TP301 (2.2m). The next highest total PAH concentration recorded was 7,170mg/kg at WS306 1.75m. The highest PAH compound recorded at this location was phenanthrene (2,000mg/kg). WS303 (0.75) recorded a total PAH concentration of 1,410mg/kg, however all other total PAH concentrations were below 1,000mg/kg.

The concentrations recorded are consistent with the hydrocarbon impact and odours that were observed at this location. Significant site-wide impact was not identified with the highest concentrations focused at WS306 1.75m and TP301 2.2m.

Total Petroleum Hydrocarbons (incl. BTEX)

Concentrations of BTEX were generally low and all below the Ramboll GAC, with the exception of one benzene concentrations were recorded a concentration of 0.34mg/kg at TP301 2.2m.

TPH was recorded in concentrations in excess of the Ramboll GAC in a total of 12 locations. The fractions that recorded the most elevated concentrations were aromatic C12-C16 (41,000mg/kg) and aromatic C16-C21 (39,000mg/kg) at TP301 2.2m. The total TPH concentration for TP301 2.2m was recorded as 139,000mg/kg. The next highest total TPH concentration recorded was 22,400mg/kg at WS306 1.75m. The highest TPH fractions recorded at this location were aromatic C16-21 (8,700mg/kg) and aromatic C21-35 (6,500mg/kg).

Concentrations of TPH compounds that exceeded the GAC correlate with visual and/or olfactory evidence of soil impact recorded during the investigation works and appear to relate to the vicinity of the previously remediated area in the north of site (i.e. residual contamination or is outside of the remediation footprint) or a central area in the vicinity of the western site boundary and in the vicinity of the gasholder in the east of site.

Volatile and Semi-Volatile Organic Compounds

Concentrations of SVOCs and VOCs were generally below the laboratory limit of detection and where detected were low in concentration. Of the samples analysed only two samples exceeded the Ramboll GACs, they were:

- Trimethylbenzene-1,2,4 was recorded at concentrations above GAC at TP319 3.1m, RH305_2.8 and TP301_2.2. The maximum concentration was 12,000mg/kg at TP319_3.1.
- Trimethylbenzene-1,3,5 recorded at concentrations above GAC at TP319 3.1m, RH305_2.8 and TP301_2.2. The maximum concentration was 12,000mg/kg at TP301_2.2m.

Detections of VOCs were sporadic and not representative of a source area.

6.3.2 Phytotoxicity Assessment

As part of the proposed development soft landscaped areas are present. And as such the soil results have been subject to a phototoxicity assessment to determine the suitability of soils as a growing medium within soft landscaped areas.

The soil results for the phytotoxic metals copper, nickel and zinc are assessed against the respective thresholds for phytotoxic contaminants provided in 'Specification for topsoil and requirements for use' (British Standard 3882, 2015). Table 9.1 below provides a summary.

Table 9.3: Summary of Elevated Phytotoxic Contaminants in Soil

Determinand	GAC (pH>7)	No. of Samples	No. of Exceedances	Max Conc. (mg/kg)
Copper	200	57	3	1,500
Nickel	110	57	1	150
Zinc	300	57	14	1,900

Notes: the GAC is pH dependent, typical pH is 9.0 so the GAC for pH>7 has been adopted.

Exceedances of copper and zinc, including additional physical parameters (including the known presence of asbestos fibres) make the Made Ground soils unsuitable to be used as a growing medium within the soft landscaped areas.

6.3.3 Groundwater (Human Health)

There was a limited number of contaminants concentrations detected in groundwater that exceeded the Ramboll GAC for human health (Controlled Waters discussed in the next section). In total only two contaminants were detected above the GAC at three locations, as detailed below:

Polycyclic Aromatic Hydrocarbons (PAHs)

One PAH compound was recorded above the GAC, Naphthalene at RH309 recorded a concentration of 222µg/l which marginally exceeded the GAC of 220µg/l. Given the marginal exceedance, the concentration is not considered to represent a significant risk.

Volatile Organic Compounds

Similar to the soils, VOC above the GAC was limited to Trimethylbenzene-1,2,4 which recorded concentration of 129µg/l at RH305 and 43.1µg/l at CP303, above the GAC of 24µg/l. Again, this is not considered a significant risk as it is isolated and only marginally elevated.

6.3.4 Invasive Species

Giant Hogweed has been recorded within the south of the site. Ramboll understands that the Client's ecologist (Ecology Services) has developed a strategy for the removal of the invasive species as part of the redevelopment of the site. Invasive are not considered further in this report.

6.3.5 Construction Workers

This report and the generic assessment criteria (GAC) consider long term and chronic risk to humans based on defined exposure scenarios set out in the Contaminated Land Exposure Assessment (CLEA) model. In some cases contaminants may also pose acute hazards to workers at a site, or a worker's exposure scenario may differ from the scenarios considered when deriving the GAC.

As exposure times for construction workers are generally short term, risks from site contamination are generally addressed through the use of appropriate working procedures and the use of personal protective equipment (PPE) in line with the Management of Health and Safety at Work Regulations (1999), Construction (Design and Management) Regulations (2015) for some sites and the Control of Substances Hazardous to Health Regulations (2002). This potential source-pathway-receptor linkage is considered further in section 8.

7. WATER ENVIRONMENT ASSESSMENT

7.1 Assessment Approach

In the absence of relevant published water assessment criteria, the potential risk to the aquatic environment from entry of pollutants (either directly or via a groundwater pathway) has been assessed using commonly accepted UK guidelines including the Water Supply (Water Quality) (England) Regulations 2000 (DWS) and the Environmental Quality Standards (EQS) defined in European legislation such as the Water Framework Directive (WFD) (2000/60/EC).

For those determinands included in the analytical suite which do not have a corresponding UK screening criteria derived from the above sources, reference is made to a hierarchy of international guidance in accordance with Environment Agency guidance.

Whilst there is a stream located in the south of site, it is culverted and therefore considered not to be in continuity with the groundwater. As such, GACs relevant to the protection of groundwater (i.e. DWS) have been used in the first instance, and where relevant GACs are not present, GACs relevant to protection of surface waters (i.e. EQS) have been utilised.

7.2 Analytical Results

The exceedances recorded as part of the screening are summarised in Table 7.1. Analytical certificates for groundwater are presented in Appendix 6.

Exceedance of screening criteria does not infer that an unacceptable risk is present; the outcome of the screening is assessed further in the context of a qualitative contaminant-pathway-receptor risk assessment presented in Section 10.

Table 7-1: Summary of Groundwater Analytical Results (Controlled Waters)

Determinand	Conc. Range (µg/l)	Location of Max. Conc.	Ramboll Controlled Waters GAC (µg/l)	No. and Location of Exceedance
Inorganic Compounds				
Ammoniacal Nitrogen	400 – 16,000	RH308	300 [E]	16 (CP303, RH302, RH303, RH304, RH305, RH308, RH309, RH310, RH311, RH313, RH315, RHA, RHB, RHC. RH306, RHD)
Cyanide	<LoD – 330	RHA	50	8 (RH303, RH304, RH308, RH310, RH311, RH313, RHA, RH312)
Sulphate (SO4)	24.5 – 738	RH310	250	3 (RH308, RH310, RHA)
Heavy Metals				
Iron	0.02 – 0.57	RH305	0.2	6 (RH302, RH303, RH305, RH308, RH310, RHA)
Polycyclic Aromatic Hydrocarbons				
Naphthalene	<LoD – 220	RH309	2 (D)	2 (RH305, RH309)
Phenanthrene	<LoD - 23	CP303	5 (C)	1 (CP303)
Anthracene	<LoD – 3.30	CP303	0.1	4 (CP303, RH309, RH310, RHD)
Total Petroleum Hydrocarbons				
TPH Aliphatic C12 – C16	<LoD – 280	RH305	10	3 (CP303, RH305, RH312)
TPH Aliphatic C16 – C21	<LoD – 810	CP303	10	3 (CP303, RH305, RH312)
TPH Aliphatic C21 – C35	<LoD – 1,200	CP303	10	3 (CP303, RH305, RH312)

Table 7-1: Summary of Groundwater Analytical Results (Controlled Waters)

Determinand	Conc. Range (µg/l)	Location of Max. Conc.	Ramboll Controlled Waters GAC (µg/l)	No. and Location of Exceedance
TPH Aromatic C8 – C10	<LoD – 550	CP303	10	4 (CP303, RH305, RH309, RH312)
TPH Aromatic C10 – C12	<LoD – 790	RH309	10	6 (CP303, RH305, RH308, RH309, RH310, RH312)
TPH Aromatic C12 – C16	<LoD – 600	RH309	10	7 (CP303, RH305, RH308, RH309, RH310, RH312, RHD)
TPH Aromatic C16 – C21	<LoD – 1,600	CP303	10	5 (CP303, RH305, RH309, RH312, RHD)
Benzene	<LoD – 180	CP303	1	4 (CP303, RH305, RH310, RH312)
Volatile Organic Compounds				
Styrene	<LoD – 36.9	RH309	20	1 (RH309)

Notes:

Environmental Quality Standards (EQS) based on Priority Substances (Directive 2008/105/EC) daughter directive of the Water Framework Directive (WFD) (2000/60/EC) Annex VIII. In the absence of an EQS the following criteria has been used:

A – UK Drinking Water Standards

B - Regional Screening Level for Tapwater (US EPA, April 2009)

C – Dutch Intervention Values, 2009 UK Drinking Water Standards

D – EQS for List II substances (non-statutory)

E – WFD classification for surface water

NC – No criteria available

N/A – Not applicable

LoD – Limit of Detection

7.3 Discussion of Results

Inorganics

Ammonium was detected above the GAC in all groundwater samples collected from across the site with the exception of RH312. The maximum concentration recorded at RH308 (16,000µg/l). There is not one area of the site where high concentrations are focussed, but a spread across the site. Given the relatively limited gas works infrastructure on the subject site, in comparison to the 'heaviest' gas works usage (and the most contaminative) undertaken on the wider gas works to the west, the presence of ammonium cannot be attributed solely to the subject site, but is considered to be reflective of background groundwater conditions given the historical presence of the wider Lea Bridge Gas Works site.

Cyanide was detected in all groundwater samples across the site with the exception of RH309, RHB, RHC and RHD. Cyanide was recorded in concentrations exceeding the Ramboll GAC at eight locations. The maximum concentration was at RHA (330µg/l). Six of these eight locations are located along the western boundary of the site and as such it is considered likely that the presence of the elevated concentrations is attributable to the historical wider gas works site. (i.e. off-site sources).

Sulphate was detected in all groundwater samples across the site, exceeding the Ramboll GAC at three locations; RH308, RH310 and RHA. The maximum concentration was recorded at RH310 (738µg/l).

Heavy Metals

Concentrations of nickel, chromium, copper, zinc, lead, arsenic, boron and cadmium were noted to be detected across the site but below the Ramboll GACs. Iron was detected across the site and in excess of the Ramboll GAC at six locations in the north and western portions of the site. The highest concentration was recorded at location RH305 (0.57µg/l), above a GAC of 0.2µg/l.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs were noted to be detected in groundwater across the site and in four locations were recorded in concentrations in excess of the Ramboll GACs, all consistent with visual and olfactory evidence of hydrocarbon contamination in the soils and groundwater at these locations.

The PAH compounds that recorded the highest concentrations were naphthalene (220µg/l at RH309) with the next highest concentration of acenaphthene (40µg/l) at this location. High concentrations of naphthalene are consistent with soil laboratory results and observations of staining and hydrocarbon odours in soil samples at these locations.

The concentrations of PAHs do not suggest a significant site wide issue, but of localised impact. The majority of elevated concentrations of PAHs were recorded at CP303 in association with identified groundwater impact adjacent to the gas holder in the east of site, RH309 located adjacent to the gas holder in the centre of site, RH305 located in the area of previous remediation and RH309 on the western site boundary. At CP303, these concentrations are consistent with a sheen on the groundwater and a strong hydrocarbon odour. At RH309, the concentrations are consistent with a slight hydrocarbon odour in the groundwater.

Total Petroleum Hydrocarbons (incl. BTEX)

Petroleum hydrocarbon concentrations were recorded in concentrations in excess of the Ramboll GAC in a total of seven locations (CP303, RH305, RH309, RH308, RH310, RH312 and RHD). These elevated concentrations were consistent with observations of hydrocarbon odours within the groundwater and a sheen on samples collected at CP303 and RH305. The fractions that recorded the most elevated concentrations were aromatic C16 -C21 (1,600µg/l) and aliphatic C21

–C35 (1,200µg/l) at CP303. At all seven locations, observations of black staining and a hydrocarbon odour in sands and gravels was also noted during drilling.

The elevated concentrations mostly correlate both with recorded soil concentrations. The most impacted relate to CP303 and RH305. Similar to the concentrations of PAHs, the TPH concentrations do not suggest a significant site wide issue, but of localised impact.

Concentrations of benzene were found above the Ramboll GAC at three locations; CP303, RH305 and RH310. The maximum concentration of benzene was recorded at CP303 (180µg/l).

Petroleum hydrocarbon concentrations below the LoD were recorded in nine groundwater samples. Of note is the absence of elevated concentrations in the RH313 and RH315, considered to be the downgradient boreholes on site, suggesting that significant off-site migration of contaminants is not present.

A figure showing TPH concentrations are provided in Appendix 1.

Volatile and Semi-Volatile Organic Compounds

Concentrations of SVOCs and VOCs were generally below the laboratory limit of detection and where detected were low in concentration. Of the samples analysed only one sample exceeded the Ramboll GACs. Styrene was recorded at a concentration of 36.9µg/l at RH309, marginally above the Ramboll GAC of 20µg/l. This is not considered significant.

8. BUILT ENVIRONMENT ASSESSMENT

8.1 Ground Gases

8.1.1 Assessment Approach

Ground gases can be produced as a result of the decomposition of organic materials and may also originate from natural sources, such as coal seams and organic-rich soils. The principal components of ground gas are methane and carbon dioxide, although other gases may be present in trace concentrations. Ground gas can present a hazard to site occupants and property as result of flammable / explosive hazards, physiological effects, odour and effects on vegetation.

Ramboll has applied a semi-quantitative method in line with current good practice guidance on risk assessment to assess ground gas risks.

8.1.2 Discussion of Results

Atmospheric Pressure

Monitoring round 1 was undertaken under low atmospheric pressure conditions, with the atmospheric pressure stable in the 24 hours prior to the monitoring.

Flow Rates

There was no flow recorded in any of the boreholes during the monitoring rounds.

Methane and Carbon Dioxide

Carbon dioxide concentrations ranged from 0.1% to 8.8% by volume. The highest concentrations were recorded in RH302 (north of the site). Other areas of elevated carbon dioxide concentrations were WS308 (south of the site) and WS304 (north-centre of the site).

Detectable concentrations of methane were recorded in WS302, WS304 and RH302, all in the northern portion of the site, at concentrations ranging from 1% to 11.3% by volume. In the remaining boreholes, methane was recorded to be <0.1% by volume (i.e. below the instrument detection limit).

Oxygen

Oxygen concentrations varied from 0% by volume in WS302, RH302 and WS304 to 20.2% by volume in WS307 (south-east of the site). Oxygen levels were recorded to be below 18% by volume in six out of eight monitoring wells indicating depleted oxygen concentrations beneath the site. The lowest oxygen levels generally correspond with the highest recorded methane and carbon dioxide concentrations and is likely to be a result of the higher carbon dioxide and methane concentrations displacing the oxygen.

Volatile Organic Compounds

The ground gas monitoring has identified elevated VOC concentrations (measured with a PID in the monitoring wells) at concentrations ranging between 0.5 and 39.9ppm. The highest concentrations were recorded in WS302 and WS301.

8.1.3 Initial Site Gas Screening Value (SGSV)

Ramboll has used the Modified Wilson and Card method to define a characteristic situation for the site, by calculating a site Gas Screening Value (SGSV). The SGSV is calculated using a worst-case scenario (i.e. the maximum gas concentration and flow rates detected) across the entire site during the monitoring period. The SGSV is calculated for both methane and carbon dioxide, and

the 'Characteristic Situation' is derived by comparison with a table relevant to each method. It is important to note that SGSVs are not absolute thresholds but guideline values.

The initial carbon dioxide SGSV for the site has been calculated as 0.0088 l/hr by multiplying the maximum carbon dioxide concentration (8.8% in RH302) by the highest steady state flow rate (0.1 l/h i.e. the limit of detection as they were no flow recorded). This corresponds to CIRIA C665 Characteristic Situation 1 (very low risk). However, guidance states to consider the application of Characteristic Situation 2 (low risk) where carbon dioxide concentrations are above 5%.

The initial calculated SGSV for methane (using the same method) has been calculated as 0.0113 l/hr by multiplying the maximum methane concentration (11.3% at WS302) by 0.1 l/hr. This corresponds to CIRIA C665 Characteristic Situation 1 (very low risk). However, guidance states to consider the application of Characteristic Situation 2 (low risk) where methane concentrations are above 1%.

8.1.4 Summary

From the data set, gas protection measures are required for proposed developments , primarily due to the elevated concentrations of carbon dioxide and methane. Ground gas has been assessed to represent a low risk (Characteristic Situation 2 – CS2) at site and on the basis of the data appropriate gas protection measures in-line with BS8485:2015 would be required as part of a future residential development.

8.2 Water Supply Pipes

Buried water supply pipes can be at risk from permeation and accelerated deterioration from certain contaminants. A detailed assessment of existing and future pipe materials is outside of the scope of this investigation; however, architects and designers should liaise with the local water supply company and are directed to the following document for guidance:

- Guidance for the Selection of Water Supply Pipes to be used in Brownfield sites; UK Water Industry Research (UK WIR), 2010 (Ref. 10/WM/03/21).

8.3 Building Materials

There are a number of contaminants that may attack some building materials under certain conditions if present. The focus of this investigation is to assess risks to human health and environmental receptors and no assessment has been made of impact to building materials.

9. PRELIMINARY WASTE ASSESSMENT

9.1 Introduction

It is likely that there will be a requirement for material requiring disposal off-site due to pile arisings and external works. As such, a preliminary waste classification assessment has been conducted as part of this report. This waste classification is based on discrete samples from different horizons in the ground. Any Contractor using this information must fully understand where the samples were from in relation to waste that it generates. The Contractor should prepare its own methodologies on how it will classify waste and cannot rely solely on this assessment.

9.2 Methodology

The assessment has been undertaken using available soil chemical data and HazWasteOnline, a web-based tool for classifying waste. The software utilises Environment Agency guidance and European regulations to classify samples in line with current requirements.

9.3 Soils Assessment

All samples collected during the ground investigation were entered into the HazWasteOnline assessment tool. The HazwasteOnline output sheets are provided in Appendix 7.

Table 9.1: Summary of Waste Classification

Exploratory Hole	Depth (mbgl)	Waste Classification	Hazardous Properties
CP303	0.25	Non-Hazardous	
CP303	2.6	Non-Hazardous	
RHA	1.1	Non-Hazardous	
RHC	1.2	Non-Hazardous	
RHC	0.5	Non-Hazardous	
CP303	0.8	Non-Hazardous	
WS302	1.2	Non-Hazardous	
WS308	1.3	Non-Hazardous	
WS302	2.9	Non-Hazardous	
RHA	2.2	Non-Hazardous	
WS302	0.4	Non-Hazardous	
RH302	0.5	Non-Hazardous	
WS307	0.6	Non-Hazardous	
WS308	0.3	Non-Hazardous	
RH303	0.35	Non-Hazardous	
TP307	0.3	Non-Hazardous	
TP307	2.8	Non-Hazardous	

Table 9.1: Summary of Waste Classification			
TP309	0.4	Non-Hazardous	
TP310	0.3	Non-Hazardous	
TP313	0.3	Hazardous	HP 7, HP 11, HP 14
TP316	0.75	Non-Hazardous	
TP327	0.35	Non-Hazardous	
WS303	0.75	Non-Hazardous	
WS303	2.4	Non-Hazardous	
WS304	0.9	Non-Hazardous	
WS306	1.0	Non-Hazardous	
WS306	1.75	Hazardous	HP 14
WS307	2.9	Non-Hazardous	
TP320	1.7	Non-Hazardous	
TP305	0.4	Hazardous	HP 7, HP 10, HP 11, HP 14
RH308	3.0	Non-Hazardous	
RH305	1.5	Non-Hazardous	
RH310	2.2	Non-Hazardous	
TP319	3.1	Non-Hazardous	
RH308	6.1	Non-Hazardous	
TP319	0.3	Non-Hazardous	
RH304	0.4	Non-Hazardous	
RH310	0.75	Non-Hazardous	
RH304	6.6	Non-Hazardous	
RH304	4.5	Non-Hazardous	
RH303	1.1	Non-Hazardous	
TP301	0.2	Hazardous	HP 6, HP 7, HP 11, HP 12, HP 14
TP320	0.5	Non-Hazardous	
TP301	2.2	Hazardous	HP 6, HP 14
TP319	0.7	Non-Hazardous	

Table 9.1: Summary of Waste Classification			
RH305	0.6	Non-Hazardous	
RH315	0.5	Non-Hazardous	
TP305	2.3	Non-Hazardous	
RH305	2.8	Non-Hazardous	
CP305	9.5	Non-Hazardous	
RH311	3.5	Non-Hazardous	
RH312	0.5	Non-Hazardous	
TP312	1.9	Non-Hazardous	
TP321	0.7	Non-Hazardous	
TP315	0.2	Hazardous	HP 14
RH313	1.5	Non-Hazardous	
RHB	2.6	Non-Hazardous	
WS301	0.5	Non-Hazardous	
RH312	4.0	Non-Hazardous	
HP302	0.5	Non-Hazardous	
Notes HP3(i) = Flammable, HP6 = Acute toxicity , HP7 = Carcinogenic, HP8 = Corrosive, HP10 = Toxic for reproduction, HP11 = Mutagenic, HP12 = Release of an acute toxic gas and HP14 = Ecotoxic			

9.4 Asbestos

Although no visual evidence of asbestos containing materials (ACM) was observed during the site investigation by Ramboll (drillers log notes potential ACM at one location), ten of 36 samples were found to contain asbestos by the laboratory analysis. Where laboratory analysis identified the presence of asbestos, the relevant samples were scheduled for quantification of asbestos by weight.

Where waste contains identifiable pieces of asbestos (i.e. any particle of a size than can be identified as potentially being asbestos by a competent person by the naked eye), then the asbestos must be assessed separately.

The Hazardous Waste (England and Wales) Regulations 2005 requires that any waste having an asbestos (ACM) content greater than 0.1% w/w be classified as Hazardous Waste. Any waste with an asbestos content of less than 0.1% w/w can be classified as non-hazardous waste, unless there are other contaminants present which would make the waste hazardous. Additionally, if the waste contains fibres that are free and dispersed then the waste will be hazardous if the waste as whole contains 0.1% w/w or more asbestos.

The highest concentration was recorded at WS306 1.75m 0.066%. Which is below the hazardous 0.1% threshold. Note: quantification for HP302 is awaited.

Where the asbestos is deemed to be of a fibrous nature (free fibres and fibre bundles), such as in the case of this investigation, the Health and Safety Executive (HSE) require that the handling of the material is undertaken by a suitably licensed company. The Carriage of Dangerous Goods (etc.) Regulations 2009 (CDG2009) applies in this instance.

9.5 Summary

The results of the preliminary waste assessment suggest that for the most part the soil encountered are likely to be classified as non-hazardous waste. Where hazardous soils were identified they ranged from 0.2m to 2.2m due to elevated concentrations of metals, TPHs and PAHs and cyanide.

On this basis in the vicinity of the identified hazardous soils it may be preferable to locally excavate and segregate the upper 2.0 – 2.5m of soils ahead of piling or other works to minimise the risk of condemning the entire length of pile arisings as hazardous waste.

Shallow excavations for utilities and foundations etc are likely to be within the upper 1.5m and as such will likely produce soils classified as hazardous waste.

In addition, given the inherent heterogeneity of Made Ground, the identified hydrocarbon soil impact and the detections of asbestos on site, it would be prudent to make a provisional allowance for encountering or suspecting the presence of previously unidentified ground contamination. During redevelopment a 'Hotspot Protocol' will need to be implemented to allow groundworkers to act appropriately in this scenario. Contractor vigilance and specialist advice is advised along with further asbestos quantification testing to determine the appropriate waste stream for materials requiring disposal.

Note that the indicative waste classifications provided as a part of this assessment should be confirmed by any receiving facility prior to disposal, under Duty of Care, following discussions with the producer of the waste. Additional WAC analysis is likely to be required to be undertaken by the contractor prior to disposal, under current legislative requirements post excavation.

Given that net import of material is envisaged due to the requirement to infill the remnants gas holder bases there is an opportunity for soil re-use on site. Re-use of site won materials is considered to be the most sustainable solution for material management and should it be possible to reuse any materials on site, consideration should be given to the risk to human health and the environment that any such material may pose as part of its new use. This could be under for example, the provisions of the CL:AIRE Definition of Waste: Development Industry Code of Practice (DoW COP).

10. SOURCE-PATHWAY-RECEPTOR RISK ASSESSMENT

10.1 Revised Conceptual Site Model

Using information obtained during this site investigation, the preliminary conceptual site model presented in Section 4.1 has been refined and is described in Table 10.1 below.

Table 10.1: Revised Conceptual Site Model

Sources of Contamination

On the basis of this site investigation, the following contaminants have been identified at elevated concentrations on site within soils and groundwater:

Soils:

- Quantifiable asbestos recorded within the Made Ground
- Elevated concentrations of metals within Made Ground
- Limited concentrations of cyanide within Made Ground
- PAHs, petroleum hydrocarbons within Made Ground and Natural Soils
- Limited volatile contaminants in shallow soils
- Ground gas (methane and carbon dioxide) have been detected
- Presence of Giant Hogweed in the south of site

Groundwater:

- Naphthalene and trimethylbenzene above GAC for protection of human health
- Ammonium identified across the site in groundwater
- Concentrations of cyanide predominately located in the west of site
- Metals concentrations located in central and west of site
- Petroleum hydrocarbons (incl. benzene) and PAH concentrations within groundwater
- Elevated styrene concentration at one location

Potential Contaminant Linkages The following potential pollutant linkages have been identified at the site and are considered further in the qualitative risk assessment:			**Potential Contaminant Linkage**
Human Health (Future Residential Users and construction workers)	On-site	Dermal contact & ingestion	PCL1
		Inhalation – dust and asbestos fibres	PCL2
		Inhalation – volatile organic compounds	PCL3
Water Environment	On-site	Leaching of contaminants from the unsaturated zone to groundwater	PCL4
	Off-site	Migration of contaminated groundwater to off-site watercourses	PCL5
Built Environment	On-site	Migration of vapours ground gases into buildings and structures	PCL6

10.2 Qualitative Risk Assessment

The principal sources of contamination, receptors and potential pollutant linkages have been assessed using a qualitative source-pathway-receptor approach and are summarised in Table 10.2 below. A pictorial CAM is provided in Appendix 1.

Table 10.2: Qualitative Risk Assessment – Residential Site Use without Plant Uptake					
Potential Contaminant Linkage	**Contaminant**	**Pathways**	**Receptors**	**Discussion**	**Risk**
PCL1	Asbestos, metals, PAHs, TPH and VOCs in Made Ground and Natural Soils. Giant Hogweed	Dermal Contact, Ingestion	Future site Users	**Future Residential Users** The proposed development plan comprises apartment blocks i.e. building cover with areas of external hardstanding; this will cap the underlying contaminants and as such there is not considered to be a pathway between the contaminant and future site users. Where landscaping is proposed, these areas will require mitigation. The mitigation would be expected to comprise the installation of a cover system, including a geotextile membrane to prevent soil mixing as well as an appropriate depth of imported 'clean' topsoil. A separate strategy will be developed by the Client's ecologist for the removal of the Giant hogweed as part of the site's redevelopment.	**Low**, assuming appropriate mitigation measures and re-use of Made Ground materials
				Construction workers Precautionary control measures, such as basic personal protective equipment and good hygiene practices should be maintained. As would be expected on brownfield development sites.	**Low,** assuming the use of appropriate hygiene and protective measures
PCL2	Asbestos, Inorganics, PAHs, TPH and VOCs in soils	Inhalation - volatilisation or dust and asbestos fibres	Future site Users	**Future Residential Users** Asbestos was recorded in quantifiable concentrations is ten locations. Hydrocarbons (PAHs, TPH and VOCs) were detected in soils, however, many of the highest concentrations were recorded at depths over 1m. Where the highest hydrocarbon concentrations are recorded correlate with areas that will likely require remediation from a controlled waters perspective. However, a quantitative risk assessment should be undertaken for the contaminants that exceed the GAC in order to confirm if mitigation and or remediation is necessary. The presence of asbestos is not considered to be a risk given that the cover system referenced above comprising a geotextile membrane and the installation of 'clean' topsoil in addition to the presence of building over and areas of hardstanding will provide a barrier that will prevent a pathway from the contaminants within the soils to the future site users. As per the point made above, if soils are to be re-used on site they must be done under an appropriate materials management plan and must demonstrate they do not pose a risk to future site users or controlled waters.	**Medium**, a human health vapour risk assessment should be undertaken to inform on mitigation or remediation measures necessary for the protection of human health.

Table 10.2: Qualitative Risk Assessment – Residential Site Use without Plant Uptake					
Potential Contaminant Linkage	**Contaminant**	**Pathways**	**Receptors**	**Discussion**	**Risk**
PCL3	Naphthalene and trimethylbenzene identified in groundwater	Volatilisation	Future site Users	**Construction Workers** The use of appropriate risk assessment and working procedures, such as PPE where necessary (usually incorporated into the Construction Environment Management Plan (CEMP) will mitigate risks to workers.	**Low**, assuming the use of appropriate control measures
				Contaminants have been identified in excess of the GAC from a volatilisation pathway. Naphthalene was recorded at 222µg/l which only just exceeds the GAC of 220µg/l. Given such a minimal exceedance and the isolate nature of concentration a significant risk is not considered to be present. Furthermore, the naphthalene concentration was recorded at RH309 where groundwater mitigation and/or remediation is considered to be required, which will in turn reduce risks from a volatilisation perspective. As part of the recommended quantitative risk assessment required for human health, it is recommended that the potential risks posed from trimethylbenzene is assessed further to confirm if mitigation / remediation is required. As above, the concentrations of trimethylbenzene were recorded at locations where groundwater remediation is likely to be undertaken and this should eb factored into the quantitative risk assessment.	**Low**, a human health vapour risk assessment should be undertaken to inform on mitigation or remediation measures necessary for the protection of human health.
				Construction Workers The use of appropriate risk assessment and working procedures, such as PPE where necessary (usually incorporated into the Construction Environment Management Plan (CEMP) will mitigate risks to workers.	**Low**, assuming the use of appropriate control measures
PCL4	TPH, PAHs and VOCs identified in soil	Leaching of contaminants in unsaturated zone	Groundwater in the underlying aquifers	Localised elevated concentrations of TPH, PAHs and VOCs were identified in soils that may be in concentrations that could pose a risk to controlled waters. Mitigation or remediation may be required to remove or treat soils in order to mitigate risks to controlled waters. As mentioned above, if soils are to be re-used on site they must be done under an appropriate materials management plan and must demonstrate they do not pose a risk to future site users or controlled waters. A DQRA will provide the criteria the soils must meet to demonstrate they do not pose an unacceptable risk.	**Medium**, a detailed quantitative risk assessment should be undertaken to inform on mitigation or remediation measures necessary for the

Table 10.2: Qualitative Risk Assessment – Residential Site Use without Plant Uptake

Potential Contaminant Linkage	Contaminant	Pathways	Receptors	Discussion	Risk
					protection of controlled waters.
PCL5	Metals, inorganics, PAHs, TPH and VOCs identified in groundwater	Lateral Migration via groundwater	Groundwater in the underlying aquifers, on and off-site surface water receptors	Contaminants have been identified within the groundwater at concentrations that may pose a risk to controlled waters. Whilst concentrations of metals and inorganics do not appear to relate one source and potentially may be reflective of background water quality, the TPH, PAH and VOC concentrations do not appear site wide and attributable to particular areas of the site. The concentrations TPH, PAH and VOCs do not suggest a significant site wide issue, but of localised impact and furthermore, the concentrations appear to be limited in terms of potential off-site migration, however, a Detailed Quantitative Risk Assessment will be required to determine if the concentrations do pose a risk and therefore require remediation. It is envisaged that a degree of remediation of groundwater will be required and the DQRA will inform the extent of this. In terms of risks to surface water receptors, the culvert on site is not considered to be in continuity with the groundwater. The nearest surface water feature is approximately 49m south-west of site which appears to connect the River Lea flood relief channel (approximately 220m south-west of site) to the Dagenham Brook, approximately 250m north-east of the site. This appears dry according to satellite imagery. As such it is considered that this lowers the potential risk to surface water receptors, however, a DQRA will inform further on this risk and subsequent actions i.e. remediation.	**Medium**, a detailed quantitative risk assessment should be undertaken to inform on mitigation or remediation measures necessary for the protection of controlled waters.
		Vertical Migration via groundwater	Groundwater in the underlying aquifers and off-site controlled waters (public water supply abstraction)	The identified contaminants in groundwater pose a potential risk to more sensitive groundwater at depth (Principal aquifer) and the associated public water abstraction. However, impact to groundwater was identified in the shallow superficial aquifer and the presence of the Lambeth Group (in which contamination was not identified), which is of lower permeability and thickness (over 10m), will offer a degree of protection to the underlying Chalk aquifer. Developmental activities such as piling still pose a risk to the deeper geology and groundwater due to the potential to create pathways for contaminants or to drag	**Low**, assuming a FWRA is completed.

Table 10.2: Qualitative Risk Assessment – Residential Site Use without Plant Uptake					
Potential Contaminant Linkage	**Contaminant**	**Pathways**	**Receptors**	**Discussion**	**Risk**
				contaminants down. Therefore, if piling is required, a foundation works risk assessment (FWRA) will be required.	
PCL6	Ground gases	Lateral and vertical migration	Future site Users and Built Environment	Results of the ground-gas monitoring completed to date indicate the site to be Characteristic Situation (CS) 2, given the presence of carbon dioxide above 5% and methane above 1%. In this scenario basic gas protection measures will be required. On the basis of the data appropriate gas protection measures in-line with BS8485:2015 would be required as part of a future residential development.	**Low**, assuming mitigation installed as part of development

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 Summary

Ramboll's investigation targeted historic sources of contamination, previously remediated areas and general site coverage in order to undertake an appropriate environmental assessment. The findings and conclusions of the investigation are outlined below.

Soils (Human Health)

The investigation has identified elevated concentrations of typical contaminants for a historic gas works site including, metals (arsenic, beryllium, lead), inorganics (cyanide), PAHs, TPH and VOCs (petroleum hydrocarbons). The presence of TPH and PAH impact correlate with field evidence (visual / olfactory) of impact. Asbestos was identified in quantifiable concentrations in ten locations with the highest concentration recorded as 0.066% at WS306 (1.75m).

Mitigation is required to reduce risks from those contaminant concentrations above the GACs. Much of the mitigation will be offered by the proposed development plan, comprising apartment blocks i.e. building cover with areas of external hardstanding. This presence of this hardstanding and building cover will cap the underlying contaminants and as such 'break' the pathway between the contaminant and future site users. Where landscaping is proposed, these areas will require mitigation. The mitigation would be expected to comprise the installation of a cover system, including a geotextile membrane to prevent soil mixing as well as an appropriate depth of imported 'clean' topsoil. **Mitigation Recommended.**

However, a detailed quantitative risk assessment should be undertaken for the contaminants that exceed the GAC from a volatilisation pathway (TPH, PAH, VOCs) in order to confirm if mitigation and or remediation is necessary. **Vapour Risk Assessment Recommended.**

If soils are to be re-used on site they must be done under an appropriate materials management plan and must demonstrate they do not pose a risk to future site users or controlled waters.

Soils (Controlled Waters)

Whilst mobile contamination (e.g. free phase product) was not identified during the investigation, significant impact was identified within the soils that may pose a risk to controlled waters. Impact to groundwater has previously been identified by third-parties and Ramboll's investigation confirmed this, as such groundwater remediation may be required which will include a detailed quantitative risk assessment. As part of the DQRA, the potential risk from elevated soil concentrations should be assessed to inform if mitigation and or remediation is required in soils for the protection of controlled waters. **Quantitative Risk Assessment Recommended.**

Groundwater (Human Health)

There were just two contaminants that exceeded the GAC for protection of human health; naphthalene and trimethylbenzene. Given naphthalene only just exceeded the conservative GAC, the concentration is not considered to pose a significant risk, plus groundwater remediation is expected at this location, which will reduce the concentrations.

Trimethylbenzene was also identified marginally above the GAC, however, given the exceedances are isolated and marginal exceedances of the conservative GAC, the concentrations are not considered to pose a significant risk to the proposed development.

Groundwater (Controlled Waters)

Contaminants in groundwater have been recorded in concentrations that may pose a risk to controlled waters. Whilst the concentrations do not appear site wide and appear to be suggest that significant off-site contaminant migration is not occurring, a Detailed Quantitative Risk

Assessment will be required to determine if the concentrations recorded therefore require remediation in order to reduce risks. It is envisaged that a degree of remediation of groundwater will be required and the DQRA will inform the extent of this.

In terms of risks to surface water receptors, the nearest surface water feature is approximately 49m south-west of site which appears to connect the River Lea flood relief channel (approximately 220m south-west of site) to the Dagenham Brook, approximately 250m north-east of the site. This appears dry according to satellite imagery. As such it is considered that this lowers the potential risk to surface water receptors, however, a DQRA will inform further on this risk and subsequent actions i.e. remediation. **Quantitative Risk Assessment Required.**

Ground Gas

From the information obtained to date, ground gas has been assessed to represent a low risk (Characteristic Situation 2 – CS2) at site and on the basis of the data appropriate gas protection measures in-line with BS8485:2015 would be required as part of a future residential development. **Mitigation Required.**

11.2 Conclusion

In Ramboll's experience, the contamination identified at Lea Bridge Gas Works is relatively modest in comparison with many other gas works. Hotspots of contamination have been identified that were visually obvious and confirmed by chemical testing of the soil and groundwater. Industry standard remediation techniques are likely to be appropriate to mitigate risks from the identified contamination.

Sensitive environmental receptors that will drive remediation include groundwater within the shallow aquifer, the on-site culvert and new residential site users. Groundwater and surface water are moderately sensitive in this location and detailed quantitative risk assessment is required to fully understand remediation requirements.

'Standard' development-led mitigation measures for protection of human health are likely to comprise building / hardstanding cover 'barriers' to the soil, capping in landscaped areas and gas/vapour membrane (if required).

11.3 Recommendations

The Mitigation measures are considered to be required as part of the development of the site and these are outlined below.

- **Human Health Vapour Risk Assessment:** will be required in order to determine if the exceedances in soils do pose a risk to future site users and therein will determine if mitigation and /or remediation is required.
- **Controlled Waters Detailed Quantitative Risk Assessment:** a controlled waters DQRA will be required in order to firstly determine if the concentrations recorded in soils required remediation for the protection of controlled waters and secondly to inform on the remediation requirements (i.e. extent) of the identified impact and recorded elevated concentrations in groundwater for the protection of controlled waters on and off-site.
- **Remediation Strategy:** the findings of the DQRAs will be utilised to inform the mitigation and / or remediation that is required on site to reduce the identified risks. The document shall set out the overall objectives and outline methodologies to be used to undertake the mitigation / remediation. The Remediation Strategy will outline criteria that the remediation should meet in order to demonstrate that risks have been suitably reduced. The Remediation Strategy will also describe the verification and validation requirements for mitigation and remediation works.

- **Remediation Implementation Plan:** this is a design document to be undertaken by or in conjunction with a remediation contractor and will confirm the detailed design of how the remediation objectives outlined in the Remediation Strategy will be achieved and validation undertaken.
- **Materials Management:** If re-use of Made Ground is proposed as part of the development (i.e. a cut and fill exercise to regrade the site's level to attain a flat development platform), the appropriate materials management plans should be produced and agreed with relevant qualified persons and regulators prior to the enabling works. This is to ensure that the correct and suitable re-use of the soils.
- **Ground Gas Mitigation**: Further monitoring and assessment is recommended to determine the appropriate gas protection measures (if any) for a proposed building development. If required, appropriate gas protection measures in-line with BS 8485 will be required as part of a future commercial development. The chosen gas protection measures will require subsequent validation in-line with CIRIA C735: 2014.
- **Groundwater Monitoring**: A programme of groundwater monitoring is recommended in order to complement the information obtained by this investigation and recent third-party investigations, as well as start to build a baseline data set for the site.
- **Hotspot Protocol:** During redevelopment a 'Hotspot Protocol' will need to be implemented to allow groundworkers to act appropriately upon encountering or suspecting the presence of previously unidentified ground contamination.
- **Foundation Works Risk Assessment (FWRA):** Contaminants in soils could potentially pose a risk to controlled waters and therefore, an appropriate risk assessment of the preferred foundation solution (assuming piled foundations) will be required.
- **Development Considerations**: A proposed redevelopment will need to consider typical precautions for redeveloping a brownfield site, including *inter alia* appropriate health and safety management for construction workers, waste soil classification, and method statements for unexpected contamination. These are considered normal and standard for a brownfield site redevelopment.
- **Health & Safety:** Appropriate H&S management precautions will need to be followed prior to and during the construction phase. This report and the generic assessment criteria (GAC) consider long term and chronic risk to humans based on defined exposure scenarios set out in CLR11. In some cases, contaminants may also pose acute hazards to workers at a site and a worker's short exposure is not considered when deriving the GAC. Asbestos in soil is not considered by CLR11 and will need to be considered for the redevelopment works. The data generated by the investigation should therefore be considered in the appropriate pre-works health and safety assessment, together with the appropriate shorter exposure times for construction workers and more direct contact with the ground. It is anticipated that these short-term risks can be appropriately addressed through the use of appropriate, health and safety plans, safe working procedures and the use of personal protective equipment (PPE), in line with relevant legislation and guidance. Groundworks undertaken by the contractor should be given to CAR 2012 (or CAR-SOIL guidance) when undertaking works at the site.