Intended for
St William Homes LLP

Date
March 2020

Project Number
1620006510

LEA BRIDGE GASWORKS OUTLINE REMEDIATION STRATEGY

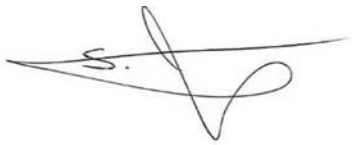
RAMBOLL

LEA BRIDGE GASWORKS
OUTLINE REMEDIATION STRATEGY

Project No.	**1620006510**
Issue No.	**03**
Date	**31/03/2020**
Made by	**Alice Kilner**
Checked by	**Simon Stoker**
Approved by	**Matthew Pannett**

Made by:

Checked/Approved by:



Version Control Log

Revision	Date	Made by	Checked by	Approved by	Description
01	27/02/2020	AK/JG	SS	MP	Draft Issue to Client
02	05/03/2020	AK/JG	SS	MP	Revised Draft Issue to Client
03	31/03/2020	AK/JG	SS	MP	Revised Draft Issue to Client

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

CONTENTS

APPENDICES

EXECUTIVE SUMMARY

Ramboll UK Limited ("Ramboll") was instructed by St William Homes LLP to prepare a remediation strategy for Lea Bridge Gas Works, in view of its proposed residential development. The strategy is based on a series of site investigations and detailed quantitative risk assessments that have characterised ground contamination at the site.

In general, the contamination identified was reasonably modest in comparison to other gasworks and this may also reflect the site's history of being only a small part of a much wider gasworks (the more contaminative elements of the former gasworks were located off-site). There are, however, hotspots of contamination that require remediation and mitigation measures are required within the proposed development.

Remediation is required for protection of human health, ecology and Controlled Waters, as described below.

The approach outlined within this strategy is subject to agreement with the Local Authority (Waltham Forest London Borough Council) and the Environment Agency (EA) and should be treated as draft until written confirmation of those party's agreement is provided.

Human Health

Mitigation measures are required to break pollutant linkages between human health and the ground, similar to most brownfield site developments. These are expected to include:

- Excavation of soil contamination where a vapour risk has been identified.
- Gas membrane installation and verification for Characteristic Situation 2 (in the scenario where hydrocarbon impacted soil and groundwater identified to pose a vapour risk is remediated).
- Vapour membrane installation and verification where hydrocarbon impacted soils and groundwater have been identified to pose a vapour risk remain in place.
- Appropriate re-use of site won soils.

Ecology

Soil imported onto site must meet horticultural and ecological requirements for the protection of pre-existing ecology (e.g. new landscaping, protected trees).

Controlled Waters

There is disagreement between the DQRA and empirical site investigation data. The site investigation data shows clearly defined hotspots of contamination that are static and not migrating. Data from around the culvert and down hydraulic gradient do not show significant impact to groundwater, or off-site contaminant migration. The DQRA, at its most conservative, does show an impact off-site. However, less conservative assumptions and 'probabilities' more closely match the empirical data. Therefore, the remediation strategy is based on a balance between an overly conservative DQRA and the actual site conditions.

The main elements of remediation in terms of Controlled Waters comprise:

- Excavation of an area of soil contamination in the central area of the site as defined by previous investigation, DQRA, proven impact to groundwater, and visual site observations of 'mobile' contamination;
- Treatment of groundwater in the area of Gas Holder 6. Groundwater, but not soil, down-gradient of the gas holder has been identified by the DQRA as a risk to Controlled Waters. It is planned to create an in-situ 'treatment zone' in the vicinity of the gas holder as the most sustainable approach to this area; and

- Excavation of areas of visually 'mobile' contamination that have not been identified as a significant risk by the DQRA. This is to be undertaken on a precautionary basis.

The following table and plan provide a high level summary of the remediation strategy:

Remediation Area	Reason for Remediation	Action
Soil Area A - E	Visual observations of mobile contamination. No impact identified by DQRA.	Excavate, treat/re-use and validate to DQRA targets
Groundwater Areas 1 & 2	Visual / olfactory evidence of impact, elevated concentrations recorded in groundwater. Area 1 considered to be hotspot / boundary issue	Implement in-situ remediation technologies comprising a combination of oxidation and activated carbon
Ground gas or vapour protection	Elevated ground gas concentrations and elevated hydrocarbon vapours (in soils and groundwater) were recorded.	Installation and verification of gas or vapour membrane as part of development
Landscaping and imported soil	Elevated contaminant concentrations identified within Made Ground; soils not suitable as growing medium	Installation and verification of capping strategy in areas of landscaping
Watching brief/unexpected contamination	Unknown ground conditions or historic structures may be present at the site.	Ramboll attendance during certain activities and implementation of unexpected ground conditions protocol
Long term monitoring	To monitor groundwater after remediation works have been completed as well as during and post development.	Monitoring to be undertaken during certain development activities (e.g. piling) as well as during and on completion of remediation and post development completion

A plan highlighting the impacted soil and groundwater areas that will be subject to remediation are shown in Appendix 1.

1. INTRODUCTION

1.1 Brief

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 strategy presents an overview of previous environmental investigations and risk assessments and the approach for remediating the site in view of its proposed end use. This remediation strategy approach should be considered in the context of the finalised development designs and in consultation with the contractor who will build the scheme, hereafter referred to as 'the Contractor'.

The approach outlined within this strategy is subject to agreement with the Local Authority (Waltham Forest Council) and the Environment Agency (EA) and should be treated as draft until written confirmation of those party's agreement is provided.

1.2 Proposed Development

The proposed development is understood to comprise a comprehensive phased development comprising demolition of existing buildings and structures, and erection of buildings to provide a mixed use scheme including residential units (Use Class C3), flexible residential facilities and commercial uses (Use Classes A1, A2, A3, A4, B1, C3, D1 and D2), together with public open space; public realm works and landscaping; car and cycle parking; servicing arrangements; sustainable energy measures; formation of new pedestrian and cycle access onto Clementina Road; formation of new pedestrian, cycle and vehicular access onto Orient Way; means of access and circulation within the site; and site preparation works.

1.3 Previous Relevant Reports

The site has previously been characterised and remediated during several phases of groundworks between 1993 and 2019 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; and
- 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.
- Ramboll completed an investigation in late 2019 (reported in January 2020) to provide a 'final' view of site conditions. A summary of the above relevant third party assessments are documented within Ramboll's January 2020 Phase II report.
- On the basis of the Ramboll's 2020 environmental a Detailed Quantitative Risk Assessment (DQRA)[1] was also undertaken with the objective of establishing remedial targets for soil and groundwater which are protective of futures users (human health) and Controlled Waters.

1.4 Constraints and Limitations

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 which form the basis of this document 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.

[1] Controlled Waters Detailed Quantitative Risk Assessment; Ramboll, dated January 2020 (ref: 1620006510_01_DQRA);

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.

2. ENVIRONMENTAL SETTING AND GROUND CONDITIONS

Full details of the ground conditions are provided in the Phase II Ground Investigation Report[2] with a summary provided in the following sections.

2.1 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 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

2.2 Geology

Ground conditions recorded in the 2019 Ramboll site investigation recorded the following:

- **Made Ground:** anthropogenic material deposits overlying natural deposits 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.
- **Alluvium/River Terrace Deposits:** Underlying the Made Ground at all exploratory locations were the superficial deposits to a maximum depth of 9.5 bgl. This generally consisted of very gravelly sand. This has been recorded as River Terrace Deposits elsewhere. A distinct separation between Alluvium and River Terrace Deposits was not noted.

[2] Ground Contamination Interpretative Report; Ramboll, dated January 2020 (report ref: R1620006510_03)

- **Lambeth Group:** Varying layers of clay, sands, silts and Upnor formation pebble beds encountered to depths of 17.2 - 21.5m bgl.
- **Thanet Sands Formation:** Green-grey sand, encountered in deep cable percussive boreholes. The depth to the base was not proven.

2.3 Hydrogeology

The EA currently classifies the superficial deposits (Alluvium) as a Secondary Undifferentiated aquifer and the underlying River Terrace Deposits are a Secondary A aquifer. The bedrock geology of the Lambeth Group is classified as a Secondary A aquifer. Beneath the Lambeth Group are the Thanet Sands (Secondary Aquifer (A). Chalk (Principal Aquifer) is present at depth and was not encountered during the investigation.

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.

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. A SPZ I is located approximately 250m south-west of the site at its closest point.

2.4 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.

2.5 Ramboll Investigation Findings - 2020

An overview of the findings of Ramboll's ESA is provides 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 nine 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.**

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 stream on site is culverted and therefore considered not to be in continuity with the groundwater; the nearest surface water course (Dagenham Brook) is located 250m north-east. 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.**

3. QUANTITATIVE RISK ASSESMENT OVERVIEW

3.1 Introduction

Following the Phase II qualitative risk assessment, a detailed quantitative risk assessment for risk to human health and Controlled Waters was undertaken which is summarised below.

3.2 Human Health

A detailed quantitative assessment has been undertaken to consider the potential risks to future site occupants arising from the migration of vapours associated with contaminants identified from sampling of unsaturated soils and also groundwater samples. Note, the qualitative risk assessment did not identify the migration of contaminants off-site to the north towards the residential land use.

The results obtained from the assessment indicate that the predicted concentrations for 2-methylnaphthalene, 1,2,4-trimethylbenzene, benzene, naphthalene and aliphatic and aromatic hydrocarbons (C8-C10, C10-C12, C12-C16) and aliphatic hydrocarbons (C8-C10 and C10-C12) in localised areas would exceed the inhalation health criteria values where just a concrete floor is present as part of the proposed development.

The inclusion of a HDPE-type membrane reduces the number of exceedances to only 124-trimethylbenzene in RH305 at 2.8m bgl and 2-methylnaphthalene, naphthalene and C10-C12 aromatic hydrocarbons in TP301 at 2.2m bgl for soil sources with C10-C12 aliphatic hydrocarbons in WS103 (Patrick Parsons 2018) for groundwater sources. A HDPE-type membrane will be required for ground gas mitigation (to comply with Characteristic Situation 2).

An assessment based on a vapour resistant membrane indicates the predicted steady state concentrations for all contaminants would be well below the inhalation health criteria values for child and adult receptors.

It is noted that the locations where the exceedances have been identified that require a gas or vapour resistant membrane coincide with locations considered to be source areas for risks to Controlled Waters. As such, impacted soils at these locations will likely be removed and also the groundwater within these areas will be treated with in-situ remediation techniques.

Therefore, it is considered that remediation for risks to Controlled Waters will align with the identified risks to human health and reduce risks to an acceptable level (i.e. where a significant risk is not identified). As part of the verification works for the remediation, soils and groundwater will require testing to demonstrate that the risks to human health have been mitigated (i.e. soil sampling or membrane installation). It is acknowledged that a ground gas membrane will still be required for all proposed residential buildings given the site has been classified as a Characteristic Situation 2.

The assessment has been based on proposed construction and use of the buildings, so it would be necessary to review the findings from this assessment should these change. It will also be necessary to review the membrane proposed for use in the construction works.

3.3 Controlled Waters

Risks to Controlled Waters are predicted to occur when conservative assumptions are used within the DQRA. However, empirical evidence from the site investigations do not support the 'worst case' predictions of the model. A number of factors are likely to contribute to this imbalance between the DQRA and actual site conditions. This could include differences in physical properties of the aquifer, faster degradation of contaminants, or other attenuation factors. By changing some model input assumptions it is possible to match 'empirical and theoretical' predictions and observations. Ramboll therefore considers that the less conservative DQRA inputs and

probabilities are protective of the environment and realistic. On this basis, significant risks to off-site receptors have not been identified based in a 50m compliance point with the exception to the compliance point down-gradient from CP303 in the east of site. It is noted that boreholes CP305, BH302 and RH315 are considered down-gradient of RH312 and CP303, all of which recorded less than limit of detection for hydrocarbons in groundwater (i.e. the plume from CP303 / RH312 area is limited in its migration extent off-site.

3.4 Summary

Based on the results of the DQRA and taking into account the empirical data from the Phase II investigation five areas of soil contamination and three areas of groundwater contamination have been identified as requiring remediation in order to reduce the identified potential risk to human health and Controlled Waters. This is discussed further in Section 5 of this report.

4. REMEDIATION CONCEPTUAL SITE MODEL

4.1 Introduction

The remediation conceptual site model follows the contaminant-pathway-receptor philosophy that is a main principle of UK guidance and legislation. The remediation conceptual site model presented in this section provides the basis of the remediation strategy. A pictorial conceptual site model (CSM) is provided in Appendix 1.

Table 4.1: Remediation Conceptual Site Model

Contaminant	Pathways	Receptors	Risk
Asbestos, metals, PAHs, TPH and VOCs in Made Ground and Natural Soils	Dermal Contact, Ingestion	Future site Users	**Mitigation Required for TPH concentrations**
Asbestos, Inorganics, PAHs, TPH and VOCs in soils	Inhalation - volatilisation or dust and asbestos fibres	Future site Users	**Mitigation/Remediation required for TPH concentrations**
		Construction Workers	Implement appropriate control measures
Naphthalene and trimethylbenzene identified in groundwater	Volatilisation	Future site Users	**No Mitigation/Remediation required**
			Implement appropriate control measures
TPH, PAHs and VOCs identified in soil	Leaching of contaminants in unsaturated zone	Groundwater in the underlying aquifers	**Remediation required for TPH concentrations**
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	**Remediation required for TPH concentrations**
	Vertical Migration via groundwater	Groundwater in the underlying aquifers and off-site Controlled Waters	Implement mitigation / control measures as part of Foundation Works Risk Assessment (FWRA)
Ground gases	Lateral and vertical migration	Future site Users and Built Environment	**Mitigation Required**

5. REMEDIATION ACTIONS AND GENERAL CONTROLS

The Ramboll 2020 ground investigation identified a number of contaminants of concern and associated pollutant linkages at the site. These pollutant linkages have the potential to adversely impact future residential end users, water supply pipes, property and Controlled Waters should mitigation/remedial measures not be incorporated within the enabling works, construction works and operational stages of the development. A subsequent detailed quantitative risk assessment (DQRA) was completed in order to confirm where mitigation and / or remediation was required and this Remediation Strategy has been prepared to address these identified impacted areas and deliver a development that is suitable for the proposed use.

The remediation activities required at the site are described in detail in the following sections of this report.

Section 6 - Specific Remediation Activities

- Impacted Soil Removal (human health & Controlled Waters)
- Groundwater Remediation (human health & Controlled Waters)
- Piling
- Groundwater Monitoring
- Capping System
- Ground Gas / Vapour Protection Measures
- Borehole Decommissioning

Section 7 - General Site Environmental Controls

- Material Re-Use Strategy
- Material Importation Strategy
- Waste Management Strategy
- Groundwater Management
- Unforeseen Contamination Protocol
- Water Supply Pipes and Service Corridors

6. SPECIFIC REMEDIATION ACTIVITIES

6.1 Introduction

The data from the Ramboll 2020 site investigation and detailed quantitative risk assessments clearly characterises the areas of contamination as isolated areas. As such, the design of the remediation has been based on treating these identified areas, as described below.

Following redevelopment, the majority of the site will be covered with hardstanding which is expected to reduce infiltration into the underlying soils and therefore reduce leaching of contamination to groundwater. This is a significant improvement for the potential for rainwater infiltration and leaching from current site conditions which are largely open.

6.2 Remediation Specification

The sections below provide the strategy to achieve remediation. Prior to commencing remediation works, the Contractor will need to prepare a Method Statement/Implementation Plan detailing how the remediation works will be undertaken. Ramboll will prepare a design specification for the Contractor to include in its Method Statement/Implementation Plan. The Contractor should liaise with Ramboll and the provider of the proprietary remediation products (further detail below) as part of preparing its Method Statement/Implementation Plan.

6.3 Remediation Excavations

6.3.1 Protection of Human Health (future site users)

There are considered to be a number of options for implementing mitigation / remediation measures for the protection of future site users. Ground gas protection is required in-line with Characteristic Situation 2; therefore a gas membrane will be required for the proposed development. The DQRA identified that even with a gas membrane installed there were soil and groundwater hydrocarbon concentrations that still posed a potential risk (this was isolated to TP301 (2.2m), RH305 (2.8m) in soils). Therefore, in order to reduce the risk, either mitigation (e.g. vapour membrane) or remediation (soil removal / groundwater treatment) can be implemented. These options are:

- To mitigate risks to future site users the contamination within the shallow soils and groundwater that has been identified by the DQRA (as detailed above) as requiring remediation will be removed in order to improve ground conditions and reduce the potential risks to human health. Associated remediation excavations will require subsequent validation.
- The DQRA identified that if the impacted soils remain in place a vapour membrane will mitigate the risks to future site users. The vapour membrane will require design so the adequate mitigation is provided and the installation will require verification and testing.

6.3.2 Impacted Shallow Soil Removal (Controlled Waters)

Whilst the DQRA did not identify soils that pose a risk to Controlled Waters, however, it is considered prudent for the protection of Controlled Waters, that areas of identified and 'significant' impacted soil is removed in order to improve ground conditions and further reduce the potential risks to Controlled Waters.

Ramboll's investigation identified these areas where shallow soils were considered to be 'significantly' impacted. The extent of these areas has been calculated using visual and olfactory observations from the investigation, soil and groundwater chemical analysis and the findings of the DQRA. The source areas were based on the following criteria:

- visual and/or olfactory evidence has been identified;

- elevated concentrations of contaminants in soil from the unsaturated zone; and
- elevated contaminant concentrations in groundwater (note: not all the locations recorded elevated concentration in groundwater.

Excavation of these areas is to be undertaken on a precautionary basis in order to reduce a potential ongoing risk. Figures presented in Appendix 1 show the approximate extent of the impacted areas, which include:

- **Area A:** this relates to the area of previous remediation undertaken by WYG in the late-90s: estimated to be 750m^2 in size with an assumed depth to groundwater of 2.5m. Groundwater in this area was impacted but was determined not to be a risk by the DQRA.
- **Area B:** this area potentially relates to a boundary source (i.e. there is no evidence to suggest the presence of a historic source in this area) and is located in vicinity of RH308, WS103 (Patrick Parsons, 2019) and TP403 (WYG, 2019); estimated to be 200m^2 in size with an assumed depth to groundwater of 2.5m.
- **Area C:** located in vicinity of WS304 and estimated to be 100m^2 in size with an assumed depth to groundwater of 2.5m.
- **Area D:** located in vicinity of WS306 and TP301: estimated to be 250m^2 in size with an assumed depth to groundwater of 2.5m. RH313 is in close vicinity and in a down-gradient position, and did not recorded elevated hydrocarbon concentrations in groundwater.
- **Area E:** located to the east of Gas Holder 5: estimated to be 100m^2 in size with an assumed depth to groundwater of 2.5m.

Figures presented in Appendix 1 show the approximate soil areas.

The hotspots will be excavated under a watching brief by Ramboll. During excavation of the hotpots, the soils will be carefully segregated by the contractor into 'clean' soils, 'contaminated soils' and 'grossly contaminated soils' and stockpiled. The excavations should be extended to approximately 5m x 5m; where impacted soils are no longer encountered. Where grossly impacted soils are encountered these should be chased out as far as is reasonably practicable.

Verification samples will be collected from the base and faces of the excavation and analysed for the criteria set out in Table A2.1 of Appendix 2. As above, the verification samples will be compared to human health targets in the first instance and if exceedances are recorded, these the concentrations be qualified by Ramboll in order to determine if a potential risk is still present. Verification samples should be collected at a rate of **one sample per 10m by 10m grid square across the base** and **one sample every 10m along the face** of the excavation.

On receipt of acceptable verification analysis, the excavation can be backfilled with material which meets chemical and geotechnical verification requirements. If required, 'sacrificial fill' can be used for backfill purposes whilst awaiting the results of the verification (subject to the Contractor removing the sacrificial fill, should verification samples not be acceptable).

6.3.3 Soil Excavation Requirements

- The Contractor will provide an appropriately qualified remediation engineer to supervise all excavations and keep records of visual and olfactory observations, ground conditions and preferential migration pathways.
- Where 'clean' material is present overlying the impacted soils (based on available analytical data and visual / olfactory observations and portable photoionization (PID) readings), these soils should be segregated and stockpiled for re-use on site, subject to verification in line with Section 8.
- Excavation shall proceed to where the water table is encountered (as directed by the environmental consultant) in order to remove impacted soil. The Contractor shall be

responsible for ensuring that any water entrained in the excavated soil for stockpiling shall be handled so as to minimise the potential for any ground contamination during the works.

- Should apparent conduits for contamination be observed during the excavation these would be 'chased out' by the Contractor as far as reasonably practicable (e.g. if a service trench, drain or more permeable horizon of soil is found to be heavily impacted with contamination);
- The Contractor shall keep a photographic record of the excavation works, including the base and faces of each excavation.
- Following excavation of each area, the Contractor will collect verification samples from the sides of the excavations in order to verify that the at the lateral extent of the excavated area, material remaining in-situ meets remedial objectives (refer to Section 8). Further excavation may be required if the verification targets are not met.
- If relevant, the excavations will remain open until verification results from the laboratory confirm that the soil treated by bioremediation can be used as backfill (or any other site won material deemed appropriate for reinstatement). An exception is where there are Health and Safety concerns, or groundwater control dictate otherwise, in which case 'sacrificial fill' shall be used. Should sacrificial fill be used, there may be a requirement to remove the sacrificial backfill should verification samples not be deemed acceptable.
- Excavation verification samples from the lateral extent of the excavations which do not meet the chemical verification criteria will generally not be considered as acceptable by the environmental consultant, and the Contractor will need to excavate impacted soils until acceptable verification results are achieved.
- However, the environmental consultant may use professional judgement, for example in the event that a limited number of determinands marginally exceed the verification criteria. This will be at the discretion of the environmental consultant.
- Once verification of the excavations is complete and prior to backfilling, the Contractor shall survey the as dug extents to national grid reference and ordnance datum, including the extent of the base and top of the excavations.

The identified impacted area in the vicinity of the previous remediation area will comprise 'clean' backfill that has been deposited overlying impacted soils. As such, careful excavation practices should be adopted by the Contractor to separate the 'clean' backfill from the previous remediation and to target the residual impacted soils that remain.

It should be noted that these impacted areas are estimates only, based on the findings from exploratory locations advanced during the Phase II investigations and may be subject to revision based on validation sampling works (i.e. lesser or additional excavation volumes may be identified during excavation works). For the purposes of the tender process and remediation contract, the Contractor will be responsible for calculating contingencies for volume of materials to be excavated, and the breakdown of types of material requiring treatment or off-site disposal in accordance with the strategy.

6.3.4 Excavation Validation Criteria

The ConSim modelling as part of the DQRA has identified solubility for hydrocarbons as the soil remediation criteria. However, for conservatism the human health soil screening criteria will be applied in the first instance to compare against soil validation analysis. If failures are present, the results will be further assessed by Ramboll to qualify if a risk is present. Consideration for the implementation of gas or vapour membranes will also be factored into assessing the soil validation analysis.

The threshold details are detailed in Table A2.1 in Appendix 2.

6.4 Environmental Consultant Watching Brief

The environmental consultant will undertake a watching brief during groundworks (involving excavation) and remediation works. It is envisaged that the watching brief will be undertake during the following:

- Periodic watching brief during the removal of hardstanding at site, where present, including during the removal of the floor slab / hardstanding associated with remaining buildings and infrastructure on site which, to date, have not been identified as requiring remediation, to assess ground conditions immediately underlying the hardstanding.
- Full time watching brief during the excavation and segregation of soils in the areas of identified impacted soils that have been identified in this strategy.
- Periodic watching brief during the backfill of the remediation excavations.
- Periodic attendance on site to view the groundwater treatment injection works.
- Periodic watching brief during the backfilling of the gas holders to view the final condition of the soils and the condition of other backfill materials (e.g. crushed demolition materials, imported soils or aggregates).

The Contractor shall provide the environmental consultant with office space for the duration of the remediation work, including a desk and chair, and access to welfare facilities. The Contractor shall liaise with the environmental consultant with regards to the programme and timing of the works, to ensure that the environmental consultant can attend site at appropriate times.

6.5 Groundwater Remediation

6.5.1 Protection of Human Health

The DQRA identified that with a gas membrane installed hydrocarbon concentrations at WS103 (Patrick Parsons), BH301 (WYG) and DUP6 (duplicate of BH301) required further mitigation i.e. a vapour membrane. WS103 aligns with an area that has been targeted for groundwater remediation (see below) which will also serve to reduce contaminant concentrations from a human health risk. BH301 (and DUP6) is not located within a groundwater treatment area, therefore, in order to reduce the risk, either mitigation (e.g. vapour membrane) or remediation (groundwater treatment) can be implemented. These options are:

- To mitigate risks to future site users the contamination within the groundwater that has been identified by the DQRA (as detailed above) as requiring remediation will be removed in order to improve groundwater conditions and reduce the potential risks to human health. Associated remediation will require subsequent validation.
- The DQRA identified that if the impacted groundwater concentrations are not treated a vapour membrane will mitigate the risks to future site users. The vapour membrane will require design so the adequate mitigation is provided and the installation will require verification and testing.

6.5.2 Protection of Controlled Waters

Area 1: Dissolved Phase Impacted Groundwater at RH308 and WS103 (West of Site)

The elevated concentrations identified at these locations are potentially a boundary issue as the borehole positions north and south of these positions have significantly reduced concentrations. Where elevated concentrations of hydrocarbons have been identified within groundwater, the concentrations are amenable to enhanced bioremediation. Remediation within the identified source areas will be achieved through the application of a chemical oxidant to promote In Situ Chemical Oxidation (ISCO). Promotion of in situ bioremediation can also be facilitated by

injection of proprietary activated carbon compounds that form a layer over the substratum that draws in the contaminant and provides a surface for biological activity as an 'in-ground bioreactor'. An example of this is PetroFix (manufactured by Regenesis) which has been designed specifically for hydrocarbons and combines sulphate and/or nitrate with proprietary 1-2 µm carbon.

In addition, to utilising a remediation compound like PetroFix, it is recommended that this supplemented with utilising an additional compound. A combination of remediation compounds such as PetroFix and ORC-Advanced which can be applied via direct push injection is considered appropriate for the concentrations recorded and spatial distribution. PetroFix is a liquid activated carbon amendment which will quickly sorb the contamination to the activated carbon. Pulling it out of the groundwater preventing any further migration. The ORC-Advanced will provide a controlled release of oxygen for up to 12 months to enhance the rate of degradation within the aquifer.

It will be essential for the Contractor to liaise with Ramboll to discuss and agree the specification and protocol for oxidant addition and application, and to do so in conjunction with the propriety remediation compound supplier (e.g. the compounds referenced above are manufactured by Regenesis); and to address all pertinent Health and Safety issues associated with it.

The proposed treatment areas are presented on figures in Appendix 1.

Area 2: Dissolved Phase Impacted Groundwater in East of Site

Boreholes RH312 and CP303 recorded elevated concentrations of hydrocarbons in groundwater, but not the shallow soils. A soil source has not been identified up-gradient (the adjacent gas holder base is comparable with the water table). Similar to the area of remediation described above, the concentrations recorded are amenable to enhanced bioremediation through the application of a chemical oxidant to promote In Situ Chemical Oxidation (ISCO). There are also many constraints in this area of site including the gas holder, site boundary, tree root protection, PRS easement and gas main easement.

The in-situ remediation strategy of using a combination of remediation compounds such as PetroFix in the first instance is considered appropriate to quickly sorb the contamination to the activated carbon, removing it from the groundwater and preventing further migration of contaminants.

Given the presence of constraints within this vicinity, it is proposed that the area surrounding Gas Holder 6 should be treated with ORC-Advanced in order to provide a controlled release of oxygen for up to 12 months to enhance the rate of degradation in the aquifer. Thereby creating an in-situ 'treatment zone' in the vicinity of the Gas Holder 6 as the most sustainable approach to this area.

The strategic objective for this element of the remediation works will be two-fold:

- firstly to address TPH contamination already present at and just beyond the site boundary; and
- secondly to create an 'oxidative reactive zone' with an anticipated lifetime of at least 12 months, in order to address residual TPH in groundwater in the area of Gas Holder 6 (if present) flowing towards the south/south-west (where it is not possible to fully investigate due to the constraints).

The proposed treatment areas are presented in Appendix 1.

The Contractor will require to liaise with the Ramboll and the supplier of the proprietary remediation product (e.g. Regenesis) in order to agree and confirm the detailed design and application in order to achieve the desired remediation.

6.5.3 LNAPL or DNAPL Impacted Groundwater

No LNAPL or DNAPL was identified by during Ramboll's investigation. If NAPL is identified during groundworks or remediation works, this will be classed as unforeseen contamination and the protocol laid out in Section 7.7 must be followed by the Contractor.

6.5.4 Groundwater Remediation Validation Criteria

Whilst the DQRA modelling has not identified significant migration of contaminants off-site (i.e. CP303 shows potential off-site migration but down-gradient wells suggest it's limited), the following remediation criteria will be used to assess the groundwater treatment for the site. If exceedances are noted, then the results will be further assessed to qualify if a risk is present.

Table 6.1: Groundwater Validation Criteria

Analytical Determinand	Verification Target (ug/l)
Benzene	10
Aromatic C8-10	300
Aromatic C10-12	400

Notes:

The contaminant suite and verification targets have been derived from the Ramboll Detailed Quantitative Risk Assessment (DQRA) report (ref: R1620006510_02_DQRA, dated January 2020).

The criteria will be used for all groundwater remediation area sin the first instance and as stated above, if exceedances are noted then the results will be further assessed to qualify if a risk is present.

6.6 Remediation Monitoring

Ramboll will oversee the remediation on its behalf. The objective of the oversight role will be to interact closely with the Contractor to ensure that their systems of work, monitoring, recording and verification processes are consistent with the detailed requirements of the remediation strategy, including the application of remedial techniques to achieve the strategy objectives. The Contractor will be responsible for compliance with regulatory and other relevant guidance referenced above.

The scope of the oversight role will comprise:

1. **Pre-Remediation Work:**
   - Reviewing and commenting upon the Contractor's tender submission, detailed remediation design, phasing of works, programme, method statements and overall remediation strategy compliance in advance of commencing works on-site.
2. **Remediation Work:**
   - Liaison with the Client, their appointed representatives and the Contractor, together with regular site inspections to monitor the progress of works and to check the Contractor's performance against the overall scope, the prescribed methods and programme.
   - Maintain an intermittent watching brief during the breaking out and removal of hardstanding and building floor slabs.
   - Maintain a watching brief during the remediation work relating to both the soils and groundwater to confirm that the work has been undertaken in accordance with the strategy by the Contractor.

- Maintain an intermittent watching brief during the backfilling of the excavations to view the condition of the backfill materials (e.g. treated soils, site-won soils, imported aggregates etc.).
- Documented reporting to the Client in relation to progress including non-compliance and rectification measures on the part of the Contractor.
- Reviewing the verification process during the works to ensure the remediation is being properly validated by the Contractor and that materials proposed for re-use and imported backfill materials are also properly validated. Reviewing the results of groundwater monitoring prior to, during and following the remedial works.

3. **Production of a Verification Report:** the environmental consultant will produce a verification report incorporating the requirements listed in Section 8 of this remediation strategy.

6.6.1 Alternative Approach

Should the Contractor wish to suggest an alternative approach to the various elements of the remediation work this would be considered by the Client team. Any alternative approach would need to meet the overarching aims of the remediation.

6.7 Piling

Once a proposed technique has been confirmed by the client, a Piling Risk Assessment will be completed by Ramboll in accordance with EA guidance[3] which will discuss the potential risks to the water environment that may arise from proposed piling activities at the site and will need to be considered by the piling contractor in determining the final proposed piling scheme method and designs.

6.8 Groundwater Monitoring

As construction works have the potential to mobilise contaminants, monitoring and sampling will be required during the course of the enabling works, piling and construction. In addition, groundwater monitoring will be undertaken following the implementation of groundwater treatment.

6.8.1 Baseline Monitoring

Monthly groundwater monitoring from the groundwater monitoring wells utilised during Ramboll's Phase II investigation will be undertaken in order to build up a baseline data set for the site and allow a direct comparison with the Phase II dataset.

For verification purposes the results of the groundwater sampling will be compared against baseline concentrations and the assessment criteria used as part of the Phase II investigation and assessment.

Undertaking baseline monitoring and sampling not only allows the collation of a robust dataset to use as a comparison for monitoring during construction works, but it also allows the opportunity to test the strategy outlined in this document. As such, it is recommended that on completion of the baseline monitoring the results are assessed and the recommendations of this report checked against the findings.

[3] Environment Agency. Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention, 2001.

Laboratory Analysis

The laboratory analysis suite of analysis is recommended to target the contaminants of concern as identified by Ramboll's Phase II, and as such will comprise the following:

- TPH CWG, speciated PAHs and VOCs including BTEX and MTBE; and
- Monitored Natural Attenuation (MNA) Suite (pH, sulphate, sulphide, ammonium as NH4, nitrate and nitrite, manganese, Fe2+ and Fe3+.

Collection of In-Situ Groundwater Data

As part of each programmed groundwater monitoring round, in-situ parameters (including pH, temperature, conductivity, dissolved oxygen, oxygen reduction potential) will also be collected.

6.8.2 During Development/Construction Groundwater Monitoring

Groundwater monitoring from 10 No. wells will be carried out weekly in advance of piling; weekly during piling; and one week after completion of piling.

A longer-term groundwater monitoring programme is also proposed during the follow-on enabling works and during construction (monthly monitoring during enabling works and quarterly for one-year post piling).

For verification purposes the results of the groundwater sampling will be compared against baseline concentrations and assessment criteria used as part of Ramboll's previous assessment.

Laboratory Analysis

The laboratory analysis will comprise the same suite of analysis as the baseline detailed above and in-situ parameters (including pH, temperature, conductivity, dissolved oxygen, oxygen reduction potential) will also be collected.

Monitoring Boreholes

The locations of monitoring boreholes are shown in Appendix 1 and are also detailed below:

- RH303, RHA, RHD, RHB, RH310, RH313, RH315, CP303, RH312 and BH302.

During the groundworks and construction, the boreholes will require protection. At present it is recommended that the protection comprise a concrete ring placed encompassing the borehole as well as signage denoting the borehole's presence, thereby protecting it from plant or excavation.

On each monitoring visit the condition of the wells will be checked and any damage recorded. Should these wells become damaged during the course of works it will be Contractor's responsibility to repair or replace them with suitable installations before the subsequent monitoring round.

The monitoring wells will not be decommissioned until agreement and approval is obtained from the EA. The wells will be decommissioned in line with the Borehole Management Plan which will be produced by Ramboll.

6.8.3 Post-Remediation Monitoring

Following completion of the groundwater remediation works at the site, a groundwater monitoring programme will be implemented for a six-month period, the results will be reviewed after each monitoring round to determine if additional groundwater monitoring is required.

The locations of monitoring boreholes are shown in Appendix 1.

The laboratory analysis will comprise the same suite of analysis as the baseline suite detailed above and During the groundworks and construction, the boreholes will require protection. At present it is recommended that the protection comprise a concrete ring placed encompassing the borehole as well as signage denoting the borehole's presence, thereby protecting it from plant or excavation.

On each monitoring visit the condition of the wells will be checked and any damage recorded. Should these wells become damaged during the course of works it will be Contractor's responsibility to repair or replace them with suitable installations before the subsequent monitoring round.

The monitoring wells will not be decommissioned until agreement and approval is obtained from the EA. The wells will be decommissioned in line with the Borehole Management Plan which will be produced by Ramboll.

6.9 Surface Water Monitoring

If access can be obtained, sampling of the culverted watercourse in the south of the site is recommended on a precautionary basis to further demonstrate the absence of a significant risk to surface water receptors.

If possible, the culvert will be sampled up-gradient of the site, on site and down-gradient.

The laboratory analysis will comprise the same suite of analysis as the baseline suite detailed above and in-situ parameters (including pH, temperature, conductivity, dissolved oxygen, oxygen reduction potential) will also be collected.

6.10 Baseline Reporting

Ramboll will issue a water quality baseline report presenting the results of the baseline groundwater monitoring analysis before piling commences. This report will be issued to the EA.

Thereafter, i.e. during the weekly monitoring during piling, Ramboll will issue a summary letter report following each round to ensure the EA are kept up to date with the current groundwater conditions at the site.

6.11 Verification Reporting

The results of the groundwater (and surface water monitoring if obtainable) will be presented in the verification report (refer to section 8), including presenting all groundwater monitoring results and trends in data graphically, with a view to demonstrating that the development has been completed successfully with no impact to Controlled Waters receptors. The Verification Report will also document decommissioning of the long-term monitoring wells.

6.12 Capping System

Based on the elevated concentrations of contamination encountered during the ground investigation, a clean capping system will be required as part of the development within soft landscaped areas to protect end users. Note: consideration for root protection areas will be required during the installation of the capping system so that there is no tree root loss.

Within communal soft landscaped areas, a clean cap of **450mm** is required which will incorporate 350mm of topsoil/subsoil and a granular break layer of 100 mm thickness to separate the clean cap from the residual Made Ground (subject to landscaping and planting requirements).

The clean capping layer will comprise imported subsoil and topsoil which meets the requirements of the British Standards for subsoil and topsoil (BS8601:2013 and BS3882:2015) and has been

chemically verified to ensure it is suitable for its intended use. The threshold details are detailed in Table A2.3 in Appendix 2.

Imported topsoil and subsoil should be verified for chemical suitability at a rate of **one sample per 250m^3**.

Documentation on the source, quantity and testing results shall be retained on site for inspection and subsequent inclusion in the Verification Report. The Contractor shall retain records on the location, depth of excavations and how/where any imported material is placed.

General Fill Material

Whilst not strictly part of the capping system material, imported material for use as general fill (such as recycled aggregate) should be sampled at a frequency of **one sample per 250m^3**.

Site derived material for reuse as general fill material under the CL:AIRE Code of Practice (refer to section 4.2) should be sampled at a frequency of **one sample per 100m^3.**

Imported material and site-won material used as general fill shall conform to the contaminant thresholds detailed in Table A2.2 in Appendix 2.

6.13 Ground Gas Protection Measures

Previous ground gas monitoring and risk assessment has identified that the site is classified as Characteristic Situation 2 and basic gas protection measures are required to be incorporated into the proposed residential properties. In addition, the DQRA identified that elevated hydrocarbons in soils and groundwater required mitigation and/or remediation.

As mentioned earlier in this report, as a minimum, a gas membrane is required in-line with the requirement of Characteristic Situation 2. The DQRA identified that taking the installation of a gas membrane into account, there remained exceedances for soil and groundwater hydrocarbon concentrations. Therefore, in order to mitigate the elevated concentrations, either a vapour-resistant membrane is to be installed or the elevated concentrations in soil and groundwater are remediated through soil excavation and groundwater treatment. It is noted that only part of the site (as detailed earlier in this report) was identified to require further consideration and therefore the chosen remediation or mitigation methodology need only apply to this area e.g. the site can be zoned to reflect the identified location of elevated hydrocarbon vapours. Further monitoring may be required in order to demonstrate the application of site 'zoning'.

BS8485:2015+A1 2019 requires a gas protection score to be identified for the proposed development (which are categorised as 'building types'), with gas protection measures selected to meet the required gas protection score. In accordance with the guidance, the future residential development would be classed as a 'Type B' building. A 'Type B' development situated on a site with a Characteristic Situation 2 gas regime would be required to achieve a ground gas solution score of 3.5 points. Gas protection measures are required in the proposed residential buildings to achieve a score of 3.5.

Selection of Gas Protection Measures

Gas protection solutions for buildings are typically based on a combination of the following three elements, which are used to achieve the required gas protection score for the type of building:

- structural barrier (floor slab);
- ventilation measures; and
- gas resistant membrane.

Solution scores are awarded for each type of gas protection membrane. BS8485:2015 indicates the gas protection system should consist of at least two different elements from the list above,

for example a barrier element (e.g. floor slab) with either a membrane or a ventilation or dilution element (or both). The single elements work independently and collaboratively, and a single element should not be used as there would be no redundancy to allow for defects in the component.

In order to achieve a score of 3.5, the recommended ground gas protection measures and method of construction is summarised in Table 6.3 below.

Table 6.3: Recommended Ground Gas Protection

Type of Gas Protection	Score
Reinforced cast in-situ suspended floor slab with minimal services	1.5
Validated gas resistant membrane	2.0
Total	**3.5**

The gas protection membrane should be selected specifically to mitigate vapour ingress to buildings as well as from ground gases.

The final performance requirements of the ground gas protection measures necessary should be confirmed as part of detailed design in consultation with a specialist contractor and in agreement with Building Control.

All ground gas protection measures incorporated into the design of the buildings will need to be documented on-site by the Contractor in accordance with verification procedures outlined in CIRIA C735[4] and C748[5]. Photographic evidence prior to concrete pours of the general installation, taping and sealing of a membrane is required for each block to be able to provide sufficient information to complete a Verification Report upon completion of the construction works.

6.14 Vapour Mitigation – Human Health

6.14.1 Overview

The 2020 Ramboll investigation identified hydrocarbons in shallow soils and groundwater at concentrations which could represent a risk to future residential site users from ingress into buildings, and as such, mitigation measures are considered necessary.

It is proposed that mitigation will be achieved by implementing protection measures which will remove the pathway from the 'contaminant-pathway-receptor' model that is used to determine whether land is contaminated or not.

The guidance document CIRIA (C716) *Remediating and mitigating risks from volatile organic compound (VOC) vapours from land affected by contamination, 2012* provides more detail and considerations for the various aspects concerning the mitigation required. The methods commonly used to mitigate the risks from volatile hydrocarbons by managing contaminant pathways are similar to the methods available to mitigate the risks presented by other bulk gases including carbon dioxide and methane.

[4] CIRIA (2014). C735 Good practice on the testing and verification of protection systems for buildings against hazardous ground gases.
[5] CIRIA (2014). C748 Guidance on the use of plastic membranes as VOC vapour barriers.

6.15 Pathway Management

CIRIA C716 indicates there are a wide range of pathway management techniques that could be used to manage the risks from hydrocarbon vapours. The pathway management techniques are divided into three broad categories:

4. In-ground techniques.
5. Engineering controls associated with structures (vapour intrusion).
6. Engineering controls associated with other air spaces (vapour emission/vapour release).

As with gas protection measures, multiple levels of protection are usually required to provide mitigation for vapours. The principle behind installing multiple levels of protection is that it provides some redundancy to protect the future site user (residential in this case) from factors outside the designer's control (e.g. ventilation become partially blocked by vegetation or works undertaken by the future home owner).

6.15.1 Selection and Design of Vapour Protections Measures

Similar to the gas protection section above, the mitigation should be provided by more than one level of mitigation, which at this stage is envisaged would comprise:

- *Ventilation via the Sub-Floor Void*

  For new developments, the proposed size and type of building influences the type of floor and foundation type selected, which then influences the sub-floor void. The inclusion of a ventilated sub-floor void would provide at least some dilution of vapours before they could migrate into an overlying building.

- *Appropriate Vapour Membrane*

  Specific chemical-resistant membranes with a higher degree of resistance to either degradation or corrosion are available for hydrocarbons. As described within CIRIA Report C716[6] certain types of membrane are specifically designed for use in-ground where the membrane may be in contact with chemicals at high concentrations. However, specific chemical-resistant membranes may not be required in all scenarios e.g. where located above floor slab and a ventilated sub-floor void where the membrane will not be in direct contact with contaminants in the ground and it can be demonstrated that an unacceptable risk should not be present.

It will be necessary for the detailed design to demonstrate that the mitigation proposal would remove the unacceptable risks identified from vapours and is capable of achieving the design specification, for example through the use of further risk assessment which considers the level of subfloor ventilation and presence of a membrane. The calculations and the justification for selected input parameters should be clearly reported.

6.15.2 Summary

Unlike for gas protection in new buildings, no reference tables are provided within the guidance for vapours which can be used when determining the mitigation / protection requirements to reduce the risks from vapour ingress.

Therefore, an assessment should be undertaken as part of the detailed design report of the vapour mitigation to demonstrate that the level of protection proposed will be sufficient to reduce risks to future site users. It will be necessary to ensure that the proposals for vapour mitigation also take the gas protection requirements into account (and vice versa).

[6] Remediating and mitigating risks from volatile organic compound (VOC) vapours from land affected by contamination (C716). London: CIRIA, 2012.

The mitigation measures to be utilised as part of the proposed residential development will need to be described and detailed within a dedicated design report (described below).

6.16 Design Report

The mitigation measures selected for ground gas and vapours should be developed as part of the detailed design which defines and justifies the protection design and product specifications, and provides any supporting assessments.

The designer should ensure that the report clearly details critical assumptions behind the design philosophy and identifies crucial design elements. The report should make it explicit that where construction proposals change, then the design should be re-checked to ensure compliance with the overall design objectives and, where appropriate, might need refinement.

The proposed design / specification will need to be submitted to the Council and NHBC for approval prior to the construction works commencing.

6.17 Borehole Decommissioning

After undertaking baseline monitoring of the site a total of 10 monitoring wells will remain present at the site from the various stages of development monitoring (e.g. piling, remediation) which will be utilised for ongoing groundwater monitoring. A separate Borehole Management Plan will be produced by Ramboll in accordance with EA guidance[7] which highlights the wells which require decommissioning and the scope of work to be undertaken.

[7] Environmental Agency (2012) Good Practice for decommissioning redundant boreholes and wells ref LIT 6478 / 657_12

7. GENERAL SITE ENVIRONMENTAL CONTROLS

7.1 General Site Environmental Controls

The following section provides an outline of the expectations of the contractor, in order to ensure environmental compliance throughout the enabling and remedial works.

7.1.1 Air Quality, Odours, Dust and Asbestos

Odour and dust control are of importance in respect of any major earthmoving, on-site stockpiling or vehicle loading and movement over unsurfaced areas. The Contractor is required to put in place appropriate measures to deal with odour, dust and the identified contamination during the works and shall be responsible for obtaining any necessary authorisations required by the Local Authority, including liaison for any monitoring requirements to be adopted.

Asbestos fibres have been positively identified at several locations in the Made Ground. The Contractor will need to consider appropriate health and safety precautions for site workers during excavating through Made Ground. The pathway by which site workers may come into contact with asbestos in soil is through inhalation. This overarching approach is discussed in industry guidance published in CIRIA C733, 2014: Asbestos in Soil and Made Ground: A Guide to Understanding and Managing Risks. Appropriate risk mitigation measures should be outlined within an Asbestos Management Plan and employed on a precautionary basis.

The Contractor shall ensure that emissions to air (including odours) are minimised and that all necessary precautions to prevent the occurrence of smoke emissions, fumes or odours from *inter alia* contaminated soil, groundwater, site plant, stored fuel or other substances and prevent any emissions for fumes drifting into the nearby residences, workplaces or public open spaces.

It will be necessary to ensure that all plant is in good repair and conforms to the manufacturers or legislative/British Standard emission standards. Plant shall not be left running for long periods when not directly in use. Where appropriate or practical, electrically powered plant shall be used instead of diesel.

Suppression techniques and monitoring requirements are likely to include (but are not exclusive to) soil dampening with the use of a dedicated site water bowser, use of dust curtains and air quality monitoring stations along site boundaries.

The following measures shall be used to minimise the generation of dust where appropriate:

- covering of stockpiles;
- wheel washing and street sweeping (where appropriate);
- loading/unloading within designated bays/areas;
- hoarding around site and/or appropriate locations (such as plant);
- maintenance of plant;
- liaison with neighbours; and
- highest standards of housekeeping.

No vehicles shall leave the site with earth, mud, etc. adhering to the wheels in a quantity which may result in its being deposited on the public highway or footpath, and creating a nuisance, or hazard to vehicles or pedestrians. Suitable wheel washing equipment to avoid such problems shall be installed, operated and maintained on the site until the development is completed.

The written consent of the EA and local utility provider shall be obtained regarding the disposal of wheel wash water to surface water drains.

7.1.2 Noise and Vibration

The Contractor shall be responsible for obtaining any necessary authorisations required by the local authority, including liaison for any monitoring requirements to be adopted. Any 'out of hours' work shall require prior agreement with the local authority.

The Contractor shall be responsible for the implementation of any noise and vibration monitoring required by the local authority.

The Contractor shall take all practical measures to minimise noise and vibration during the works and where relevant, comply with BS 5228 Code of Practice for Noise and Vibration Control on Construction and Open Sites.

The following measures should be implemented to minimise the generation of noise and vibration:

- use of acoustic silencers on equipment;
- regular maintenance of plant;
- unloading and loading of material within designated areas; and
- shutting down items of plant when not in use.

7.1.3 Oils, Fuels and Chemicals

The use of plant equipment on-site during the remediation works could result in the potential for the release of contaminants to ground, such as fuel, oils, coolants and lubricants. To avoid the accidental leakage of fuel, oils and/or lubricants, all plant should be maintained to a safe and efficient working condition at all times and any oils or fuels should be contained in accordance with Control of Pollution (Oil Storage) (England) Regulations 2001 SI 2954.

As a minimum all liquids and solids of a potentially hazardous nature (e.g. diesel fuel, oils, degreasers, stored pumped groundwater and free phase oil etc.) shall be stored with appropriate secondary containment (e.g. bunding). A dedicated area for the refuelling of plant and vehicles away from any surface water drains shall be established and the fuelling area shall be kept clean at all times. No refuelling shall be undertaken outside of the established refuelling area. Spillages or leaks of fuel shall be cleaned up immediately by The Contractor and contingency arrangements for dealing with spillages shall be available at all times, including absorbency granules and dedicated spill response kit.

All equipment containing fuel/oils (e.g. pumps and generators) shall be placed on spill mats, plant nappies or similar and these shall be maintained by The Contractor. Drip trays shall not be utilised.

The storage and use of hazardous materials on-site will be conducted in accordance with the Control of Substances Hazardous to Health (COSHH) Regulation 2002. In accordance with COSHH, records held of all hazardous materials on-site will be maintained by The Contractor will be responsible for the completeness and accuracy of all records held.

7.1.4 Environmental Incidents

Environmental incidents can be defined as unexpected events which lead to, or could in different circumstances have led to, adverse effects on people, property or on environmental resources such as habitats or watercourses. Procedures shall be put in place by The Contractor to deal with environmental emergencies and incidents.

A relevant response plan would be developed by The Contractor in the unlikely event of an incident occurring during the remediation work, such as a fuel spillage or an episode of unexpectedly elevated noise and dust levels.

7.2 Material Reuse Strategy

If site-won materials are to be re-used as part of the proposed groundworks (e.g. for infilling hotspots etc.), this should be undertaken using the CL:AIRE Definition of Waste Industry Code of Practice[8].

In brief, under the Code of Practice, it will be necessary to ensure:

- the use of this material is protective of human health and the environment;
- materials are suitable for use (either with or without treatment);
- there is certainty materials will be used; and
- only the required quantity is used.

The excavation, movement, tracking and placement of materials at the site should be undertaken in accordance with a Materials Management Plan (MMP) for the site under the Code of Practice to be produced by The Contractor and signed-off by a Qualified Person.

The MMP ensures that material excavation is correctly recorded and materials are tested against relevant criteria (chemically and geotechnically) prior to placement in suitable locations. The MMP details the tracking system used and relevant records to be kept in order that verification of material movements can be undertaken at a later date.

In addition, opportunities for the recovery of recycled aggregate e.g. concrete, should be sought by The Contractor under the WRAP Protocol or an MMP providing the materials are demonstrated to be suitable for use in line with the reuse criteria.

The Contractor will be responsible for ensuring the suitability of materials placed as general fill and ensuring appropriate testing is undertaken. Any materials re-used as general fill beneath the hardstanding and buildings are required to be subject to certification and analysis against the testing suites and frequencies detailed within Section 5.4 and Table A2.1 of Appendix 2.

Site won material is not considered suitable for use within the clean capping system.

7.2.1 Gas Holder Backfill

As part of the redevelopment of the site, the voids associated with the three gas holder that are currently present will require infilling. It is considered to be a sustainable approach to utilise as much site-won material as possible, however, the proposed site-won material for re-use must be suitable for use.

The strategy for backfilling of the gas holders has not yet been confirmed and therefore a technical note will be provided by Ramboll detailing the proposed backfilling strategy and the associated re-use criteria for soils. For example, one proposal may be to stabilise site-won materials at the base of the gas holders, thereby creating a low permeability layer, which may lead to a different re-use criteria for subsequent overlying site-won materials.

The proposed strategy will require to be undertaken using the CL:AIRE Definition of Waste Industry Code of Practice.

7.3 Stockpiling

Excavated materials which need to be temporarily stockpiled whilst awaiting disposal or reuse on-site. The materials will be stockpiled in accordance with the following:

[8] The Definition of Waste: Development Industry Code of Practice (DoWCoP); CL:AIRE (2008)

- Soils excavated will be segregated during excavation based on visual and olfactory evidence of contamination, and stockpiled separately, as 'clean', 'grossly contaminated' and 'contaminated' soil streams.
- All stockpiles will be kept to a manageable size and good housekeeping procedures implemented.
- All stockpiles will be placed in an impermeable area of the site, covered with impermeable sheeting and secured.
- Each stockpile will be labelled by The Contractor with specific identification.
- The stockpiles should be managed to prevent rainwater run-off from the stockpiles.

7.4 Material Importation Strategy

In addition to any geotechnical specification, all materials and imported aggregates used beneath buildings, under hardstanding and within the construction of communal soft landscaped areas should be sourced from a reputable supplier and require certification to determine the materials suitability for use where scheduled for placement on site prior to importation. Separate certification is required for each type of material utilised. All imported materials will need to be accompanied with chemical certification to demonstrate its suitability for use on-site.

Imported materials should be compliant with the description in Appendix 2 of the CL:AIRE DoWCoP[7]. This refers to the direct use of clean, naturally occurring soil and mineral materials. By using only natural occurring soil and mineral materials, waste legislation would not apply, i.e. the site will not require an Environmental Permit or Waste Exemption. The materials must be sourced from:

- Greenfield sites not subject to past contaminative use; or
- Brownfield sites where the natural soils have been extensively characterised and proven to be clean.

Where soils have naturally elevated concentrations of substances such as metals and this is typical of local conditions, they may still be used. A Qualified Person is required to confirm that the appropriate lines of evidence are in place in relation to the direct transfer of imported materials.

Evidence of suitability for use must be provided, i.e. from desk-based research for a greenfield site; or from site investigation data from a brownfield site.

For imported general fill material, this will need to comply with the chemical criteria detailed in Table A2.2 of Appendix 2.

Frequencies for testing are provided in Section 5.4.

Imported aggregate for uses such as temporary surfacing to haul roads or set-up areas or piling mat etc. will need to adhere to the same site controls as outlined above for buildings and hardstanding (with the exception of virgin quarried materials). Where recycled aggregates are sourced, the producer of the aggregate must show the material has been fully recovered and is no longer a waste. To do this the producer must follow the quality protocol for the production of aggregate from inert waste, as outlined by WRAP.

The Contractor will be responsible for retaining accurate records of all imported material in accordance with the requirement Verification Plan outlined in Section 8. Documentation on the source, quantity and testing results shall be retained on site for inspection and subsequent inclusion in the Verification Report. The Contractor shall retain records on the location, depth of excavations and how/where any imported material is placed.

7.5 Waste Management Strategy

The waste disposal routes of 'grossly contaminated' excavated soils and other materials to landfill, recycling or treatment facilities will be determined by The Contractor and will follow relevant guidance and legislation. The Contractor will provide full details of the disposal route which will be via a new road junction to be constructed on Orient Way, avoiding residential streets to the north including Clementina Road and Perth Road.

The Contractor is responsible for arranging laboratory analysis for waste classification and (if necessary) waste acceptance criteria (WAC) purposes. This should be undertaken at an appropriately accredited laboratory.

The Contractor will provide all relevant documentation on completion of its work to Ramboll, including:

- methods used to classify the waste and the results of the classification;
- results of WAC analysis (if required);
- the place of disposal;
- waste volumes; and
- waste transfer notes and other Duty of Care information.

A fully auditable waste management procedure will be prepared by The Contractor. Correspondence with the landfill or receiving facility regarding the classification of waste will also be provided to Ramboll by The Contractor.

The Contractor will be responsible for identifying the appropriate disposal route. The disposal options should consider soil treatment and recycling as well as disposal to landfill.

7.6 Groundwater Management

To mitigate identified risks to Controlled Waters, the remediation strategy includes for excavation and removal of six identified 'hot spots' of contamination within the Made Ground.

The Contractor should describe in their method statements how they will manage and dispose of water from excavations. Perched water, groundwater or 'contaminated' surface water run-off which has collected in excavations must not be returned to the ground or pumped directly to surface waters once extracted from the ground.

Should waters be impacted by free phase hydrocarbons they should be treated with absorbent materials or a surface skimmer pump. If impacts are encountered to be more extensive then alternative methods such as an oil water separator or similar may be preferable.

Should disposal to surface water or public sewer be deemed appropriate, The Contractor will be responsible for any pre-treatment, additional sampling and monitoring. Any specific testing requirements will need to be agreed with the EA for discharges to surface water, or if to public sewer, with the local authority and water authority, prior to any discharge taking place.

7.7 Unforeseen Contamination Protocol

The possibility remains of contamination or structures being encountered that were not identified by past assessments. The Contractor shall provide a method statement outlining the protocol to be followed should unexpected areas of contamination be encountered during groundworks. Potentially contaminated materials are those which via visual or olfactory evidence may be suspected to be contaminated (i.e. the presence of staining, odours or deleterious materials). Unexpected contamination would not include those contaminants known from past investigations.

The unforeseen contamination protocol should include as a minimum:

- the contractor stopping work in that area and immediately informing St William Homes LLP or their representative and Ramboll to discuss the proposed action;
- the contractor liaising with the statutory authorities including the EA and Waltham Forest Council to agree proposals for dealing with this material;
- the implementation of measures to remove contaminated materials (where feasible). In relation to soils for the segregation, storage or stockpiling within a bunded and polythene covered area whilst testing is undertaken and in relation to waters the pumping, skimming treatment or storage whilst testing is undertaken;
- a record of the volume of material removed and the extent of any required excavation;
- excavation of the full extent of the contaminated material (minimum 0.5m overdig laterally and vertically) and furthermore validated by a suitably qualified engineer;
- completion of laboratory testing of representative samples from the base and sides of the excavation (minimum of 1 sample per 10m length of sides and 1 per 100m^2 base) and testing of the material for a suitable suite of contaminants. The suite and chemical criteria for verification are to be defined in consultation with Ramboll and the regulatory authorities based on the nature of the contamination encountered. *It is considered likely that the remedial targets generated from Ramboll's DQRA would be suitable for verification criteria; however, this will depend on the nature of contaminants;*
- if the material fails comparison against the re-use thresholds, exclusion of this material from the re-use strategy and alternative scenarios for re-use. The last option should be disposal off-site in accordance with current waste regulations. Records including laboratory analytical certificates, waste transfer notes, consignment notes and volumes requiring removal should be retained by the contractor; and
- if the material passes comparison with re-use thresholds (and is geotechnically suitable), the determination and record of the location of placement of the material.

It will be necessary to retain all records relating to testing, quantity, depth and location of the material identified. Where such material is re-used, it will be necessary to demonstrate suitability through appropriate chemical testing and to retain records on where this material was placed. If this material is removed off-site, then in addition to records on the source area outlined above, it will also be necessary to retain duty of care records relating to waste transfer notes, quantities and the receiving site.

7.8 Water Supply Pipes and Service Corridors

Elevated concentrations have been recorded in the shallow soils on site and as such, barrier pipe is recommended to be installed at the site. The Contractor should consult with the local water supply authority regarding the final selection of water pipe materials.

As part of the measures to protect future maintenance workers and manage the risk of exposure from asbestos fibres and other contaminants in Made Ground, certified clean materials should be used to backfill service corridors. These should be lined with a geotextile membrane to provide a marker layer between the clean service trench fill materials and Made Ground.

8. VERIFICATION

8.1 Verification Plan

A Verification Plan is required to demonstrate that the works set out within this Remediation Strategy has been completed.

The Contractor shall be required to obtain all necessary information for the environmental consultant to complete the Verification Report, including (but not limited) to the following:

- Records of the implementation of clean capping including demonstration of the chemical compliance, thickness placed and the presence of gravel break layer (including photographs);
- Records, chemical testing results and information on remediation excavation and groundwater works;
- Quantities of material imported to site;
- Chemical testing results and information on the source of any imported material and plans showing where this material has been used;
- Chemical testing results and information on any re-used materials and plans showing where this material has been used;
- Plans showing locations of any additional samples obtained for testing due to unforeseen contamination along with any delineation of materials and quantities;
- Results of any additional chemical and WAC testing undertaken along with method of sample collection and transportation to laboratory, laboratory quality assurance and accreditation;
- Quantities of any material disposed off-site as waste classification and details of the receiving site/s and copies of all Waste Transfer Notes;
- Records of the groundwater and surface water monitoring programme and compliance with the required standards;
- Records of the borehole decommissioning works (including photographs);
- Records of any asbestos management measures employed;
- Records of the ground gas protection measures installed at the site (including inspection records and photographs);
- Details of any areas of unexpected contamination and the actions undertaken;
- Details of any water removed from excavations and disposed off-site, including chemical testing;
- Details and demonstration of any relevant permits or exemptions required for the works;
- Details on any protection measures installed for contamination and monitoring (if applicable) of such measures – in particular records will be required to confirm whether protection measures were required for contaminants present in excavations or water supply pipes; and
- Details of regular dialogue and any additional liaison and agreements with regulators.

All laboratory analysis conducted as part of the verification phase of works will need to be submitted to a UKAS/MCERTs accredited laboratory to ensure the accuracy of data obtained.

On completion, the Verification Report should be submitted to the Local Planning Authority for approval. A copy of the Verification Report will need to be retained on-site within the health and safety file.

APPENDIX 1
FIGURES

APPENDIX 2
VERIFICATION CRITERIA

Table A2.1: Excavation and Groundwater Verification Criteria	
Analytical Determinand	**Verification Target (mg/kg)**
Total Petroleum Hydrocarbons (TPH)	
TPH Aliphatic C5-6	24
TPH Aliphatic C6-8	53
TPH Aliphatic C8-10	13
TPH Aliphatic C10-12	62
TPH Aliphatic C12-16	510
TPH Aliphatic C16-35	42000
TPH Aliphatic C35-44	42000
TPH Aromatic C8-10	22
TPH Aromatic C10-12	120
TPH Aromatic C12-16	1100
TPH Aromatic C16-21	1900
TPH Aromatic C21-35	1900
TPH Aromatic C35-44	1900
TPH Ali&Aro C44-70	1900
Polyaromatic Hydrocarbons (PAHs)	
Acenaphthene	2000
Acenaphthylene	2000
Anthracene	30000
Benz(a)anthracene [3]	12
Benzo(a)pyrene [3]	5.3
Benzo(b)fluoranthene [3]	4
Benzo(ghi)perylene [3]	360
Benzo(k)fluoranthene [3]	110
Chrysene [3]	30
Dibenz(ah)anthrancene [3]	0.31
Fluoranthene	1500
Fluorene	2200
Indeno(123-cd)pyrene [3]	45
Naphthalene	0.99
Phenanthrene	1300
Pyrene	3700
BTEX & MTBE	
Benzene	0.37
Ethylbenzene	34
Toluene	370

Table A2.1: Excavation and Groundwater Verification Criteria	
Xylene-m	34
Xylene-o	37
Xylene-p	33
Methyl tert-butyl ether	39
Notes: The contaminant suite and verification targets have been taken using the human health criteria as well as professional judgement.	

Analytical Determinand	**Verification Target (ug/l)**
BTEX, MTBE	
Benzene (C4SL)	500
Ethylbenzene	10000
Toluene	230000
Xylene-m	9500
Xylene-o	12000
Xylene-p	9900
Methyl tert-butyl ether	83000
Total Petroleum Hydrocarbons (TPH)	
TPH Aliphatic C5-6	1900
TPH Aliphatic C6-8	1500
TPH Aliphatic C8-10	57
TPH Aliphatic C10-12	37
TPH Aliphatic C12-16	NV
TPH Aliphatic C16-35	NV
TPH Aliphatic C35-44	NV
TPH Aromatic C8-10	1900
TPH Aromatic C10-12	6800
TPH Aromatic C12-16	39000
TPH Aromatic C16-21	NV
TPH Aromatic C21-35	NV
TPH Aromatic C35-44	NV
TPH Ali&Aro C44-70	NV
Polyaromatic Hydrocarbons (PAHs)	
Acenaphthene	170000
Acenaphthylene	220000
Anthracene	NV
Benz(a)anthracene	NV
Benzo(a)pyrene	NV

Analytical Determinand	**Verification Target (ug/l)**
Benzo(b)fluoranthene	NV
Benzo(ghi)perylene	NV
Benzo(k)fluoranthene	NV
Chrysene	NV
Dibenz(ah)anthrancene	NV
Fluoranthene	NV
Fluorene	210000
Indeno(123-cd)pyrene	NV
Naphthalene	220
Phenanthrene	NV
Pyrene	NV

Table A2.1: Verification Criteria for General Fill Material (Imported)	
Analytical Determinand	**Verification Target (mg/kg)**
Inorganics	
Asbestos identification and quantification (analytical methods accredited to ISO17025)	No asbestos detected in screen / <0.001% by weight within the quantification
Arsenic	40
Beryllium	1.7
Boron	11,000
Cadmium	150
Chromium VI	21
Chromium III	910
Copper	7,100
Lead	310
Mercury (inorganic)	56
Nickel	180
Selenium	430
Zinc	40,000
pH	5.5 to 8.5
Free Cyanide	49
Ammonium as NH4	477[1]
BTEX suite	
Benzene	0.37
Toluene	370
Ethylbenzene	34
m/p Xylenes	33
o Xylenes	37
Speciated Total Petroleum Hydrocarbons (TPH CWG Suite)	
Aliphatic C5-6	24
Aliphatic C6-8	53
Aliphatic C8-C10	13
Aliphatic C10-C12	62
Aliphatic C12-C16	500[2]
Aliphatic C16-C21	500[2]
Aliphatic C21-C35	500[2]
Aromatic C8-C10	22
Aromatic C10-C12	120
Aromatic C12-C16	500[2]
Aromatic C16-C21	500[2]

Table A2.1: Verification Criteria for General Fill Material (Imported)	
Aromatic C21-C35	500[2]
Polycyclic Aromatic Hydrocarbons	
Acenapthene	500[2]
Acenaphthylene	500[2]
Anthracene	500[2]
Benzo(a)pyrene	5.3
Benzo(g,h,i)perylene	360
Benzo(a)anthracene	12
Chrysene	30
Benzo(b)fluoranthene	4
Benzo(k)fluoranthene	110
Dibenzo(a,h)anthracene	0.31
Fluorene	500[2]
Fluoranthene	500[2]
Indeno(1,2,3-cd)pyrene	45
Naphthalene	0.99
Phenanthrene	500[2]
Pyrene	500[2]

Notes:

Except where stated, the imported general fill material verification targets are based on Ramboll's risk based Generic Assessment Criteria (GAC) for residential use without plant (i.e. vegetable) uptake.

[1] The verification target has been taken from the Tier 2 Soil Remediation Target Values (RTVs) derived from the Ramboll Detailed Quantitative Risk Assessment (DQRA) report (ref: R1620006959_01_DQRA, dated July 2019)

[2] The risk based GAC for these hydrocarbon fractions and PAHs are generally in excess of 1,000mg/kg (and some in excess of 5,000mg/kg). Although the GAC concentrations do not present a risk to human health it is considered that a lower verification target is required to ensure that only clean, naturally occurring soils are brought onto site. As such, a verification target of 500mg/kg has been selected based on Ramboll's professional judgement.

Table A2.3: Verification Criteria for Imported Topsoil/Subsoil	
Analytical Determinand	**Verification Target (mg/kg)**
Inorganics	
Asbestos identification and quantification (analytical methods accredited to ISO17025)	No asbestos detected in screen
Arsenic	40
Beryllium	1.7
Boron	930
Cadmium	150
Hexavalent chromium	21
Total chromium	685
Copper[1]	100 at <pH6.0 / 135 at pH6.0 to 7.0 / 200 at pH>7.0
Lead	310
Mercury (inorganic)	8.9
Nickel[1]	60 at <pH6.0 / 75 at pH6.0 to 7.0 / 110 at pH>7.0
Selenium	430
Zinc[1]	200 at <pH6.0 / 300 pH >7.0
pH	5.5 to 8.5
Free cyanide	49
BTEX suite	
Benzene	0.37
Toluene	Sum <6 mg/kg
Ethylbenzene	
Xylenes (sum)	
Speciated Total Petroleum Hydrocarbons (TPH CWG Suite)	
Aliphatic C5-6	24
Aliphatic C6-8	53
Aliphatic C8-C10	13
Aliphatic C10-C12	62
Aliphatic C12-C16	100[3]
Aliphatic C16-C21	100[3]
Aliphatic C21-C35	100[3]
Aromatic C8-C10	22
Aromatic C10-C12	100[3]
Aromatic C12-C16	100[3]
Aromatic C16-C21	100[3]
Aromatic C21-C35	100[3]

Table A2.3: Verification Criteria for Imported Topsoil/Subsoil	
Sum of all individual aliphatic and aromatic TPH C5-35 fractions	500
Polycyclic Aromatic Hydrocarbons	
Acenapthene	<100[3]
Acenaphthylene	<100[3]
Anthracene	<100[3]
Benzo(b)fluoranthene	4
Benzo(k)fluoranthene	<100[3]
Benzo(a)pyrene	5.3
Benzo(g,h,i)perylene	<100[3]
Benzo(a)anthracene	12
Chrysene	30
Dibenzo(a,h)anthracene	0.31
Fluorene	<100[3]
Fluoranthene	<100[3]
Indeno(1,2,3-cd)pyrene	45
Naphthalene	0.99
Phenanthrene	<100[3]
Pyrene	<100[3]
Sum of all PAHs (in addition to meeting the speciated PAH criteria listed above)	<100

Notes:

Except where stated, the topsoil/subsoil verification targets are based on Ramboll's risk based Generic Assessment Criteria (GAC) for residential use without plant (i.e. vegetable) uptake. This is considered to be protective of both human health and vegetation (for compounds where BS 3882:2015 does not provide targets).

[1] The verification targets for nickel, zinc and copper are based on the BS 3882:2015 Specification for Topsoil, which is below the risk based GAC for human health.

[2] The soil pH remedial target is based on the pH range for multipurpose topsoil as presented in BS 3882:2015 Specification for Topsoil.

[3] The risk based GAC for these hydrocarbon fractions and PAHs are generally in excess of 1,000mg/kg (and are all in excess of 100mg/kg). Although the GAC concentrations do not present a risk to human health it is considered that a lower verification target is required to minimise the potential effects on vegetation growth when the topsoil is seeded. As such, a remedial target of 100mg/kg has been selected based on Ramboll's professional judgement. In addition, the sum of all TPH fractions should not exceed 500mg/kg and the sum of all PAH compounds should not exceed 100mg/kg.

Table A2.3: Groundwater Verification Targets	
Analytical Determinand	**Verification Target (ug/l)**
Benzene	10
Aromatic C8-10	300
Aromatic C10-12	400
Notes: The contaminant suite and verification targets have been derived from the Ramboll Detailed Quantitative Risk Assessment (DQRA) report (ref: R1620006510_01_DQRA, dated January 2020).	